frontiers | Frontiers in Sustainable Food Systems

TYPE Original Research
PUBLISHED 01 October 2025
DOI 10.3389/fsufs.2025.1677669

OPEN ACCESS

EDITED BY
Kareem M. Usher,
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REVIEWED BY
Nataliya Apanovich,
University of Arizona, United States
John Murphy,
Northern Illinois University, United States

*CORRESPONDENCE
Maya Carrasquillo
✉ mcarrasquillo@berkeley.edu

RECEIVED 01 August 2025
ACCEPTED 11 September 2025
PUBLISHED 01 October 2025

CITATION
Chhour K and Carrasquillo M (2025) A drop in the bucket: examining practice and policy for water resilient urban agriculture and urban food system resilience.
Front. Sustain. Food Syst. 9:1677669.
doi: 10.3389/fsufs.2025.1677669

A drop in the bucket: examining practice and policy for water resilient urban agriculture and urban food system resilience

Kristida Chhour and Maya Carrasquillo*

Department of Civil and Environmental Engineering, University of California, Berkeley, Berkeley, CA, United States

Climate change is increasing the frequency and intensity of disasters that disrupt supply chains and threaten urban food supplies. Urban agriculture can make urban food systems resilient to such threats by localizing food production and recycling urban waste as food production inputs. The urban environment, however, brings unique water access and management challenges that can threaten the viability of urban agriculture, particularly in water-scarce regions. This case study of the San Francisco East Bay, a region vulnerable to water scarcity, examines (1) how stakeholders manage water resources for urban agriculture under water-scarce conditions and (2) the potential for urban agriculture to be both water resilient and a contributor to overall urban resilience. We employed a mixed-methods approach consisting of identifying and mapping 91 urban agriculture sites, interviewing 34 stakeholders, and analyzing the region's general and climate action plans. Urban growers were the main actors in water management, and they maximized water conservation regardless of drought conditions. Municipalities and water utilities were minimally involved in water management for urban agriculture, but provided access to land and water. Land access played a significant role in water access by dictating the available infrastructure and water pricing. We found a large gap between the actual practice of urban agriculture and the idealized systems modeled in academic literature. Although urban agriculture sites withstood previous droughts, they had not implemented water resilience strategies, such as urban greywater and reclaimed water use, that are often modeled in studies on urban agriculture and resilience. Sites were dependent on municipal water sources. Institutional support is necessary to stabilize long-term access to land and water at urban agriculture sites. With greater stability, urban agriculture can further pursue infrastructural improvements that enhance water resilience and overall food system resilience.

KEYWORDS
urban agriculture, water, food systems, food system resilience, drought, policy, planning, climate resilience

1 Introduction

Competition between urban and agricultural water demands has historically shaped California's water resources management (Medellín-Azuara et al., 2024). These tensions are exacerbated by climate change-related threats to California's water systems, such as the increasing probability of severe droughts, sea level rise, and wildfires (California Department of Water Resources, 2023; Williams et al., 2015). Each of these disasters would put significant stress on urban water security. Urban agriculture uniquely sits at the intersection of these issues: in California, urban agriculture has emerged despite the imminent threat of drought and water scarcity (Diekmann et al., 2017).

Urban agriculture (UA) is defined as farming activities that occur in an urban environment and utilize and provide materials and resources within the urban sphere (Mougeot, 1999; Smit et al., 2001). Local food production through UA has been posed as a key pathway for building urban food system resilience because it reduces reliance on external resources by creating distributed systems and increasing local resource reuse (Langemeyer et al., 2021; Yan et al., 2022; Gulyas and Edmondson, 2021). These benefits support the ability of urban food systems to produce and provide food in the face of disasters that sever longer supply chains, which are vulnerable to shocks at points of production, processing, and transportation.

Literature on the role of urban agriculture in urban resilience is commonly rooted in the concept of urban metabolism. Urban metabolism is defined as "the sum of the technical and socioeconomic processes that occur in cities, resulting in growth, production of energy, and elimination of waste" (Kennedy et al., 2007). Therefore, urban metabolism models examine resource flows in and through cities, including energy, water, nutrients, and materials (Kennedy et al., 2011). Urban metabolism literature regards UA as an opportunity to improve urban resilience by utilizing secondary resources, such as food waste and wastewater, as inputs for food production as compost, irrigation, biosolids, and urine-derived fertilizer (Gondhalekar and Ramsauer, 2017; Haitsma Mulier et al., 2022; Brown et al., 2023; Wang et al., 2022; Rufí-Salís et al., 2020; Wielemaker et al., 2018). Utilizing these waste products shifts urban metabolism from linear resource use and waste production to a circular metabolism supported by local and renewable resources. This circular framework for UA aligns with the concept of circular food systems. Circular food systems prioritize reducing inputs and waste through efficient use and recycling of resources (Liaros, 2021). UA further increases system efficiency by utilizing waste at the point of generation to produce food at the point of demand. As a result, UA presents an opportunity to adapt to the impacts of climate change while reducing food systems' contributions to climate change.

In water-scarce regions, the water reuse dimension of urban agriculture can be particularly beneficial to maximize water resilience while building local and circular food systems. UA sites can contribute to water resilience by increasing rainwater capture and reuse, providing opportunities for reclaimed and greywater use, and increasing stormwater infiltration (Ebissa and Desta, 2022; Deksissa et al., 2021; Attwater and Derry, 2017; Rufí-Salís et al., 2020). These practices can reduce reliance on municipal water systems and imported water, increasing self-sufficiency.

Despite these potential benefits, water is an issue for UA. For UA sites to contribute to overall urban food system resilience in water-scarce regions, the sites themselves must be water resilient and able to function in a future of unpredictable water supply (Matthews et al., 2022). A 2024 Community Alliance with Family Farmers report on urban agriculture in California identified water as a major challenge for urban growers due to challenges with water access and affordability of municipal water (Gonzales and Fanous, 2024). Additionally, Diekmann et al., found that impacts of institutional drought were uneven across urban agriculture sites due to varying institutional arrangements and water providers (Diekmann et al., 2017). These challenges and uncertainty in accessing municipal water supply are only expected to worsen due to climate variability and extreme weather events that threaten water supply and storage (Wortman and Lovell, 2013). Climate change models anticipated that reduced precipitation across the western United States could cause soil-water deficits that would increase urban agriculture crop irrigation needs by up to 222% (Cooper et al., 2022). As a result, water access and management are a complicated facet of UA in water-scarce, urban environments that are facing mounting water security pressures.

Much of the literature on the water resilience benefits of urban agriculture is speculative: there are few documented examples of the modeled practices being implemented (Brown et al., 2023). Additionally, many existing urban metabolism models are disconnected from governing factors of urban resource use, such as governance networks, urban infrastructure and form, and socio-economic dynamics (Newell et al., 2019). For UA specifically, Caputo et al. further suggest that people be incorporated as a key factor in UA's role in urban metabolism and the food-energy-water nexus (Caputo et al., 2021). Therefore, to understand the state of UA contributions to resilience in urban food and water systems, there is a need to examine both urban grower experiences and institutional management of UA.

As a result, this case study of urban agriculture in the San Francisco East Bay area investigates stakeholder experiences, institutional perspectives, and policies that impact water management for urban agriculture. The study aims were to (1) understand how stakeholders manage water resources for urban agriculture under water-scarce conditions and (2) examine the potential of urban agriculture to be both resilient to drought and a contributor to overall urban resilience. The findings inform future pathways to support UA in becoming more water resilient and in turn contributing to overall food system resilience and circularity in the face of climate change.

2 Methods

This study design employed a convergent mixed method design composed of mapping, document analysis, and semi-structured interviews. Data collection for mapping occurred first, which entailed inventorying urban agriculture sites in the study area. This inventory informed subsequent interview participant recruitment. Document analysis, interviews, and geospatial analysis occurred concurrently. After independent data analysis, descriptive statistics from geospatial analysis and findings from document analysis were triangulated with qualitative interview data to provide context and points of comparison across stakeholder perspectives and policy intent.

2.1 Study area

The study area is the San Francisco East Bay ("East Bay") region in California, which encompasses Alameda and Contra

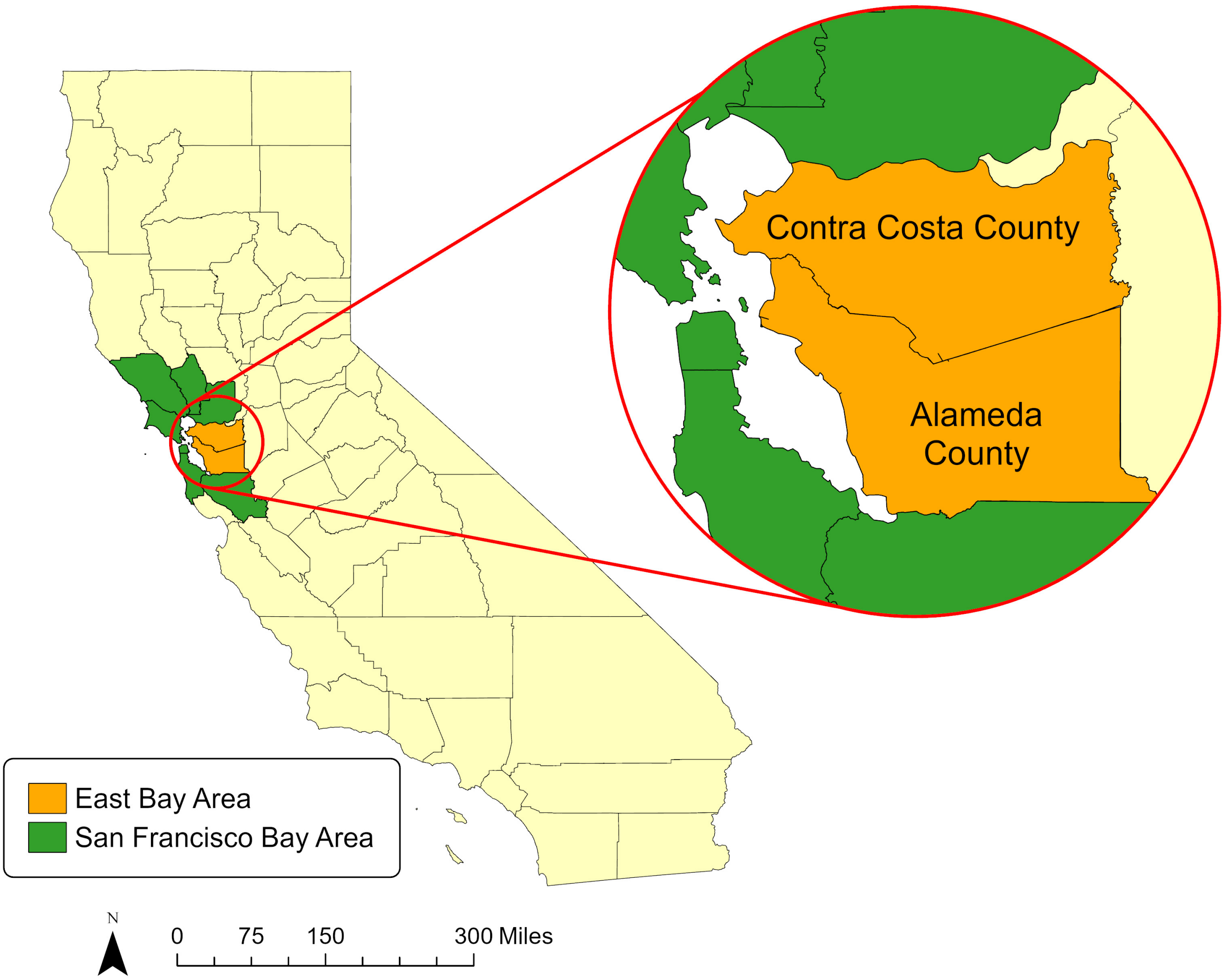

FIGURE 1
The San Francisco East Bay, a subset of the greater San Francisco Bay Area including Contra Costa and Alameda Counties.

Costa Counties (Figure 1). The East Bay is a subsection of the larger San Francisco metropolitan area. This largely urban region is characterized by a Mediterranean climate of mild, wet winters when most annual rainfall occurs, and warm, dry summers (Cayan et al., 2009). California's annual rainfall has high inter-annual variability and is dominated by large storm events that dictate wet and dry periods (Dettinger, 2016). This variability is expected to increase due to climate change and rising temperatures, thereby increasing the anticipated intensity and duration of drought (Ackerly et al., 2018).

2.2 Mapping

The goal of mapping UA sites was to evaluate the overall scope and occurrence of UA within the study area. First, an inventory of urban agriculture sites in the East Bay was compiled using Google and Google Maps searches. Site names, locations, and operational details were collected from publicly available information and satellite imagery. Each site was then categorized as a community garden or urban farm. Community gardens were defined as sites that operated on a plot-rental in which individuals were allocated plots of land to manage and cultivate. Urban farms were defined as sites that operated without a plot-ownership model to grow food collectively.

For inclusion in the inventory, sites must have met the following requirements: (1) have visible cultivation activity, such as crop rows or garden beds, on Google Maps satellite data from 2024 and 2025, (2) have online documentation of the site, (3) not be within a residential lot with a home, and (4) be within the boundaries of urban land as defined by the US Census Bureau 2020 Census (US Census Bureau, 2023). Indoor operations and gardens operated by school districts were excluded in the inventory because the site boundaries, locations, and operational details were particularly difficult to accurately identify.

Site boundaries were determined based on visible fencing or delineation of growing areas and lot boundaries using ArcGIS Pro (Version 3.1.3) and satellite imagery from the Esri World

Imagery Map Product with imagery from 2022 (Esri, 2025). These boundaries were used to calculate site areas and the total acreage of urban agriculture in the East Bay. Descriptive statistical analysis was performed using ArcGIS Pro to determine the mean, median, and standard deviation of site areas by county and site type.

2.3 Document analysis

General and climate action plans of municipalities in the study area were screened and analyzed for policies related to urban agriculture. General plans are policy documents that outline a community's policies and future development. Each city and county is required by the state of California to have a general plan including components such as land use, housing, and open space (California Government Code, 2024a,b). Climate action plans are local planning documents describing municipality goals and actions to reduce greenhouse gas emissions, improve sustainability, and/or adapt to climate change. Climate action plans are not legally required.

City and county general plans were screened for inclusion using the General Plan Database Mapping Tool developed by Banginwar et al. and the following keywords: urban agriculture, community garden(s), urban farm(s), community farm(s), school garden(s), or edible landscape(s) (Banginwar et al., 2023). The General Plan Database Mapping Tool provides an output of the city and county general plans containing each keyword, which was combined across keywords to form a list of municipalities with plans containing any of the listed keywords. The most recent general plans for these municipalities were then obtained from their official websites between January and July 2025. Climate action plans were collected via manual search and screening of all climate action plans in the study area using the same keywords. In total, seven county general plans, 23 city general plans, and 13 climate action plans were included in the analysis. These documents were analyzed for qualitative content using ATLAS.ti (Version 25.0.1.32924 for Windows) with the goal of identifying existing policies, goals, and actions related to urban agriculture and evaluating definitions and discussions of urban agriculture with special attention to water.

2.4 Semi-structured interviews

Semi-structured interviews were conducted with urban growers/site managers, technical assistance providers, and water utility representatives to document perspectives and experiences of urban agriculture operations and water management. Outreach to each subject group was conducted via email, text message, or phone call depending on the information available to the research team from online sources or personal networks. Interviews occurred between January and June of 2025.

Urban growers/site managers were defined as individuals who manage, operate, or regularly tend to urban agriculture sites. This included volunteer or paid farmers and gardeners as well as municipality representatives managing city-sponsored community gardens. Urban growers/site managers were recruited using purposive sampling methods based on the inventory of urban agriculture sites with the goal of representing sites across counties and site types. 65 potential urban grower/site manger participants were identified and contacted. Technical assistance providers included individuals who provide technical assistance services to urban agriculture sites in the study area in their roles at public agencies or universities. Technical assistance providers were recruited based on the relevance of their roles to urban growers, and a total of seven potential participants were identified and contacted. Water utility representatives included employees of water utility agencies with service areas within the study area and were recruited based on the number of urban agriculture sites located within their service areas. Five potential participants were identified and contacted.

Semi-structured interviews with urban growers/site managers and technical assistance providers consisted of questions about general site goals, water use and conservation practices, land management practices, and experiences of governance and regulation. Interviews with water utility representatives focused on perspectives and planning related to urban agriculture and drought. Interviews with urban growers/site managers took place online via Zoom or Google Meet, or in-person at the urban agriculture site. Interviews with technical assistance providers and water utility representatives took place online via Zoom. Interview guides for each subject group are available in the Supplementary material. Interviews were recorded with participant consent using Zoom (Version 6.4.6) or Otter.ai (Version 3.76.1) and transcribed using Otter.ai with manual revision.

Transcripts were analyzed using ATLAS.ti (Version 25.0.1.32924 for Windows) and guided by the six-phase process for reflexive thematic analysis detailed by Braun and Clarke (2012, 2019, 2021). This strategy was employed to interpret and discern themes from qualitative data while incorporating the influence of KC's personal experiences of urban agriculture through reflexive engagement with the data. In this iterative process, transcripts were coded using both inductive and deductive methods. A preliminary codebook was created deductively based on interview question topics and inductive codes were added and iterated upon to organize patterns across the data and ultimately develop themes. All data collection, storage, and analysis occurred in compliance with the University of California, Berkeley Institutional Review Board CPHS #2024-07-17674.

3 Results

This section begins with a description of the interview participant population. This is followed by a characterization of urban agriculture in the San Francisco East Bay Area based on site distribution, size, and operations. Then, we present the themes and subthemes constructed from interview data and document analysis. These themes revolved around water management and institutional governance.

3.1 Interview participant population

A total of 34 participants, composed of 27 urban growers/site managers, 4 technical assistance providers, and 3 water utility

TABLE 1 Interview participant population.

	Alameda County	Contra Costa County	Both	Total
Urban grower/site manager	17	10	0	27
Technical assistance provider	1	2	1	4
Utility	2	0	1	3
Total	20	9	2	34

TABLE 2 Urban agriculture sites represented in interviews by type and county.

	Urban farm	Community garden	Total
Alameda County	13	6	19
Contra Costa County	4	6	10
Total	17	12	29

representatives participated in semi-structured interviews. The urban growers/site managers represented a total of 29 UA sites. In some cases, participants represented multiple sites or multiple participants from a single site participated in an interview. Details regarding participants and represented site locations and types are detailed in Tables 1, 2.

3.2 Characterization of urban agriculture

The inventory of UA sites in the San Francisco East Bay area yielded a total of 91 sites that span a total of 204 acres. 49 of these sites were community gardens with individual plot rentals, and the remaining 42 sites were urban farms that were collectively operated. The sites identified are shown in Figure 2 with details of site type and county in Table 3. Nearly all sites grew crops in-ground or in raised-beds. Rooftop operations were included in the inventory, although rare.

3.2.1 Distribution and size of sites

Alameda County contained more UA sites of both types compared to Contra Costa County (Table 3). Sites in Contra Costa County, however, were typically larger than those in Alameda County: the median site size for Contra Costa (0.95 acres) was more than double that of Alameda (0.41 acres) (Figure 3). Site sizes overall varied widely, ranging from 0.03 acres to over 80 acres. Urban farms were generally larger than community gardens and had a wider range of fluctuation.

3.2.2 Site goals and operations

Participant descriptions of site goals and operations affirmed the two district forms of urban agriculture: urban farms and community gardens. Both site types shared the goal of providing education and opportunities related to food production. Other shared values included connecting people with nature, community, and food resources. The distinguishing factors between urban farms and community gardens were their access models and harvest destinations. Urban farms were regularly open to the public through regular volunteer hours, which provided a major source of labor. Community gardens were typically only accessible by plot holders aside from public-facing events. As for the harvest destination, urban farms were oriented toward producing for a specific cause, such as donating to a partner organization or food pantry. As a result, urban farms were usually aligned with missions of food justice and access. Food grown at community gardens belonged to whoever grew it. Multiple community gardens had shared orchards in addition to plots, and some even had areas dedicated to production for donation. As a result, at urban farms, production occurred with the intent to distribute, whereas in community gardens, excess was distributed. Across both site types, harvests were distributed very locally, typically limited to neighboring cities.

Urban farms and community gardens differed in structure and operations because of their varied goals. Urban farms relied on paid staff (sometimes just one individual) supported by volunteers to coordinate production, harvest, and distribution. These sites typically operated as nonprofits, although a small fraction of urban farms were for-profit businesses. In contrast, community gardens were largely managed by volunteers without a formal nonprofit or community organization status. Community gardeners paid plot rental fees to a volunteer-run committee that shared administrative roles, including plot assignments, financial management, and coordination with the landlord. Gardeners were expected to cultivate their plots in alignment with the site's rules and typically were required to fulfill annual service hours toward general garden upkeep.

3.3 Water management and institutional governance

In the following subsections, we outline the themes and subthemes that resulted from participant interviews and document analysis (Table 4). These themes encompass contextual factors, actions, perceptions, and policy that shape water management for urban agriculture.

3.3.1 Cascading impacts of land access on water access

Water access, metering, and payments were largely dependent on site location and the land use agreement allowing the land to be cultivated. Urban growers, however, had limited control over the sites they were granted access to because of the difficulties in obtaining land. As a result, growers had varying levels of water access, metering, and payments.

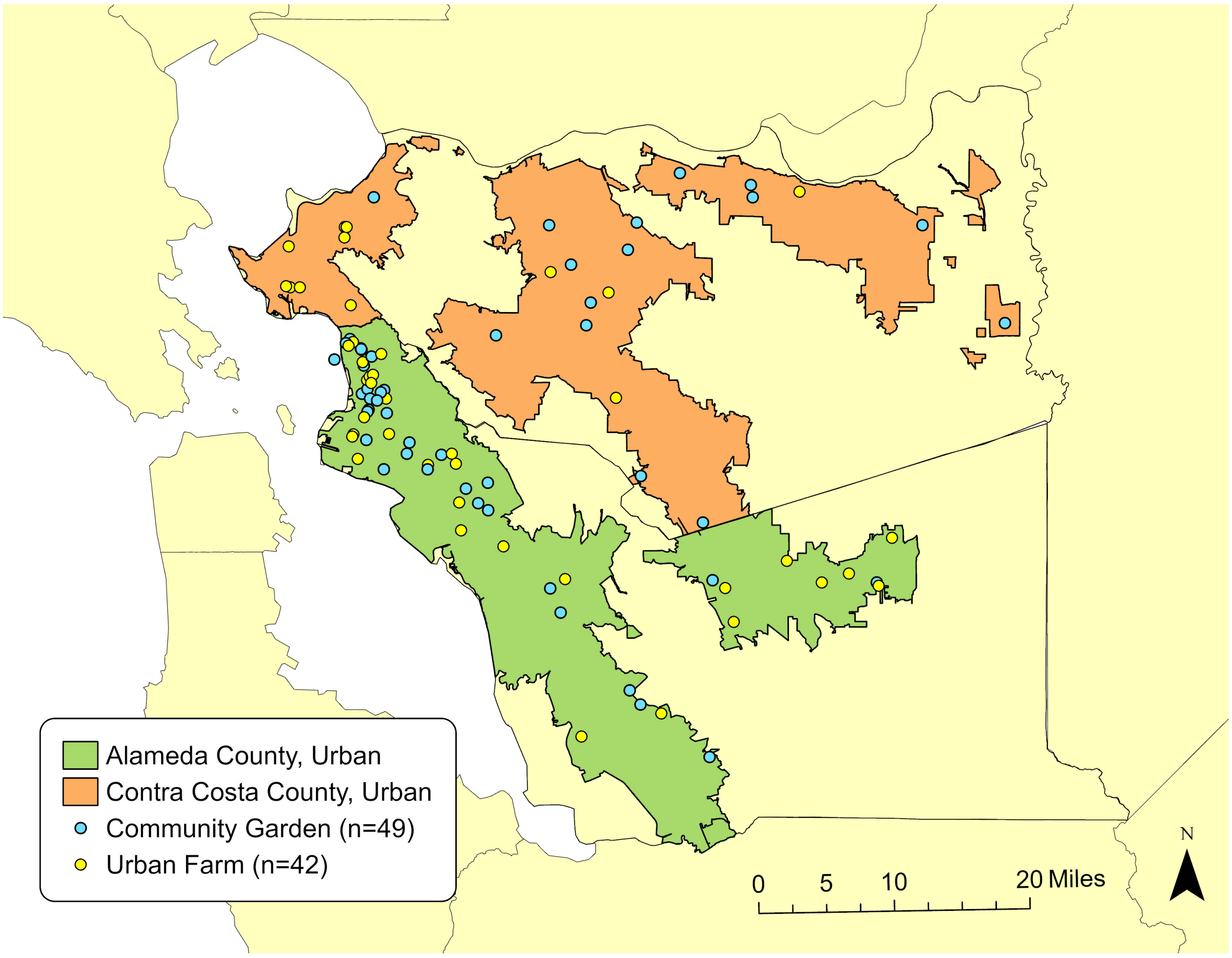

FIGURE 2
Map of urban agriculture sites in the San Francisco East Bay Area.

TABLE 3 Urban agriculture sites in the San Francisco East Bay by type and county.

	Urban farm	Community garden	Total
Alameda County	30	34	64
Contra Costa County	12	15	27
Total	42	49	91

3.3.1.1 Pathways for land and water access

Nearly all participants accessed land through a lease, memorandum of understanding, or handshake agreement with a landowner granting permission for site use. Only three sites were owned, with one site being a portion of the participant's residential lot. Cities were the main suppliers of land. Other landowners included water utilities, school districts, universities, religious institutions, and private landowners. Land access agreements had varying levels of formality, security, and associated costs, but nearly all sites accessed land for free. There were only two cases of payments to landowners for land access, which were paid as rent or property taxes.

Although each site had a unique process of gaining access to land, nearly all site origins were centered on the desire to garden on a specific piece of underutilized land, a vacant plot, or an open area slated for development. Community members then came together to advocate for their access to the land. This was a difficult process that participants repeatedly recalled as a multi-year struggle. Those who access land from cities commented on the persistence needed to navigate city bureaucracy. One participant recalled: "[The garden founder] worked with the city for, I think it was at least a year or two. [...] In order to persuade [local] officials to agree on the project, he requested the help of the Council member of that district, who turned out to be very supportive and helped move things along" (Participant 22, community gardener). Similarly, a participant from another city recalled that it took "... years, I mean, *years* of advocating and writing and going to meetings" to have city council vote on their garden (Participant 8, community gardener). Thus, land access was the primary and most difficult factor required to establish a UA site.

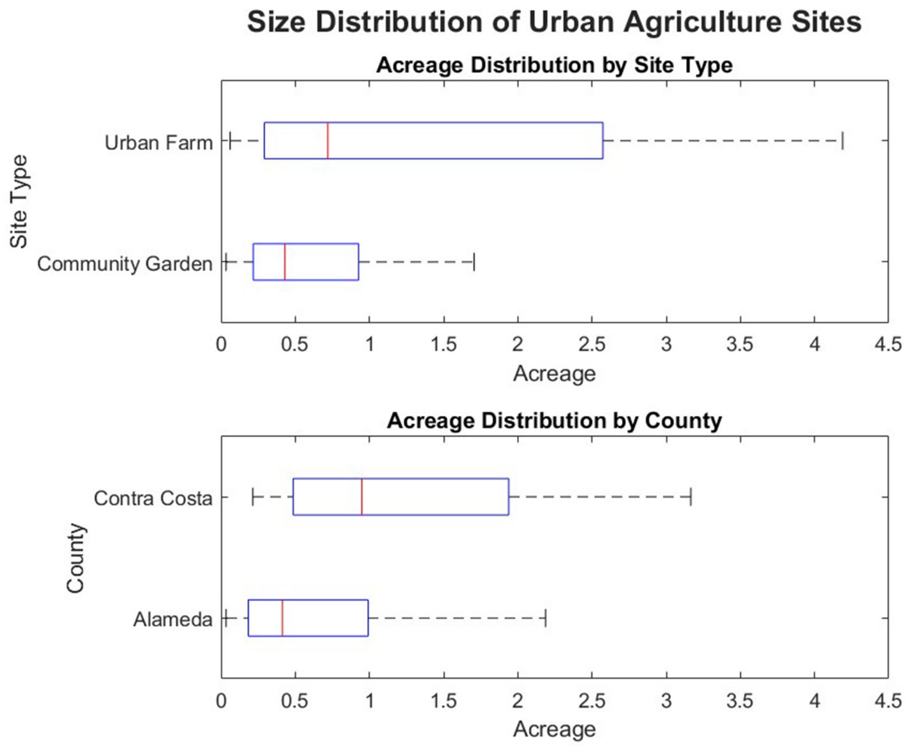

FIGURE 3
Relationships between site type and county on site size.

TABLE 4 Themes and subthemes resulting from participant interviews and document analysis.

Themes	Subthemes
Cascading impacts of land access on water access	Pathways for land and water access
	Water metering and pricing
Growers practice voluntary conservation with or without drought	Urban grower perceptions and practices
	Experiences of water scarcity
Institutional invisibility of urban agriculture	"Apples to oranges": varying definitions and metrics of urban agriculture
	State of planning and policy
	The power of individual allies

Due to the difficulties of accessing land, urban growers often had little agency over their water sources and were at the mercy of existing infrastructure. 85% of sites accessed municipal water sources that provided potable water. The remaining sites used well water (11%) or solely rainwater (4%) (while rainwater catchment was a water source that many sites utilized, it was not a substantial source of water for most sites. This is discussed further in Section 3.3.2.1.1.).

Sites located in public parks were granted access to water from existing water lines, although some were responsible for the cost and installation of any additional infrastructure, such as piping and spigots. In these cases, water access was free and there was no additional or separate water meter specifically for the UA site. Other sites on land without existing water access had a much more difficult, and sometimes costly, path. For example, multiple sites leasing land without existing water connections were responsible for installing all infrastructure for onsite water access and were then responsible for resulting water billing, despite being on city or water utility-owned land. In multiple other cases, urban growers made agreements with neighbors to use their existing water for the UA site, which often entailed running hose off the property.

3.3.1.2 Water metering and pricing

The presence of water metering data, which was related to land access and infrastructure, determined whether sites were responsible for water payments. Over half of UA sites represented in interviews had no access to water metering data, and all but one of these sites received free water. Of the sites with water metering data, only one received free water. The main recipients of free water were sites on city-owned land. A city representative attributed this to both administrative silos and other onsite water uses that could not be differentiated from UA water use: "Everything's very siloed, so I don't see any of [the water bills...] I don't know how much water we use, but also, the facility uses water... Everything would have to be compartmentalized so you could see who's using what" (Participant 17, municipality representative).

This logistical difficulty seemed to be the primary contributor to city subsidies for water use, rather than intentional charity. Sites on city-owned land that lacked preexisting water infrastructure were entirely responsible for water payments for the water services they initiated. Furthermore, one site on city property that did not have separate water metering was arbitrarily charged 25% of its plot rental fees to cover water costs. Overall, however, 75% of sites on city-owned property received free water. In contrast, less than half of the sites on non-city-owned land received free water. The non-city land sites that did receive free water did so through agreements with a university landowner, a neighboring entity or individual, or relied on well water or stormwater.

For urban growers who *did* pay a water bill, land dictated water rates through zoning. According to multiple participants, to qualify for agricultural water rates as opposed to residential rates, the land would have to be specifically zoned for agriculture. However, there was insufficient information about agricultural water rates online to confirm this process. Only one site qualified for a cheaper agricultural rate for water, which was attributed to historical zoning. Another participant had attempted multiple times to negotiate this with the water utility, but "[the utility] said 'No, even though you're growing food for other people, and your business is considered to be agricultural, you have to pay residential rates"' (Participant 19, urban farmer). The process for rezoning land as agricultural land was also reported to be complicated, and not viable for those without land ownership. One participant who was trying to rezone their site described the process as: "a lot of back and forth with the city [...] just trying to figure out how to meet whatever niche demands [the city has]" (Participant 23, urban farmer). This process had been ongoing for the past 2 years, demonstrating the institutional land-related barriers that ultimately impact water pricing.

3.3.2 Growers practice voluntary conservation with or without drought

Urban growers felt that they used water conservatively and discussed a multitude of water-efficient infrastructure and growing practices they utilized. Growers felt they were maximizing conservation, regardless of current drought conditions. As a result, many stated that they did not feel impacted by drought or that they would not change their practices during drought. The conservation practices in place were determined to be voluntary, as very few sites reported facing any type of water use restrictions. Urban growers did, however, experience water scarcity resulting from other barriers to water access.

3.3.2.1 Urban grower perceptions and practices

Urban growers across all sites consistently expressed that they used water-efficient growing practices and perceived their water use as efficient or minimal. Many attributed their water-efficient practices to personal values and cultivation principles, which were frequently expressed through terms such as "organic," "sustainable," "regenerative," or "agroecological." One urban farmer explained how their values shaped their approach to water scarcity: "We conserve water just because that's what we believe in. So, if you have the philosophy that we are sustainable and that there's only a certain amount of water we use, only what we need [...] You're not wasting in the first place. There's not much else you can do, right?" (Participant 3, urban farmer). To this urban grower, there would be little response to drought because the value of conservation characterized onsite water use whether drought was present or not. Another urban farmer connected water conservation to their broader social values: "We believe in environmental and social justice and sharing the resources of the world. And we live in a semi-arid climate, and growing food can take a lot of water, so we want to do it as ecologically responsible as possible" (Participant 20, urban farmer). Overall, urban growers were driven by a desire for responsible resource use.

Even community gardeners, who had the least incentive to conserve water because they were not personally responsible for a water bill and their water use could not be traced back to them, were adamant about water conservation. A municipality employee shared, "Back in 2018, we had a huge drought. [...] By the time we were starting to really crack down on it, people were like, 'Where have you been?! About time!' So, we had buy-in from 99.9% of the garden users at that time, which was fantastic" (Participant 17, community garden manager). Therefore, community gardeners shared the same water-conscious values as urban farmers.

3.3.2.1.1 Water-efficient infrastructure

Participants reported utilizing water-efficient infrastructure included drip irrigation, rainwater catchment, and, although minimal, greywater use. Drip irrigation was nearly universally used, except for a few community gardens. These community gardens wanted to incentivize watering as a reason for gardeners to regularly visit their plots and were wary of leaks or user errors in automatic watering systems.

Rainwater catchment systems were used at less than half of sites represented in the interviews, and there were mixed opinions on the efficacy of these systems. Multiple participants with rainwater catchment systems mentioned that the utility of their system was limited by the seasonality of rainfall in the region's Mediterranean climate. One participant explained this temporal mismatch of rainfall, stating, "you get lots of water you can store when you don't really need it, and then it's gone, and you're not able to replenish it" (Participant 32, community gardener).

The potential for rainwater catchment also depended on the total roof area from which sites could capture water. Most sites had only a small tool shed, which limited collection capacity. Here, both land access and institutional governance played roles, as most sites were space-limited, and larger sheds typically required a permit dependent on zoning. Furthermore, multiple participants shared perceptions about regulation and permitting regarding the rainwater catchment systems themselves. One participant recalled,

> "There were some permitting issues around having a certain amount of standing water over a certain period of time. I think it's mostly like a health and safety thing for mosquitoes, but it was something like I couldn't store more than 50 gallons of water for more than 90 days at a time. So, if I build up a cistern, even if it's sealed and just sitting there without access to mosquitoes, I couldn't keep it for more than three months at a time, which is kind of beside the point, right? [Because the] idea is to have [the water] in the dry season." -Participant 4, urban farmer

Additionally, once the water is collected, some participants expressed compatibility issues with existing irrigation systems. Most sites did not have pumps for their rain barrels and relied on using buckets or watering cans to apply the stored water. A farmer using soaker hoses and drip irrigation commented, "It's just not enough [water], and it's also a little bit inconvenient, if I'm being honest, because you have to have it all coming from [the greenhouse], and you have to have a pump. [..] and then you have this hose, and it goes really slowly, so it just takes a long time." (Participant 3, urban farmer). This issue was less prominent in community gardens, where water was applied on a smaller plot scale. In fact, multiple community gardens that did not pay for water had independently paid for the supplies to set up rainwater catchment systems. This indicated that they believed in the value of capturing rainwater beyond the financial incentive of reducing municipal water bills.

Greywater use was less prominent across the sites represented. Six sites featured a greywater reuse system, which typically involved channeling water from handwashing, processing produce, or laundry to a drainage system irrigating plants. Most sites did not have a significant volume of greywater onsite due to lack of water uses aside from irrigation.

3.3.2.1.2 Water-efficient cultivation practices

In addition to water-efficient infrastructure, urban growers implemented a multitude of cultivation practices that conserved water. These practices focused on reducing water waste and loss, maximizing crop water use efficiency, and increasing the soil water holding capacity.

To reduce water loss to evaporation, urban growers kept soil covered with crops, mulch, straw, or compost. This practice was consistently mentioned and visible across sites. One technical assistance provider noted that UA sites are particularly effective at maximizing soil coverage:

> *"I always think about soil coverage in urban farms, because, if you think about a large-scale farm, there's often a lot of various spaces under trees or between rows or plants. And I think urban farms are kind of the opposite of that. Every [spot] is growing something, generally speaking, and if not, it's probably mulched. [...] Urban farms do a really good job at keeping the ground covered and planted, and that allows water infiltration, and the reduction of runoff." -Participant 5, technical assistance provider*

This comparison to larger-scale agriculture indicated that urban agriculture sites are at an advantage for implementing water conservation practices in part due to scale. This was apparent across larger and smaller sites, as some of the larger sites represented did not mulch between rows due to the labor and materials required to do so over such a large area.

Another key strategy participants used to reduce water waste and loss was the active monitoring of irrigation systems. Participants closely monitored irrigation systems for leaks, with regular inspections and timer adjustments based on weather and soil moisture conditions. Those with access to water metering data found their water utility leak notification systems very helpful, as it alerted growers of unusual, continuous water use. Additionally, some participants in community gardens mentioned educating garden members about prioritizing watering the soil, rather than leaves, of crops, and watering during the morning or evening rather than midday. These practices reduce water loss to evaporation.

To maximize crop water use efficiency, urban growers focused on planting very densely and intercropping to maximize the cultivation space and use of water. Interplanting crops of different heights and needs allows plants to provide benefits of shade or soil cover to their companion plants. Cover cropping was also commonly used during the winter to take advantage of rainfall, build soil health, suppress weeds, and ensure that there was always a crop in the soil.

Urban growers also made the most of their water resources by increasing the water holding capacity of their soil by amending soil with compost and crop residue and using no-till or low-till practices. These practices were more frequently mentioned as land management practices to build soil health rather than water-related practices, but have significant water-related benefits as well. A technical assistance provider had the same observation, noting: "I think the biggest [water conservation practice] I've seen– and I don't even know if they know they're doing it [for water conservation purposes], but, it's the increasing the water holding capacity of the soil through the addition of organic matter, which is very much rooted in a lot of the permaculture practices." (Participant 35, technical assistance provider). Organic matter and soil health were key values of urban growers, and many sites produced their own compost onsite and supplemented this with purchased compost.

Community gardens generally had less control over water conservation compared to urban farms due to the agency of individual plot holders. Garden managers prioritized providing education and support to create a culture of water-awareness. Gardens provided onsite access to straw, compost, and mulch that was often funded by plot fees. Additionally, multiple community gardens had signage about drought and water conservation, but one participant noted the irony of this, as their community garden was surrounded by irrigated parkland.

3.3.2.1.3 Experiences of water scarcity

Urban growers experienced water scarcity through increased water-consciousness, infrastructural challenges, and pricing. None of the urban growers expressed having limited or inadequate access to water during drought. For municipal water users, most of the subject population, so long as they turned on the spigot, water would be available. Despite this relatively unlimited access to water, urban growers self-imposed water limitations due to feelings of personal responsibility. Multiple participants mentioned fallowing land or generally growing less to conserve water, in addition to conservation practices discussed in the previous sections. Participants who relied on well water shared that their wells did not run dry during drought periods.

Some growers experienced water scarcity through infrastructural challenges to access or store adequate water. For example, one participant noted that they were more conscious of water use simply because it was difficult for them to turn their irrigation system on and off due to their access from a neighboring building. Another site accessing water from a neighbor was limited by the storage capacity of their onsite water tanks. In another more extreme case, a site relied on solely rainwater catchment systems for irrigation. Additionally, multiple sites had to truck water onsite before their current water access infrastructure was developed.

Municipal water prices produced feelings of water scarcity through financial pressure on those responsible for water payments. Technical assistance providers highlighted the burden of cost that they have seen on urban growers, with one stating "the fact that [urban] farms are able to operate even paying residential rates– it just means that they're using, very, very little water" (Participant 2, technical assistance provider).

The burden of water pricing varied based on the economic models and situations across sites. Community gardens had a fixed annual income generated from annual plot fees, which ranged widely from $15 to $300 per year. Community gardeners did not express financial worry regarding water bills but did use the cost of water to encourage plot holders to conserve. In one case, plot fees increased after a drought year, which was inevitable as the site manager described, "we needed to cover the [water] fees in order to keep this place running, and water became a major factor when we saw less of it [during drought]" (Participant 17, municipality representative). Urban farms without annual plot fee revenue relied on sales revenue or fundraising to cover water costs. Financial resources seemed particularly strained for urban farms that had additional operating costs, such as staff expenses.

For some urban farms, water expenses were seen as costly in principle, but not extremely burdensome due to subsidies received elsewhere, such as not being responsible for lease payments. One urban farmer noted that the burden of water costs was minimal, stating, "I'm really stingy with my water use [but] I'm still always willing to pay for the water to do it. [. . .] Of course, I might have to set my prices depending on the water rates, but. . . sometimes it's so small, it doesn't really impact me." (Participant 19, urban farmer). To other participants, however, water costs were a larger burden, particularly for those without sales income. Not all urban farms sold produce. In fact, urban farms selling produce were far outnumbered by ones that primarily donated produce and were instead funded by grants and donations. As a result, some operations were better equipped to pay for water expenses than others based on the overall goals of the site, financial structure, and management.

Although discounted water rates would financially benefit urban growers, some had mixed feelings on the topic. One farmer expressed apprehension about agricultural water rates disincentivizing conservation. Another urban farmer argued that a discounted water rate was warranted based on the community benefits the site provides as a source of free produce to the community. However, this farmer also felt tensions between the benefits of subsidized water and the overall value of water, explaining: "It's an interesting position to be in, because, as somebody who knows the value of water and how sacred it is, I think we don't pay nearly enough for water as a society. Water should cost a lot more" (Participant 10, urban farmer).

3.3.3 Institutional invisibility of urban agriculture

3.3.3.1 "Apples and oranges": varying definitions and metrics of urban agriculture

Conceptualizations and definitions of urban agriculture varied across entities and impacted the institutional management and recognition of UA. The main points of tension across definitions of UA were economic models and outputs, which were well-understood by a technical assistance provider who explained:

> "There's the economic definition of agriculture, which is used by a lot of people in the field to... I wouldn't say discredit urban ag, but they see the business model as not that of agriculture. Therefore, it doesn't constitute agriculture. And by that, I mean that [for] conventional agriculture, you have your input product and your output revenue, and the goal is to balance that through your farm management practices. And [if that is how] you define a farmer, a lot of urban ag does not meet that definition. [... For] an economic model of urban ag, the [output] might be educational. It's more resource-driven and less profit-driven." -Participant 33, technical assistance provider

Consideration of these nuances is essential for the valuation of urban agriculture resource use and management based on site inputs and outputs. One urban farmer called for more recognition of the less tangible benefits of their organization's work, especially concerning the value of water use:

> "If you're comparing water usage to production [agriculture], that's like apples and oranges, you know. I don't think that's a fair comparison. You gotta consider the education, the networking, the career opportunities... Because we're not just farmers. I'm a farmer, I'm an accountant, I'm a mechanic, you know, I'm a community activist, I'm a community organizer. I gotta fundraise. I gotta do all these things to support it. And it's not just me learning it. That's my team learning these skills. That's my community learning these skills. [...] It's not just a one to one, like for this much water, this much produce. It's this much water provides for these 250+ kids that we're able to open our programming to, you know. And when we shift the paradigm for kids at that younger age, that's when they build healthy habits as adults." -Participant 10, urban farmer

Technical assistance providers were more attuned to these issues, as they are the most involved with UA compared to municipalities and utilities. In fact, technical assistance providers and their agencies chose thoughtfully to resist defining urban agriculture to reduce the exclusion of sites from agency services. One participant discussed using "a more a case-by-case definition based on what the farm is like, where it's located, [and] how densely urban or suburban it is." (Participant 2, technical assistance provider).

The two water utilities represented in the study did not have a formal definition of urban agriculture or specific policies about urban agriculture. UA was largely invisible to water utilities as subsets of water meter accounts tied to other land uses, such as general irrigation for parks or schools. Only those on agriculturally zoned land, which was uncommon, could be distinguished from other land uses. As a result, there had been little discussion within the two represented utilities about urban agriculture, despite both being institutional providers of land to UA sites. One utility representative focused on food production, stating:

> "When you say urban ag I'm thinking of food– agriculture that is specifically food production. So, you know, there's very little of that. There's community gardens, which you've mentioned. I think a lot of the community gardens that [we're focusing] on here are not for food. They're more of just like more natural space gardens, native gardens, gardens that are more for the wildlife, not for food consumption, ultimately." -Participant 15, water utility representative

Whether or not sites were producing food, however, utilities had partnered with or promoted UA sites because they promote and educate about water-efficient landscaping. One utility was even specific in framing urban agriculture as a community service and asset. This aligned more with narratives within from city and county planning documents, which broadly supported UA.

Few planning documents defined urban agriculture or used the term at all. 60% of general plans mentioned any keywords related to urban agriculture, with community gardens being the main subject. This aligns with cities being a frequent source of land for community gardens. Planning documents discussed urban agriculture in the context of public health, recreation/open space, and environmental justice. Local food production was viewed as beneficial and was associated with increasing food access, healthy food, and community-building. Community gardens were frequently grouped with farmers' markets as amenities.

Varying definitions of urban agriculture created some issues for urban growers, mostly through the overall lack of acknowledgment of UA. Issues often begin with zoning. First, urban agriculture must be allowed on a prospective site, which depends on local zoning and land use policies. During the establishment period of one UA site, community members had to advocate for zoning policy changes by the city to allow agricultural activities on infill lots. This paved the way for future UA operations in already-developed areas. When this hurdle is overcome, zoning remains relevant through its impact on water rates. Most participants were on land zoned residential and were thus charged with a residential water rate. This made sites invisible to water utilities. Should water utilities have a definition for urban agriculture, sites could be identified and categorized differently. Creating a definition and designation for urban agriculture allows water utilities to build a better understanding of urban agriculture, its occurrence, and historical water usage, which is essential to manage and support these sites during drought. Even beyond water rates and utility relations, zoning definitions also have implications for the permitting of certain activities and structures, such as tool sheds, which are necessary for rainwater catchment. Therefore, zoning and the institutional recognition and understanding of urban agriculture plays a significant role in a site's water access and management.

3.3.3.2 State of planning and policy

3.3.3.2.1 General planning and policy

Within Alameda and Contra Costa counties, there were a total of 33 urban agriculture-related policies stated in city and county planning documents. These policies and actions were from 19 of the 33 cities in the study area and Contra Costa county's general plan accounting for unincorporated areas (Figure 4). These policies supported urban agriculture through the following pathways: general support, zoning, or connections to climate or sustainability goals (Table 5). General support was the most frequently occurring policy type and policies usually referred to community gardens rather than urban agriculture generally. The main actions of cities were to "promote," "encourage," or "support" community gardens. Other mentions of urban agriculture as part of other policies promoted urban agriculture to achieve a related goal, such as supporting local food security.

The language in planning documents indicated that cities expected to play a supporting role in urban agriculture rather than an initiating role. For instance, the city of Berkeley's policy OS-8 states, "Encourage neighborhood groups to organize, design, and manage community gardens particularly where space is available that is not suitable for housing, parks, pathways, or recreation facilities" (City of Berkeley, 2002). This places many responsibilities on neighborhood groups rather than city staff, indicating that Berkeley sees its role more as a land provider. Similarly, Union City's general plan reads, "Successful community gardens require defined management policies and high levels of community involvement. [...] The City will provide basic infrastructure required for community gardening and develop garden rules and management policies" (Union City, 2019).

Throughout interviews, city policies related to urban agriculture were not significant to urban growers and were rarely mentioned when asked about experiences of regulation and governance. The only mentions of city policy were either about advocating for change to hindering policies or encouraging policies that felt performative. In the performative case, a participant felt that the city had not followed through on their commitments to support urban agriculture in planning documents and stated, "in our interactions with city officials, we noted that the city is able to promote having a community garden to the public, but we know that they don't fully support the gardeners work of keeping a valuable green space alive year in and year out." (Participant 9, community gardener). This dynamic was common across community gardens, with another participant commenting about the city's contributions to the garden: "They don't do much for us. We do for them." (Participant 16, community gardener). Therefore, the level of support and endorsement of urban agriculture stated in policies and that perceived by urban growers disagreed.

3.3.3.2.2 Water-specific planning and policy

Planning and policy regarding water management for urban agriculture was nonexistent. Between the water utilities represented in interviews, there was no official planning or consideration for urban agriculture in water contingency plans. The utility representatives all maintained that urban agriculture would not be targeted for initial water cutbacks because water uses deemed nonessential or with little economic impacts would be reduced first. Water utilities regarded urban agriculture as a beneficial use, as one representative stated, "we [believe] it's a community service, and anything that's related to community service, [the utility] supports" (Participant 12, water utility representative).

Scale also seemed to be a factor: utilities saw urban agriculture as a small drop in the bucket compared to other potential

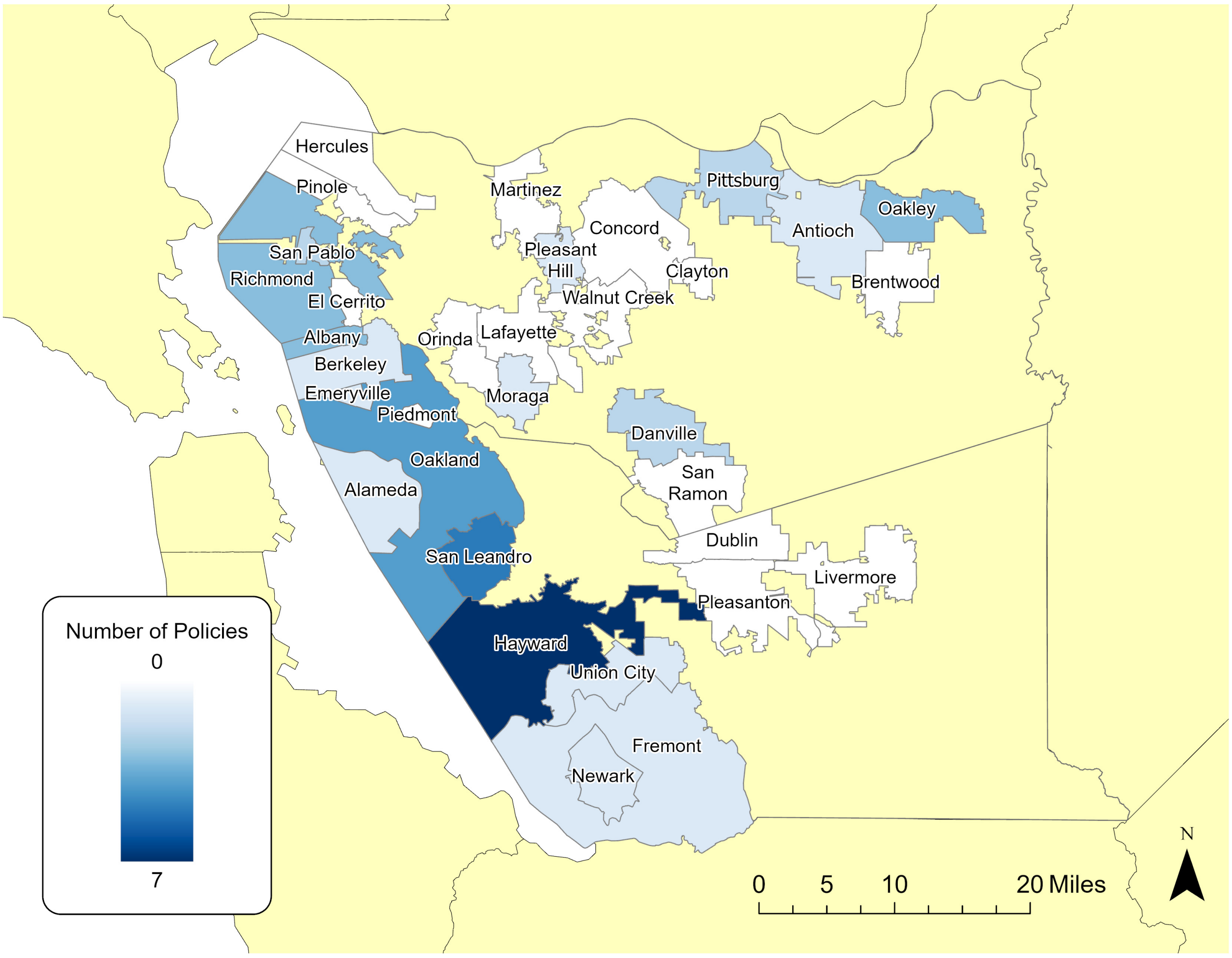

FIGURE 4
City general plan policies related to urban agriculture in the San Francisco East Bay.

targets for water use reduction, such as golf courses and irrigated ornamental landscapes. Given this context, targeting urban agriculture during drought would almost be punitive, as a participant explained,

> "Honestly, we don't have a lot of urban agriculture going on here in our service area. I don't see us cutting those things off, because a lot of them are connected to schools, community gardens, you know, nonprofit organizations. We aren't going to be telling them that, 'Hey, you need to shut the water off, and you can't grow your small plot of food here.' That's not what we are in the business of doing here at [the utility]. [...] As long as [water is] being used responsibly we're not going to say you need to turn that off." -Participant 15, water utility representative

Thus, water utilities did not express concerns about water use for urban agriculture and regarded urban agriculture as beneficial to the community. This aligned with the experiences of urban growers, who did not feel impacted by water utility regulations or water mandates.

Across planning documents, mentions of water as it related to urban agriculture were sparse, and more common in climate action plans rather than general plans. Standout policies are shown in Table 6. It is unclear, however, what progress have been made regarding these policies and the outcomes.

3.3.3.3 The power of individual allies

Because there was a lack of official planning and institutional support for urban agriculture, the role of individual allies within these institutions was critical to the success of UA sites. Multiple participants gained access to resources or policy change by allying with specific individuals, such as city council members, employees, or University of California (UC) Master Gardeners, discussed below.

Two participants representing different sites stated that individuals with institutional or political power helped establish their sites. In one case, this advocacy and support of an individual led to a city-wide policy change. The participant recounted, "... [the city didn't] allow cultivation on infill lots, which is vacant lots. [...] So we knew an ex-vice mayor. She knew all the people in the permitting and zoning department, and so we were able to present

TABLE 5 Urban agriculture-related policy types with examples.

Policy type	Example	Municipality
General support	**SC-P4.3.** Encourage urban agriculture, including urban farms and community gardens with collectively shared and managed plots, and demonstration and educational gardens operated by community organizations and educational institutions. Allow associated, limited on-site sales, processing of value-added products, and complementary agricultural activities when compatible with adjacent uses (Contra Costa Conservation Development, 2024).	Contra Costa County
Zoning	**Policy 2-6.6: Agriculture.** Allow most agricultural uses in the City's open space districts, and allow community gardening and "urban" agriculture in a wide range of settings. As defined by zoning, more intense agricultural uses in the hills may require a conditional use permit, consistent with the Hill Area Initiative of 2002 (City of Fremont, 2011).	City of Fremont
Climate and sustainability	**Policy 4.1.2 Urban Agriculture.** Continue to encourage and promote the development of urban farming operations within the City of Antioch, to provide for more sustainable, integrated agricultural production as identified by the City's Climate Action Resilience Plan (City of Antioch, 2003).	City of Antioch

TABLE 6 Examples of policies and actions related to water management for urban agriculture.

Document	Policy text
City of Berkeley Climate Action Plan (City of Berkeley, 2009)	Work with East Bay Municipal Utility District to consider a program that would provide reduced water rates for community gardens as an incentive for residents to utilize community garden space to grow their own food.
City of Oakland General Plan (City of Oakland, 2023)	Support community and home gardening efforts and—particularly in [Environmental Justice] Communities underserved by healthy food retail—by providing financial incentives such as land transfers or discounted water rates and technical assistance in the form of online and library resources and workshops on gardening basics and cooking easy, healthy meals with fresh produce.
Contra Costa County General Plan (Contra Costa Conservation Development, 2024)	Support programs administered by water or wastewater service providers that increase the availability of recycled water for urban agriculture and landscaping through self-fill stations and similar facilities.

the case pretty early [... and] we actually got it through in 6 months, which is utterly amazing!" (Participant 3, urban farmer).

Interviews with municipality representatives operating community gardens indicated that city involvement can be the will of an individual. One participant enjoyed managing and being involved with a community garden, sharing,

> "I've just fallen in love with it, which I would think a lot of other people do as well. [. . .] I've made it to be a priority of what I do, even though the revenue in it trembles in comparison to other programs and offerings that we have. But I've been able to do what I need to keep the gardeners happy. And my city, the Parks Department, has always supported me, so that I think has helped." -Participant 17, municipality representative

Multiple urban grower participants expressed appreciation for their allies within the city but also acknowledged that there was only so much one person could do given circumstances such as understaffing and lack of funding. Community garden programming was noted to be low priority to the city by both municipality representatives, and urban growers felt the effects of this.

One way that urban growers gained or leveraged institutional power was through the UC Master Gardener program. UC Master Gardeners were significant at many urban farms and community gardens as site managers, founders, and sources of gardening knowledge. These individuals underwent the University of California's gardening training program and are required to support gardening outreach and education in their respective counties. Participants frequently mentioned Master Gardeners as core to educational programming and operations. For some sites, Master Gardeners were key players in the advocacy required to establish sites. The Master Gardener status seemed to legitimize educational programs and efforts, providing individuals with institutional power by association with the university program.

4 Discussion

4.1 Roles in water management

The primary parties involved in water management for urban agriculture sites were urban growers, municipalities, and water utilities. These actors and their responsibilities were split between high-level and onsite management.

High-level management was comprised of municipalities and water utilities, both of which had institutional power. Municipalities impacted water management as land providers: they dictated the level of water access and infrastructure available to urban growers by determining the land urban growers could access. Municipal zoning also unintentionally impacted water rates for UA sites, because water utilities based water rates on zoning. Agricultural zoning was rare, so sites responsible for a water bill paid residential water rates rather than agricultural water rates. This was also the case in a study conducted in Santa Clara County, California (Diekmann et al., 2017). Moreover, municipalities implemented policies supporting urban agriculture, however, the impacts were not evident in urban grower experiences. Water utilities, on the other hand, were the primary source of water for sites. They had the ability to manage water by determining water rates and issuing water use restrictions. Ultimately, utilities did not leverage these powers and thus did not play an active role in water management.

The responsibility for water management fell largely on urban growers, who acted as onsite water managers. They implemented water-efficient infrastructure and cultivation practices. Urban growers had the most power over water use because there were little to no restrictions from water utilities, and municipalities often subsidized water use, alleviating financial barriers.

4.2 Assessing urban agriculture water resilience

The findings indicate that, thus far, UA sites have reasonably managed their water resources: they have not exhausted or exceeded their water access, nor have they generated scrutiny from water utilities or municipal landlords. This level of water resilience, however, is far from ideas presented in academic literature (Ebissa and Desta, 2022; Deksissa et al., 2021; Attwater and Derry, 2017; Rufí-Salís et al., 2020). We attribute this to a strong reliance on municipal water supply and the fragility of water access conditions.

4.2.1 Reliance on municipal water supply

The sites represented in the study were highly reliant on municipal water sources. Therefore, these sites are vulnerable to hazards that could impact municipal water supply, which can extend beyond drought to disasters such as wildfires, power outages, and earthquakes (Dobbin et al., 2023; Romero et al., 2010). The reliance on municipal water is not unique and has been documented in studies of urban agriculture in the United States, Brazil, Italy, France, Germany, Poland, and the United Kingdom (Alberti et al., 2022; Dorr et al., 2023). To reduce reliance on municipal water supply, and thus increase water resilience, sites could diversify their water sources by utilizing reclaimed water, greywater, and captured stormwater (Attwater and Derry, 2017; Moglia, 2014).

Reclaimed water was not available for use at any sites. Reclaimed water requires independent piping systems, which can be a significant financial burden to install and maintain, and is subject to local water utilities offering this service (Ward et al., 2014). Urban growers faced issues even with standard municipal water access, so these additional barriers were very prohibitive. Furthermore, it is unclear whether urban growers are interested in or willing to use reclaimed water, given that reclaimed water can face public resistance due to concerns about health risks and perceptions of color and odor (Santos et al., 2023).

Urban growers were able to diversify water resources using greywater and stormwater capture systems. However, the implementation of both practices was limited by the resources within site boundaries. Greywater reuse systems, for example, were limited by the amount of onsite water use from hand and produce washing. Similarly, the roof area of greenhouses or tool sheds limited the capacity for rainwater capture, and concerns about contaminants and suitable roof materials can be a barrier to implementation (Deng, 2021). Urban growers commonly used rainwater capture, despite their mixed opinions on the efficacy of these systems in a Mediterranean climate. Urban growers valued these systems, which was evident from the voluntary purchase and implementation of systems at sites that had free water access. As a result, reducing water costs was not a driving factor for rainwater capture, but rather the desire to maximize water resources.

Overall, urban agriculture sites did not implement water-resilient practices that harness urban greywater, rainwater, and wastewater at scale due to a lack of resources and integration into the urban environment. Sites were limited to the relatively small secondary water sources that were within the site boundaries. This emphasizes the importance of integration of UA within the greater urban sphere to fully realize the multifunctional benefits of urban agriculture, which is stressed in Mougeot's definition and analysis of UA (Mougeot, 1999).

4.2.2 Fragility of water access conditions

Water access and management for urban agriculture sites is largely based on loose agreements and convenient circumstances leading to water access. Urban growers can face immediate challenges should these conditions change due to budget cuts, staff turnover, or losses of individual allies that can cause sites to be responsible for water payments or face stricter water use mandates. A notable case is water use restrictions. Water utility representatives have stated that they do not anticipate implementing water use mandates for UA sites, but this is not explicitly stated in water contingency plans. Without concrete data on water use at UA sites water, utilities have limited evidence that these sites use water conservatively. Concrete evidence and explicit inclusion in planning are important because they provide evidence to make the case for UA sites as beneficial and not wasteful. Although interviews indicated that the water utility representatives had favorable views of urban agriculture, this may not be true across other decision makers.

A potential solution to the overall lack of water use data is to implement water metering at UA sites, which has multiple tradeoffs. This intervention could jeopardize subsidized access to water that many urban growers rely on. Even when water metering data is available, UA sites are vulnerable to being perceived as water-intensive compared to industrial outputs when comparisons are based on water inputs and production outputs. Water use is typically normalized based on growing area or crop output, however, neither of these methods capture the value of non-material outcomes of UA (Dorr et al., 2023; Pollard et al., 2018). Comparisons to conventional agriculture based on these figures are difficult, as UA sites typically do not operate on the economic model of prioritizing and maximizing harvest. Additionally, UA sites may not have the goal of replacing conventional agriculture and often use UA as a mechanism to achieve a multitude of goals beyond food production (Dorr et al., 2021; Cohen and Reynolds, 2015). These values can be lost when comparing water use data of UA to that of conventional agriculture and other competing land uses.

4.3 Pathways to food system and urban resilience

Institutional support is essential for urban agriculture sites to thrive and contribute to food system and urban resilience.

Without foundational support and secure access to land and water, urban agriculture is not positioned to achieve the many potential resilience benefits discussed in academic literature. The findings indicate that the state of UA in the East Bay can be fragile: sites are teetering on an unstable base of support from individual allies, handshake agreements, and favorable conditions for the critical resources of land and water. This instability has limited the capacity for UA to meaningfully integrate into the urban environment and its resource flows. To build capacity for UA sites to expand upon existing infrastructure and become more resilient, all while producing food and fulfilling other mission-related objectives, the basic needs of sites must be stabilized.

Institutions such as municipalities are best suited to support the stabilization of urban agriculture because they are already involved as land providers and stand to benefit from the success of UA. Many municipalities already have commitments to support urban agriculture in planning policy, and urban agriculture can help cities achieve climate action goals (Aragon et al., 2019). Water utilities, which also supply land to urban agriculture sites, can benefit from UA sites serving as educational and demonstration sites for drought-tolerant gardening. Moreover, the values and practices reported by participants indicated that the potential for urban growers to further improve water management was limited, because they were already maximizing water conservation. As a result, higher-level actors are the main leverage points for water management.

The most urgent action required is collaborative conversation across municipalities, water utilities, and urban growers about supporting the basic needs of urban agriculture sites. To support successful dialogue, stakeholders must clearly define their goals and responsibilities. Urban growers and municipalities must come to an understanding of the basic needs for UA and the responsibilities of each party in meeting these needs. This puts more substance behind vague municipality policies supporting UA and can clarify what resources and support urban growers can expect from municipalities. Furthermore, these conversations can help UA sites gain certainty regarding land tenure and access to water. Actors with institutional power that are familiar to urban growers, such as technical assistance providers from cooperative extensions, conservation districts, and the USDA Urban Service Centers and UC Master Gardeners, are needed to facilitate these processes and advocate for the needs of urban growers.

Once sites are stabilized, then progress can focus on the integration of urban agriculture into the urban environment and creating opportunities to support the multifunctionality of UA. Stakeholders should assess their appetites for making UA sites into the modeled hubs of resource reuse and resilience. Urban growers and cities alike ultimately may not want to pursue this vision due to the commitment involved, or there may be specific conditions for labor and payments to urban growers for their contributions. Coming to an agreement can prevent situations in which cities expect UA sites to develop into something beyond urban growers' capacities or desires to meet lofty climate goals. Creating a stable foundation is the immediate action needed both to support UA sites as they are, and to create a foundation for larger contributions to urban food system resilience.

4.4 Study limitations

This study was subject to limitations related to the subject population and biases within the data. The subject population represented outdoor, soil-based UA operations as these are the most common form of urban agriculture within the region of study. UA is characterized by the urban landscape it emerges from and varies across metropolitan regions (Rogus and Dimitri, 2015). Sites based on rooftop, hydroponic, and aquaponic systems, which may be more common in other regions, are not represented in this study. These sites utilize water very differently due to the differences in growing media. Additionally, the subject population for water utility representatives was limited due to the highly centralized nature of water utility service within the region. Therefore, the findings are not generalizable across water utilities. Overall, generalizable conclusions about urban agriculture and related governance are unlikely in any study, given the diversity of UA forms, municipality governance, and water governance across regions.

Additionally, the findings from participant interviews are subject to bias, and participant reporting of water conservation practices does not equate to water efficiency. In fact, a study of four urban community gardens in Central California found that the conservation values and practices of urban community gardeners did not correspond with lower actual water use (Egerer et al., 2018). Furthermore, another study of urban agriculture found that sites using drip irrigation used more water than those without drip irrigation, contradicting the expectation that drip irrigation would be more efficient than hand watering (Dorr et al., 2023). Therefore, self-reported values of water conservation and practices may not lead to *actual* reduced water use despite the intentions of urban growers.

5 Conclusion

This study investigated water management for urban agriculture in the San Francisco East Bay, focusing on stakeholder roles and urban agriculture's contributions to urban food system resilience in the face of water scarcity. We found that although urban agriculture can operate despite drought due to water-efficient urban grower values and practices, it requires institutional support to become a more significant contributor to overall urban resilience. Urban agriculture sites mainly relied on municipal water sources due to structural barriers that limit their capacity to diversify water sources and become more water resilient. Institutional support is necessary to stabilize UA access to land and water and build a strong foundation for sites to implement infrastructure to leverage local resource reuse opportunities. Significant contributions to overall urban resilience hinge on this harnessing of urban waste products for food production. This case study shows that despite some supportive policies and positive perceptions of UA water efficiency by institutional powers, support and integration are lacking, and UA sites still fight to meet basic needs. Meaningful collaboration is necessary to address the foundational needs of urban growers and establish expectations, goals, and responsibilities among stakeholders, who would all benefit from the success of urban agriculture.

These results demonstrate that examining urban agriculture's potential to optimize urban metabolism and contribute to food system resilience and climate resilience must consider policy, governance, and stakeholder experiences. Urban agriculture can be practiced, perceived, and managed very differently across geographic and political landscapes. Even within the area of interest of the study, access to resources varied widely. Therefore, the steps toward increased resilience must be determined locally through meaningful collaboration across stakeholders.

Future work should examine the appetite among urban growers for adopting practices proposed in the literature, such as the use of greywater or reclaimed water. Similarly, the nutrient recovery dimension of urban agriculture's contributions to circular urban metabolism should be investigated to understand the status of nutrient recycling practices and pathways for increasing integration with urban systems. Implementation of resource reuse practices hinges on both urban grower and institutional willingness to invest in planning and implementing these systems.

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 humans were approved by University of California, Berkeley Institutional Review Board CPHS #2024-07-17674. The studies were conducted in accordance with the local legislation and institutional requirements. The participants provided their written informed consent to participate in this study.

Author contributions

KC: Methodology, Formal analysis, Writing – original draft, Conceptualization, Writing – review & editing, Funding acquisition, Investigation. MC: Methodology, Conceptualization, Supervision, Writing – review & editing.

Funding

The author(s) declare that financial support was received for the research and/or publication of this article. Funding for this study was provided by the Berkeley Food Institute Student Research Grant program. Additionally, this article is based on the study supported by the National Science Foundation Graduate Research Fellowship under Grant No. 2146752. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Science Foundation.

Acknowledgments

The authors sincerely thank the 34 participants who graciously shared their time, experiences, and perspectives to make this article possible. Additionally, the authors thank the Berkeley Food Institute for providing funding for this project and making compensation for urban grower participants possible. Finally, the authors thank the Land and AgriFood Research Collective for their formative discussions that helped shape the direction of this study.

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/fsufs.2025.1677669/full#supplementary-material

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