

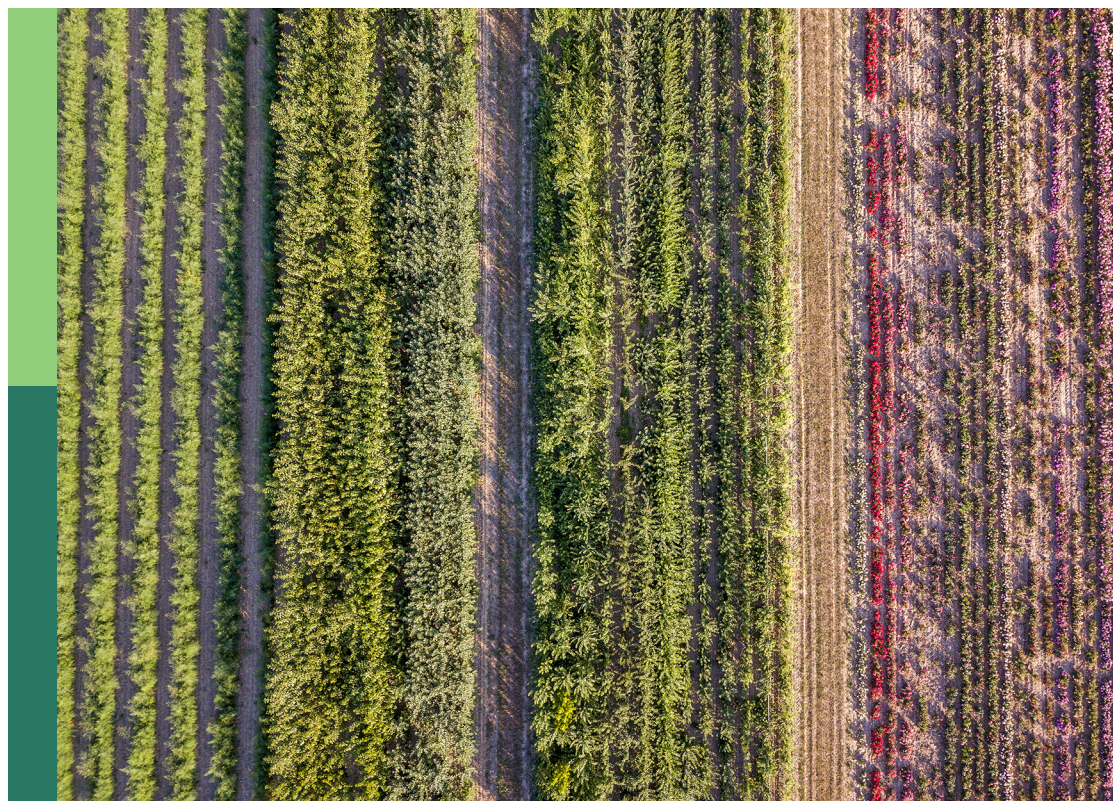
Urban agriculture as local food systems: benefits, challenges, and ways forward

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Tapan Kumar Nath and Sreetheran Maruthaveeran

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Urban agriculture as local food systems: benefits, challenges, and ways forward

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Table of contents

- 04 **Editorial: Urban agriculture as local food systems: benefits, challenges, and ways forward**
Tapan Kumar Nath and Sreetheran Maruthaveeran
- 06 **Adapting to urban gardening in China: how will policymaking help migrant and native gardeners?**
Yusi Xie and Zhong Xing
- 21 **Using the Net-Map tool to analyze stakeholder networks in the city region food systems of seven European cities**
Melissa Leimkühler, Kathrin Specht, Barbara Schröter, Anna Wissmann, Chiara Iodice, Runrid Fox-Kämper, Ann-Kristin Steines, Francesca Monticone, Antonella Samoggia, Giuseppe Carlo Modarelli, Lélia Reynaud-Desmet, Adam Curtis, Isabella Righini, Michele D'Ostuni, Jaime Ramón, Samir Amghar and José J. Pascual-Fernández
- 42 **Home food gardening in modern cities: advances, issues, and future perspectives**
Jingcheng Xu, Tingwei Lin, Ying Wang, Weijie Jiang, Qiang Li, Tao Lu, Yahui Xiang, Jingyong Jiang and Hongjun Yu
- 61 **Factors affecting the adoption of high technology in vegetable production in Hanoi, Vietnam**
Bui Huy Nhung and Dinh Duc Truong
- 72 **Adoption and desirable characteristics of Information and Communication Technologies for urban small-scale food producers in South Africa**
Robert Massimo Alfonsi, Merle Naidoo and Alexandros Gasparatos
- 89 **Exploring young consumer's understanding of local food through proximity and social representations**
Veronika László and Stefan Wahlen
- 100 **Agronomic and organizational aspects of Barcelona's community gardens**
Diego Maximiliano Macall, Xavier Gabarrell Durany and Sergio Villamayor-Tomas
- 109 **Sustainable transitions in food systems: a case study of an urban agriculture farming training program in Washington, United States**
Soumya Keefe and Jean Lee
- 118 **Do urban safety net programs affect the financial inclusion and food security of households, primarily women participating in urban agriculture? A triangulative exploration of Ethiopia**
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Editorial: Urban agriculture as local food systems: benefits, challenges, and ways forward

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KEYWORDS

community gardening, food security, agrobiodiversity, urban agriculture, local food system

Editorial on the Research Topic

Urban agriculture as local food systems: benefits, challenges, and ways forward

Urban agriculture, through community gardens and urban farms, plays a crucial role in achieving sustainable development goals, including reducing urban poverty, enhancing health and wellbeing, creating sustainable cities and communities, mitigating climate change, preserving the land, and fostering partnerships among stakeholders. Urban agriculture as a local food system (LFS) has emerged as a critical area of research due to the increasing pressures of population growth, rapid urbanization, climate change, and land use changes on agricultural productivity and food security. The COVID-19 pandemic has further highlighted the vulnerabilities in global supply chains, resulting in limited food availability and underscoring the importance of resilient local food systems. LFS, which involves locally or regionally produced food sold directly to consumers, offers a promising approach to ensuring a steady food supply during crises. Policymakers, planners, and advocates are increasingly recognizing the broader benefits of LFS, including community building, diversified economies, civic engagement, and climate resilience. This Research Topic aims to document and disseminate knowledge on urban agriculture as LFS with the primary objectives of:

- i) Exploring the various forms of urban agriculture, such as community gardens, home gardens, and urban gardening, and their contributions to the local economy, sustainability, and wellbeing. The suite of articles published in the Research Topic have advanced these understandings of urban agriculture as LFS and thereby contributed to a key perspective on urban agriculture, and
- ii) Identifying the challenges and opportunities for scaling up urban agriculture to create healthier food landscapes.

This Research Topic comprises 9 articles that focus on various aspects of urban agriculture across the Global South and North and that contribute new social and ecological perspectives (Zimmerer et al., 2021). Tareke investigated the contribution of cash transfers (CTs) to urban agriculture and food security in Addis Ababa, Ethiopia. This study reported that CTs have moderately improved financial inclusion for women and slightly increased food security. It emphasized pro-poor and gender-responsive financial inclusion options for urban agriculture development in the country. A comparative study

in Chongqing City, China, explored the value of urban gardening among local and migrant gardeners, as conducted by [Xie and Xing](#). They found that local or native gardeners value a combination of small, private greenery, ornamental plants, and edible vegetables. In contrast, migrant gardeners prefer relatively large gardens for food production that generates income.

Training, perceptions, and enabling factors for broader adoption of LSF are equally important. [László and Wahlen](#) explored how young consumers in Hungary define, perceive, and experience local food. Young people consider local food in terms of health, freshness, taste, quality, and trustworthiness, which are the relational values of LSF relevant to farmers and policymakers undertaking interventions to promote local food production systems. Drawing on a study in Washington, USA, [Keefe and Lee](#) reported that training programs create a space for social learning, changing collective practices and narratives that foster the development of community gardens or community-supported urban agriculture. They suggest that state and local governments need to intentionally support policies that recognize the importance of urban agriculture in their sustainability agendas. In Hanoi, [Nhuong and Truong](#) identified several factors, including attitude on high-tech production, access to information and credit, size of farm, membership in extension organizations, education level, visits to demonstration sites, extension services, and training to farmers that influence farmers' adoption of high technology in vegetable production. City residents and policymakers in modern cities recognize that home food gardening plays a crucial role in providing food during humanitarian emergencies and lockdowns, as noted by [Xu et al.](#) Moreover, home food gardening is becoming an increasingly popular recreational activity, offering therapeutic benefits such as fostering social bonds, improving mental and psychological wellbeing, and strengthening the connection between humans and nature.

Crop combinations, the role of actors, and information and communication technologies (ICTs) are also essential attributes for the development and wider promotion of urban agriculture. As reported by [Macall et al.](#), locals consume a diverse range of crops from community gardens within Barcelona's municipal boundaries. However, they suggested practicing monoculture cropping in community gardens across the city to achieve significant self-sufficiency, which required the professionalized and coordinated role of relevant actors. The adoption of ICTs may improve the efficiency of small-scale food production systems. [Alfonsi et al.](#) examined the adoption patterns and desirable characteristics of ICTs among small-scale food producers engaged in urban agriculture in South Africa. Producers prefer food-related mobile applications to have functions such as price comparisons, sharing best practices, and health advice. They also prefer user-friendliness, low data usage, and affordability in food-related mobile applications. This study points out the importance of comprehensive approaches to the development and

promotion of food-related ICTs when targeting small-scale food producers. By studying the food value chain across seven European cities, [Leimkühler et al.](#) stated that the city-region food systems approach helps identify the roles and relationships of various actors in the value chain.

In conclusion, articles included in this Research Topic emphasized the value of urban agriculture for conserving agrobiodiversity, promoting recreation, generating income, and ensuring food security. The involvement of women, young perceptions, training, CTs, adoption of ICTs, and collaboration among many stakeholders are critical factors that policymakers should address to promote and sustain urban agriculture in cities. To foster healthier and sustainable urban societies, LFS is essential, necessitating robust policy support and collaboration among stakeholders in the value chain.

Author contributions

TN: Writing – original draft, Writing – review & editing.
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References

Zimmerer, K. S., Bell, M. G., Chirisa, I., Duvall, C. S., Egerer, M., Hung, P.-Y., et al. (2021). Grand challenges in urban agriculture: ecological and social

approaches to transformative sustainability. *Front. Sustain. Food Syst.* 5:668561. doi: 10.3389/fsufs.2021.668561



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Adapting to urban gardening in China: how will policymaking help migrant and native gardeners?

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China's current urban gardening promotion policies mainly focus on community gardens and lack in-depth research on the differentiated needs of different urban gardeners. To meet the diverse needs of China's gardeners, this study proposes a typology that classifies gardeners into urban native and migrant ones based on their urban and rural living experiences in China. A questionnaire survey conducted in the core area of Chongqing city revealed significant differences and some similarities in gardening motivations and behaviors between urban native and migrant gardeners: (1) Although most of the gardeners approved of the value of food production and green scenery creation that Chinese urban gardening has, and disapproved of its value for family income generation, the urban native gardeners' disapproving attitude towards family income generation, and their approval of green scenery creation were more assertive, while on the contrary, the urban migrant gardeners had a more robust approval attitude towards food production. (2) The urban native gardeners preferred proximity and small private spaces for a combination of ornamental vegetation and edible vegetables. In contrast, the urban migrated gardeners preferred larger areas for gardening in non-community spaces and leaned towards edible vegetables. (3) Both have shared motivations related to the recreation and ecological conservation values of urban gardening. Given the above differences and similarities, this paper proposes an urban gardening development strategy that meets the needs of the two types of gardeners in China, including space planning and design, operation, and management of gardening spaces, and organization of activities.

KEYWORDS

China, urban gardening policy, urban native gardeners, urban migrated gardeners, gardening motivation, gardening behavior

1 Introduction

The value of urban gardening is being recognized in urban socio-economic and natural ecosystems. From a socioeconomic perspective, it promotes the physical and mental health of gardeners (Van Den Berg and Custers, 2011; Castro et al., 2013; Booth et al., 2017; Suto et al., 2021), boosts family income (Lafontaine-Messier et al., 2016), and encourages social interaction (Armstrong, 2000; Bendt et al., 2013). From the perspective of natural eco-systems, it fosters urban biodiversity (Lin et al., 2015; Speak et al., 2015; Teuber et al., 2019), maintains

ecological functions, and strengthens the relationship between residents and the natural ecosystem (Askerlund and Almers, 2016; Hemmelgarn and Munsell, 2021). Although urban gardening has been widely acknowledged for its outstanding value, policy attitudes to it vary among governments due to differences in socio-economic contexts (Djokić et al., 2018; Górna and Górny, 2020; Schoen et al., 2021).

China's current urbanization process has garnered global attention. While its speed has slowed, the primary challenge remains ensuring that individuals who have migrated from rural areas genuinely become urban residents¹ (Xinhua News Agency, 2022). Between 2000 and 2020, the number of people living in Chinese cities permanently increased by 443 million. Of this total, 187 million individuals moved from rural to urban areas. However, according to the China Population Census, they continued to be registered in rural areas (China National Bureau of Statistics, 2020). Hence, we could infer that at least 187 million people from rural areas had migrated to Chinese cities from 2000 to 2020, while the actual figure is much more significant because the rural population that officially became urban residents after completing the registration transformation process is not included in this figure. At the same time, due to the dual-track household registration policy, migrants cannot access the equivalent public and social services as urban residents, especially in large cities where resources are limited (Chan and Buckingham, 2008). In addition, their urban lifestyles and recreational needs are highly influenced by their previous experiences in rural areas (Qiu, 2013; Macdonald and Winklerprins, 2019), distinguishing them from the native urban residents.

Against this backdrop, many urban migrated gardeners (UMGs) have emerged in cities across China. These individuals are typically characterized by (1) Having a certain amount of prior farming experience and having previously relied on agriculture for income; (2) either having been displaced from their rural arable land due to urbanization and relocating to cities or choosing to live in urban areas for the sake of their children's livelihood or to pursue employment opportunities [which has also contributed to the abandonment of rural lands in China to some extent (Chen et al., 2009, 2022)]; and (3) willing to continue their traditional way of life in cities by engaging in urban gardening practices. Research indicates that migrant gardeners significantly contribute to urban cultivation, particularly in certain regions (He and Zhu, 2018). Furthermore, some studies imply a possible correlation between migrant gardeners and elevated rates of informal gardening in Chinese urban areas (He and Zhu, 2018; Ding et al., 2022), which is also referred to as "guerrilla" gardening or gardening in "self-claimed gardens" (Zhu et al., 2020). Such gardening activities frequently encounter opposition from nearby residents (Adams et al., 2014; Zhu et al., 2020), which hinders the effective

management of public spaces within the community. Between 2018 and September 2022, Chongqing Municipal Urban Management Bureau and Shanghai Municipal Urban Management and Law Enforcement Bureau took 14 and 57 verifiable actions against urban informal gardening, respectively, concerning 41.15 hectares of informal fruit and vegetable gardens in Chongqing, mainly in city parks and green spaces, including parts of community parks, and 1,800 square meters in Shanghai, primarily small-scale informal gardens in public green spaces (Chongqing Urban Management Bureau, 2023; Shanghai Urban Management and Law Enforcement Bureau, 2023).

The expanding rural-migrated population is concurrent with increased community gardens in cities across China. During the urban renewal process in China, community gardens are highly applauded by managers for making efficient use of fragmented spaces (Li et al., 2023). Notably, community gardens did not emerge in official records until 2014 (Mai et al., 2023). Hence, urban gardening before that tended to be informal. Taking Shanghai as an example, over 200 new community gardens were constructed between 2014 and 2022 in Shanghai (Kou et al., 2019; Yuelai Liu et al., 2022). Additionally, more than 900 mini community gardens (Kou et al., 2021), which focus on small-scale gardening and home planting, have been created as self-initiated projects among residents. Businesses initially funded community gardens, while local government support at the grassroots level started in 2016 (Yuelai Liu et al., 2022; Mai et al., 2023). Shenzhen has constructed 360 community gardens as government initiatives between 2019 and 2023, with plans to add another 120 gardens by the end of 2023 (Zhang et al., 2022; Wen, 2023). The rapid expansion of government-led community garden construction in China is evident.

Against this backdrop, many city-dwelling urban native gardeners (UNGs) have emerged throughout Chinese cities. These individuals possess the following traits: (1) they were born in cities and benefit from urban-based public and social services; (2) they have no prior knowledge of agricultural production in rural areas; and (3) they are happy to engage in gardening ventures in the urban scenarios (typically in community gardens or their balconies). It is evident that both UNGs and UMGs participate in urban gardening in Chinese cities; however, they are differentiated urban gardeners due to their life experiences and current living conditions in cities.

Behavioral geography investigates how people interact with their environment to optimize space (Golledge and Timmermans, 1990; Golledge et al., 2007). Current research on urban gardening behavior investigates people's participation, selection of gardening spaces, and management of these spaces (Van den Berg et al., 2010; Hardman et al., 2018; He and Zhu, 2018; Ding et al., 2022; Wei and Jones, 2022). It has been discovered that the three behaviors above may affect the attainment of the value and benefits of urban gardening. Residents participating in urban gardening show greater willingness to pay for city horticulture and protect urban ecosystems (Lohr and Pearson-Mims, 2005; Ge et al., 2021). Additionally, space selection behaviors affect the well-being of gardening activities, with allotment gardens having significantly higher overall well-being than working farms. In contrast, working farms have substantially higher economic benefits than community farms and allotment gardens (Kirby et al., 2021). Finally, variances in the management of gardening spaces significantly affect the level of biodiversity and environmental landscape within the designated area. Animal-friendly gardening practices, including the installation of bird baths,

¹ "Individuals moved to cities from rural area" refers to individuals who previously resided in rural areas but now dwell in urban areas. This encompasses individuals living in cities with rural household registration and those whose household registration and current residence are in cities but were formerly located in rural areas. When they not only live in a city but have integrated seamlessly into its social welfare, public services, attitudes, lifestyles, and more, following the practices and lives of typical city dwellers, they are considered entirely urban residents.

bird boxes, no-dig cultivation, and pest management, among others, have distinct impacts on urban biodiversity conservation, soil quality, and surrounding ecosystems (Gaston et al., 2005; Clarke et al., 2015; Liere et al., 2020). Adaptive management practices of gardening in arid environments enhance the ecological resilience of the area concerned (Egerer et al., 2020).

Motivations are at the core of their gardening behaviors (Lewis et al., 2018; Lee and Matarrita-Cascante, 2019; Philpott et al., 2020). Lewis et al. (2018) summarize urban gardening motives as social aspects, well-being, and tangible or intangible outputs. To add to this classification, nature and education are also mentioned (Menconi et al., 2020). Variations in those motivations impact the gardening behavior of individuals; for example, Wu et al. (2022) proposed that residents with positive opinions on the ecosystem advantages of urban gardening were more inclined towards taking part in gardening, as shown in a study of positive and negative perceptions of the ecological setting of gardening behavior. Meanwhile, Philpott et al. (2020) discovered that gardeners who agreed with the ecological benefits of urban planting preferred species diversification, which subsequently influenced the abundance of vegetation within the gardening space. Pearsall et al. (2019) discovered that gardeners' preference for specific plant species is influenced by their cultural identity, which is a major driving force behind their gardening activities.

The correlation among demands, behaviors, and value output in urban gardening provides a basis for policymakers to develop strategies that guide differentiated gardening behaviors, ensure better services for urban gardening spaces, and achieve the anticipated benefits of the activity (Eigenbrod and Gruda, 2014; Beavers et al., 2021; Jahrl et al., 2021; Kirby et al., 2021; Ryan, 2021). Instead of implementing a "one-size-fits-all" policy, whether it involves strict control of informal gardening or active promotion of community gardens, urban gardening authorities should allocate more resources to understanding urban gardeners' diverse needs and behaviors. This will enable them to "differentiate" and formulate urban gardening policies that cater to the diverse needs of gardeners and ensure that urban gardening can more effectively achieve its potential in promoting social well-being and ecological benefits. Lu's (2022) findings indicate that community garden projects pushed by management face maintenance problems, highlighting the need for the Chinese government to prioritize the requirements of urban gardeners.

The current policies for urban gardening heavily rely on typological classification criteria, such as age, ethnicity, and economic status, to fulfill gardener needs (Eigenbrod and Gruda, 2014; Kirby et al., 2021; Department of Agriculture and Markets, 2023; Pennsylvania Department of Agriculture, 2023). However, considering the larger context of urbanization in China, where people have migrated from rural areas to cities, they need to adapt to their new urban lives (Zhang and Song, 2003). This study aims to classify urban gardeners in Chinese cities into migrant gardeners (UMGs) and native gardeners (UNGs) based on their experiences of urban and rural life. These two groups are the central gardeners in urban China, and their previous living experiences, whether in urban or rural areas, are expected to influence their current gardening practices in cities. The contemporary urban gardening policy, which aims to promote community gardens and regulate informal gardening, may not adequately address the distinct needs of these two groups. Therefore, we utilize statistical surveys and quantitative analyses to identify

potential distinctions between the two groups. Based on this information, we develop a development strategy for urban gardening that adapts to their unique needs.

2 Materials and methodology

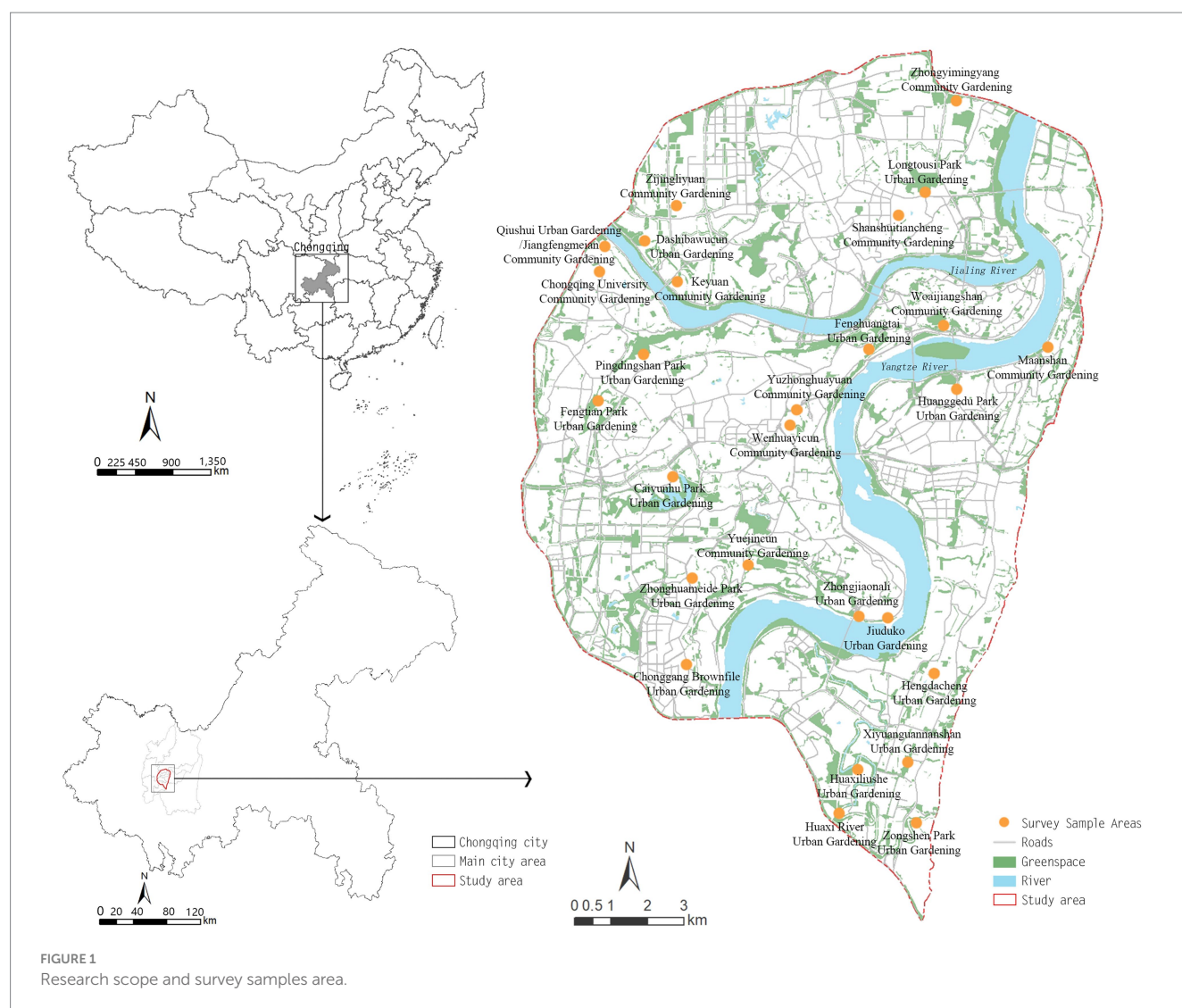
The research was conducted in two phases to explore the differences between migrant and native gardeners in urban China and to ensure reliable results. First, a questionnaire survey was conducted. The purpose was to obtain first-hand data on urban gardeners through field research. The main tasks included identifying the research area and the type of urban gardening space to be studied and selecting the sample area. The research questionnaire was also developed based on the research objectives and then distributed and collected. Finally, the data were archived, and quantitative analysis was performed. The primary purpose was to study the data collected in the first stage and determine whether there was a statistically significant difference between the two types of urban gardeners using the Chi-square test. More details are introduced in the following.

2.1 Survey sample area

2.1.1 Study area

To capture the impact of urbanization and large-scale migration from rural areas to cities in China, we narrowed our focus to metropolises with distinct urbanization characteristics and cities with potential for urban gardening. Based on our criteria, we have selected Chongqing as our target city. For three reasons: (1) Chongqing is one of China's four metropolises directly governed by the central government. Supported by the State's Chengdu-Chongqing Twin-city Economic Strategy (China Daily, 2021), it went through rapid urbanization, increasing the urbanization rate by 34.7% between 2000 and 2021, reaching 70.3%. (2) In 2021, Chongqing had a built-up area of 1,834.20 square kilometers with a resident population of 32,124,300 (Chongqing Municipal Bureau of Statistics, 2022). Such rapid urbanization in a short period, which resulted in a rapid expansion of urban land and many people with previous rural experience moving into cities, meant that the city had a significant potential urban gardening population. (3) Chongqing is a big mountainous city in southwest China, where the Jialing River and the Yangtze River pass through its center. The city is developing in the group with clear separations of mountains and waterways between them, creating natural "ecological separation zones." The influence of the fragmented mountainous terrain and the outward expansion urbanization mode resulted in many small chunks of green space that are difficult to build between large and small constructed areas. They become abundant sources of urban gardening spaces. Due to the above three factors, Chongqing's high-density construction setting has long been characterized by many residents' spontaneous gardening behavior, with rooftops, gaps, lots, and unused land gardening common to see in the city (Yufeng Wang and Wang, 2023).

Our research scope was the built-up area of Chongqing city proper, which is surrounded by its inner-ring express road, excepting the



reservation area of the “Four Mountains”² (as shown in Figure 1). This is the most critical area in urbanization, which the convergence of main city business districts and the natural topography of the intersection of the two rivers, further complicated by the Pingding Mountain, Eling, Pipa Mountain, Daliangzi Mountain, and other small mountain displacements, making the conflict between the urban development needs in the area and the gardening demands of the residents most prominent.

2.1.2 Urban gardening types in study area

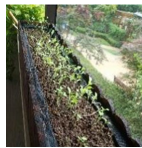
One key issue in designing the survey was ensuring the comprehensive inclusion of all types of urban gardening spaces so that the questionnaire results could reflect the status quo of urban gardeners in Chinese cities. Although urban gardening forms vary around the world (Lin et al., 2015; Kirby et al., 2021; Mackiewicz et al., 2021), community gardens remain the principal practice of

urban gardening in China, which is also the focus in the literature on urban gardening in China (Ding et al., 2022; Lu, 2022). However, after conducting field visits and literature research, we observed various forms of urban cultivation beyond residential areas, including small patches of basic farmland.³ The management of these areas resembles small-scale market gardens, a form of urban gardening run independently by the land users, and the produce is sold to the market. It also includes informal gardening spaces, like unused or abandoned land. At the same time, gardening in residential communities can be further subdivided into different forms, such as balcony gardening, roof gardening, and gardening in the spaces between residential buildings. Therefore, we compiled a list of representative types of urban gardening in China (Table 1), hoping that the survey will be more likely to cover various types of urban gardening spaces, making the research results more in line with the reality of urban gardeners in China.

² The reservation area of the “Four Mountains” refer to the development, construction and its management activities control area, planning to protect the ecological and environmental resources of Jinyun Mountain, Zhongliang Mountain, Tongluo Mountain and Mingyue Mountain in main urban area.

³ In the Chinese context, the term “basic farmland” refers to those farms that are surrounded by cities because of rapid urbanization but must be protected under China’s farmland protection policy.

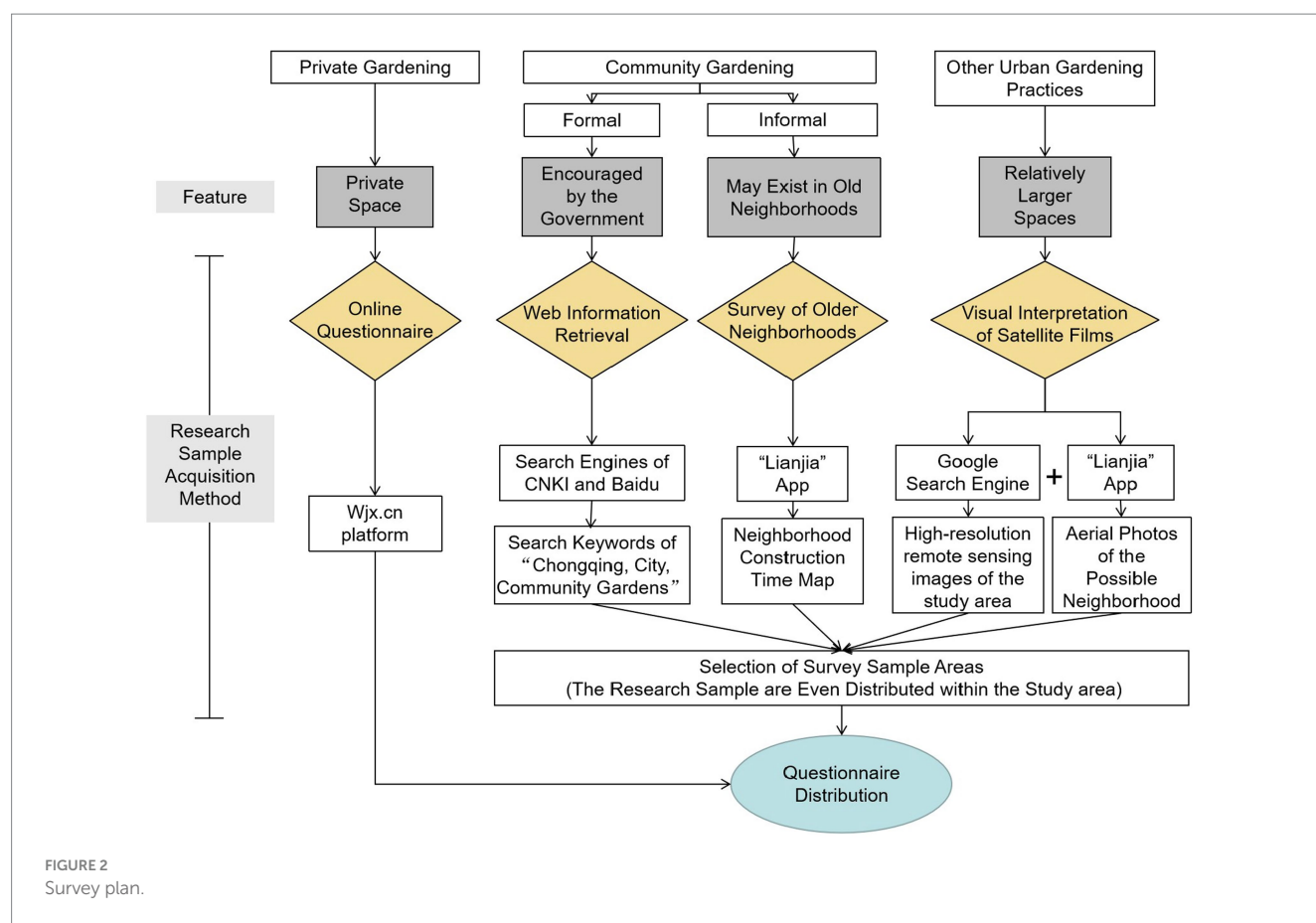
TABLE 1 Urban gardening types in research area.

Classification	Gardening type	Size	Ownership	Management	Pictures
Private gardening	Balcony gardening	About 1–10 m ²	Householder	Householder	
	Backyard gardening	About 5–30 m ²			
Community gardening	Rooftops gardening or gaps gardening between buildings	About 50–100 m ²	Apartment residents	Normally, householders on the top floor	
	Community lots gardening	Area varies	Community residents	Normally ground-floor residents	
Other urban gardening practice	Unused urban land gardening	Area varies	Citizens	Normally nearby residents	
	Inefficient urban green space gardening	About 0.5–1 ha			
	Small scale market garden	About 0.5–5 ha	Land owner	Professional farmers	

2.1.3 Selection of survey sample areas

The survey was conducted from January to May 2022. To obtain comprehensive data on urban gardeners in the study area, we adopted different survey protocols for the three broad categories of urban gardening spaces described above (see Figure 2). (1) For gardening in balconies, backyards, and other private spaces, the main difficulty in obtaining research data stems from accessibility in the COVID context. We used wxj.cn, an online questionnaire survey platform, to distribute the questionnaire. The platform pushed questionnaires to accounts that meet the research requirements based on users' information (those who engage in private gardening in Chongqing City). (2) For community gardening, determining the location of community gardens is the first step. Based on the existing literature (Zhu et al., 2020; Ding et al., 2022) and field research experience, locations of

formal community gardens, as a form of urban gardening encouraged by the government, can usually be obtained through an online search of relevant location information. In contrast, informal community gardening is generally caused by poor property management in old neighborhoods. Therefore, we used web information for the formal ones and information on the housing sales and rental platforms to determine the location of the informal ones, respectively. Specifically, we searched CNKI and Baidu for formal community gardens with the keywords "Chongqing, urban, community gardens." We screened the information we got to locate the neighborhoods where community gardens may exist. For informal community gardens, we used the neighborhood construction time map on the "Lianjia," a property realtor platform, to screen for neighborhoods in the study area built before or near 2000. (3) For other urban gardening practices



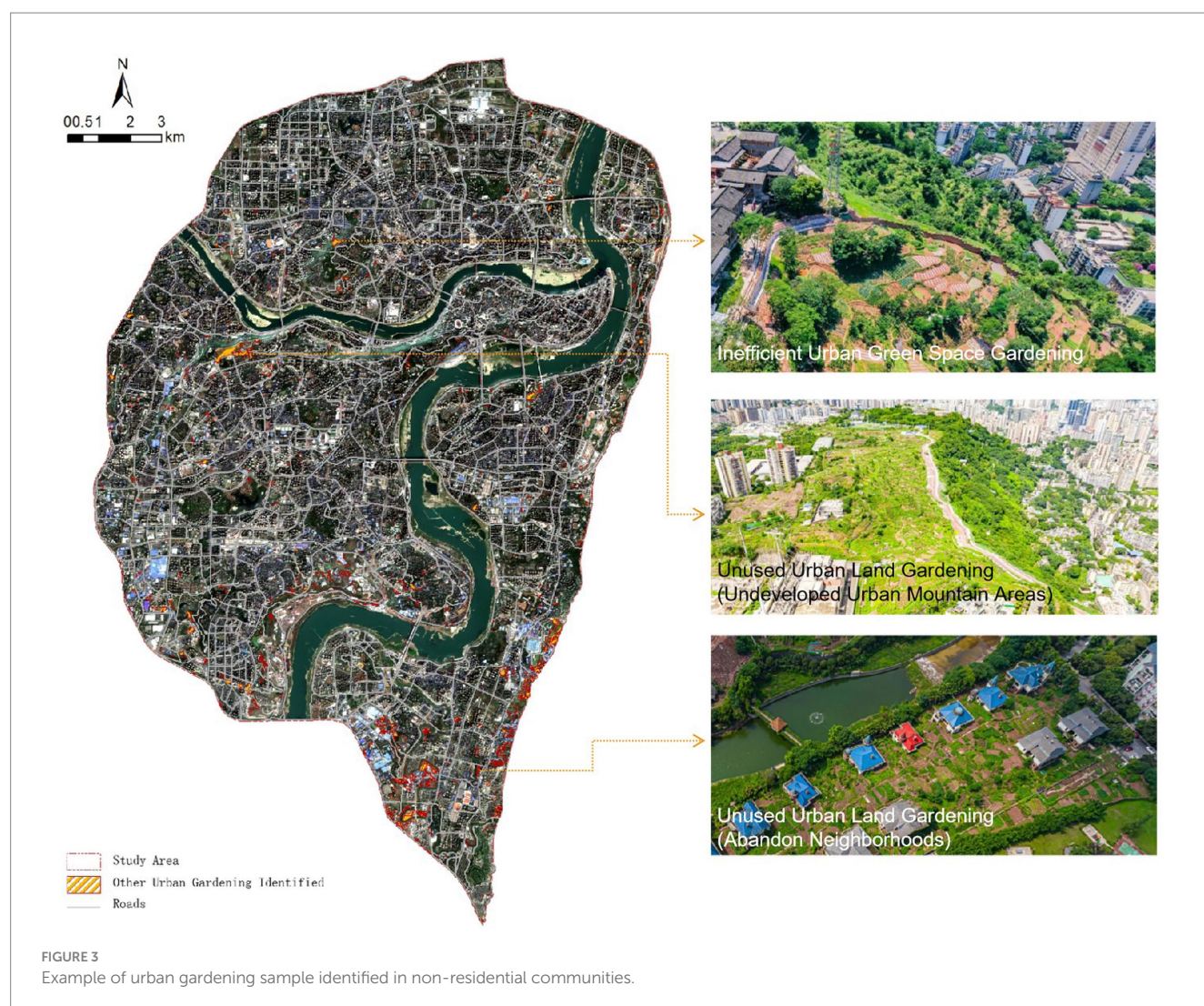
outside of the residential communities, it was also challenging to determine the locations of the survey sample area. Based on the research experience, we believe they usually occupy larger spaces, which can be identified from remote sensing imagery and aerial photographs. Therefore, we used Google satellite imagery and aerial photographs on realtor's websites to identify the more salient urban gardening areas in the study area. The Google satellite images used for identification were dated 27 March 2021. We looked for apparent urban gardening spaces, such as small-scale market gardens and unused or inefficiently used urban lands with gardening traits. We were reading the satellite images to obtain the names of the possible neighborhoods, which were rechecked by comparing them with the aerial photos of those places on [Lianjia.com](https://www.lianjia.com/). Further details and examples of such a process are shown in Figure 3.

A list of field visit targets was determined based on the results of the information search for community gardens and old neighborhoods, together with that of analysis of images from satellite remote sensing and the aerial ones from the realtor website, taking into consideration the even distribution of such targets within the study area. The primary purposes of the visits were (1) to verify urban gardening activities (due to the gap between the timing of the research and the images, the actual use of the space may have been changed) and (2) to clarify the accessibility to the urban gardening spaces (some of the neighborhoods may have strict security systems, making it difficult to enter them. At the same time, some of the gardening spaces may be within the private premises of factories and institutions, which are also inaccessible) to

determine the feasibility of having field visits to these places. After all these procedures to screen the possible survey samples of field visits, 28 areas were finally selected for field questionnaire distribution, including 11 urban gardening spaces in residence communities and 17 other spaces, the locations of which are shown in Figure 1.

2.2 Survey questionnaire

The value of urban gardening can be achieved by formulating policies to meet people's needs based on the motivation and behavior of different groups (Eigenbrod and Gruda, 2014; Beavers et al., 2021; Jahrl et al., 2021; Kirby et al., 2021). To this end, we used two variables, i.e., gardening motivation and gardening behavior, to approach the differences between UMGs and UNGs and attempted to measure them using indicators. Referring to the analyses of urban gardening motivation and behavior in the literature (Lindemann-Matthies and Marty, 2013; Lindemann-Matthies and Brieger, 2016; Menconi et al., 2020; Sanyé-Mengual et al., 2020; Song et al., 2022), and taking into account the actual situation of urban gardening in China (Ding et al., 2022; Wei and Jones, 2022), we summarize the measurement of motivation into three aspects: motivation closely related to food production, social and recreational well-being, and maintenance of urban ecology and landscape; and at the same time, the measurement of behavior is summarized into space choice and gardening management behavior. The specific indicators and data collection methods are shown in Table 2.



2.3 Data analysis

We adopted a quantitative method to determine whether there is a difference between UNGs and UMGs. According to the answer to the question “Have you ever worked in agriculture and lived in rural China?” in the questionnaire, we divide the data into two categories: (1) UMGs who have experience in rural agriculture as well as rural life and are currently involved in gardening activities in the city; and (2) UNGs who have no experience in rural agriculture as well as rural life and are currently involved in gardening activities in the city. Chi-square tests are commonly used to analyze the degree of deviation between two data sets. They are used for statistical research data analysis on gardening motivations and behaviors among UMGs and UNGs. The analysis process was as follows: (1) The research data were entered into SPSS.24.0, and the validity test and confidence test were performed. To determine whether the measurement scale of gardening motivation can effectively describe this measurement variable, validity analysis was conducted to check the distribution of the data and the degree of correlation between the topics through KMO and Bartlett's test. The KMO value is acceptable when it is more significant than 0.70, while the value of Bartlett's test of sphericity must reach the significance level

($p < 0.05$). Moreover, to ensure that the scale can reflect the data in question stably, reliability analysis was conducted by testing the Cronbach α coefficient. The scale is acceptable if the Cronbach α coefficient is more significant than 0.70. (2) To determine whether there is a difference between the two groups of survey data of UMGs and UNGs, we used the Chi-square test to discriminate the significance of the difference between the two data groups. During the Chi-square test, Fisher's exact test was used when the expected number of answers from more than 20% of the individual question items was less than five to overcome the limitations of the Chi-square test on the distribution of the sample data (Fisher, 1922).

3 Research findings

3.1 Demographics

We collected 202 valid questionnaires, including 49 UNGs and 153 UMGs. The numbers of UMGs were significantly higher than the UNGs (see Figure 4). Considering the details, there were more female gardeners than male, and there were slightly more senior gardeners

TABLE 2 Measurement indicators of urban gardening motivation and behavior.

Variables	Aspects	Indicators	Sources	Data
Gardening motivation	Motivation closely related to food production	Food production	Menconi et al. (2020); Song et al. (2022)	A 5-point Likert scale ranging from 1–5, with 1 being strongly disagree and 5 being strongly agree.
		Family income generation		
	Social and recreational well-being	Physical and mental health	Newell et al. (2022); Petrovic et al. (2019)	
		Social interaction		
		Recreation		
	Maintenance of urban ecology and landscape	Ecological conservation	Lindemann-Matthies and Brieger (2016); Lindemann-Matthies and Marty (2013); Sanyé-Mengual et al. (2020)	
Green scenery creation				
Gardening behavior	Space choice	Type of gardening space	Ding et al. (2022); Wei and Jones (2022)	Multiple choices
		Traffic (min)		
		Size (m²)		
		Type of vegetation		
	Gardening management behavior	Pesticide application	Ainembabazi and Mugisha (2014); Newell et al. (2022); Zhu et al. (2020)	
		Chemical fertilizer use		
		Composting or ecological nutrient supplementation		
		Self-construction of Equipment		

than young gardeners, and this trend was relatively more pronounced among the UMGs. After examining the education, employment status, and monthly income, we found apparent differences between UMGs and UNGs: (1) UMGs tended to have lower educational levels. 56.86% of UMGs only had primary education, a much higher percentage than UNGs (18.37%). In contrast, UNGs are more evenly distributed across educational levels, with the highest result of vocational or college education (36.73%), significantly higher than UNGs (14.38%). (2) Most UMGs experienced higher unemployment rates (58.17%) compared to UNGs (12.24%), with a large proportion of UNGs being retirees (42.86%). (3) The income level of UMGs was significantly lower than that of UNGs, with 47.06% of them having a monthly income of fewer than 500 yuan (68.6 USD), which was far below the average monthly *per capita* disposable income of urban residents of 3,951 yuan (542.7 USD) in 2021 (Statistical Bureau of the People's Republic of China, 2021). In contrast, UNGs had a monthly income mainly concentrated between 2,000 and 10,000 yuan, which is relatively higher.

3.2 Differences in urban gardening motivations

The data on gardening motivations of UMGs and UNGs passed reliability and validity tests, with Cronbach's alpha of 0.734 and a KMO value of 0.787 ($p < 0.001$). Differences in motivations between UMGs and UNGs were mainly in those closely related to food production, including food production, family income generation, and green scenery creation (see Table 3). To be more specific: (1) Food production. The study found that most gardeners (42.9% of urban non-gardeners and 50.3% of urban multi-gardeners) recognized the value of food production in urban areas. However, there were differences in their attitudes towards disagreement and complete

agreement. 6.1% and 16.3% of the UNGs had varying degrees of disagreement with the value of food production. In contrast, the percentages were 0% and 4.5% for the UMGs. There was also a significant difference among urban gardeners who ultimately agreed with the value of food production. Expressly, 37.9% of UMGs strongly agreed with the value of food production from urban gardening, whereas only 8.2% of the UNGs expressed complete agreement. (2) Family income generation. While most urban gardeners did not endorse the income-generating value of urban gardening, the percentage of gardeners in both categories who strongly disagreed and agreed with this motivation showed that UNGs had a significantly more negative attitude towards the income-generating value than UMGs. (3) Green scenery creation. While most urban gardeners recognized the importance of urban landscaping, UNGs had a much stronger positive attitude, with 67.3% agreeing with this value, significantly more than the 43.8% of UMGs.

UMGs and UNGs showed more consistent attitudes towards the recreation and ecological conservation values of urban gardening. The two groups generally recognized the physical and mental health and recreational values of urban gardening to a high degree while registering a low recognition of the social interaction value and holding a neutral attitude towards the ecological conservation value.

3.3 Differences in urban gardening behaviors

The results of the Chi-square and Fischer tests showed that the differences in gardening behavior between UNGs and UMGs were mainly in space selection. At the same time, there was some consistency in management. The behavior differences are shown in Table 4. (1) Types of spaces. Most of the UNGs preferred to use private space (38.8%), followed by community space (36.7%), whereas most

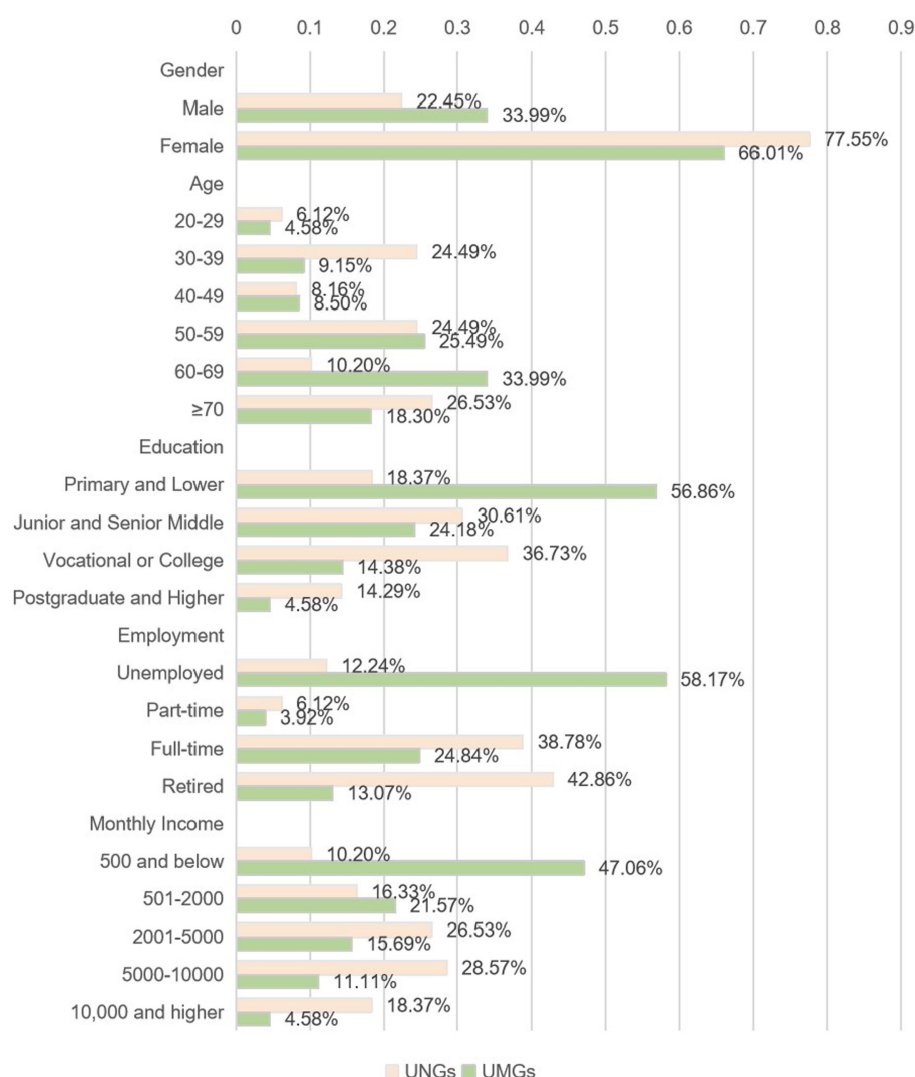


FIGURE 4
Demographics of the two groups.

of the UMGs (58.2%) preferred utilizing urban gardening spaces outside of residential communities, such as abandoned or unused land. (2) Distance to gardening spaces. Although most of the spaces were within 30 min of walking distance, most of the UNGs gardened in more convenient places, while a significantly higher percentage of UMGs reported they needed more time to reach their gardening places (24.8%). (3) Space size. The UNGs' gardening spaces were smaller (49% of UNGs had less than 10 m²), while most UMGs (41.8%) had a relatively larger gardening space of 11–66 m². (4) Types of plants. Most UMGs (57.5%) preferred to plant only vegetables, while UNGs liked to try a more diversified range of plants. Most UNGs (36.7%) chose to produce a mixture of vegetables and flowers, outnumbering UMGs (15.0%).

There were no significant differences between the two groups regarding management practices. Most gardeners did not favor the use of pesticides and did not build facilities on their land. They were neutral about using fertilizer and compost, with almost equal proportions of fertilizer users, non-users, and non-composters.

4 Discussions

4.1 Differences in the needs of UNGs and UMGs

Social and cultural contexts influence behavior (Triandis, 1989; Matsumoto, 2007). The differences in gardening motivations and behaviors between the UNGs and UMGs reflect, to some extent, the different needs for urban leisure of the native urban population and the rural migrated population in the context of China's urban–rural dual-track system (Chan and Buckingham, 2008). China's rural migrants are classified as urban residents but have limited access to public social services and welfare compared to native urban residents (Xinhua News Agency, 2022). Their rural backgrounds and differentiated access to the public service systems mean that they are more likely to face unstable employment, low-income levels, and marginalized social identities, which are reflected in the demographics of UMGs. They also have different needs for urban leisure: (1) they

TABLE 3 Gardening motivation scores and differences in UMGs and UNGs.

Gardening perception	NMGs and UNGs (N/%)					Aggregated mean	Statistical significance	Gardening perception
	1	2	3	4	5			
Food production								
UNGs	3 _a (6.1)	8 _a (16.3)	13 _a (26.5)	21 _a (42.9)	4 _a (8.2)	49(100.0)	3.31	<i>p</i> <0.001
UMGs	0 _b (0.0)	7 _b (4.6)	11 _b (7.2)	77 _a (50.3)	58 _b (37.9)	153(100.0)	4.22	
Family income generation								
UNGs	32 _a (65.3)	13 _a (26.5)	1 _a (2.0)	3 _a (6.1)	0 _a (0.0)	49(100.0)	1.49	$\chi^2(4,n=202)=16.373$; <i>p</i> =0.003
UMGs	55 _b (35.9)	50 _a (32.7)	14 _a (9.2)	21 _a (13.7)	13 _b (8.5)	153(100.0)	2.26	
Physical and mental health								
UNGs	0 _a (0.0)	2 _a (4.1)	1 _a (2.0)	34 _a (69.4)	12 _a (24.5)	49(100.0)	4.14	<i>p</i> =0.062
UMGs	5 _a (3.3)	10 _a (6.5)	22 _b (14.4)	85 _a (55.6)	31 _a (20.3)	153(100.0)	3.83	
Social interaction								
UNGs	9 _a (18.4)	23 _a (46.9)	9 _a (18.4)	8 _a (16.3)	0 _a (0.0)	49(100.0)	2.33	$\chi^2(3,n=202)=1.258$; <i>p</i> =0.739
UMGs	29 _a (19.0)	76 _a (49.7)	32 _a (20.9)	16 _b (10.5)	0 _a (0.0)	153(100.0)	2.23	
Recreation								
UNGs	2 _a (4.1)	1 _a (2.0)	3 _a (6.1)	19 _a (38.8)	24 _a (49.0)	49(100.0)	4.27	<i>p</i> =0.202
UMGs	8 _a (5.2)	15 _a (9.8)	10 _a (6.5)	70 _a (45.8)	50 _b (32.7)	153(100.0)	3.91	
Ecological conservation								
UNGs	0 _a (0.0)	1 _a (2.0)	34 _a (69.4)	14 _a (28.6)	0 _a (0.0)	49(100.0)	3.27	$\chi^2(2,n=202)=4.190$; <i>p</i> =0.123
UMGs	0 _a (0.0)	13 _a (8.5)	112 _a (73.2)	28 _b (18.3)	0 _a (0.0)	153(100.0)	3.1	
Green scenery creation								
UNGs	0 _a (0.0)	3 _a (6.1)	8 _a (16.3)	33 _a (67.3)	5 _a (10.2)	49(100.0)	3.82	<i>p</i> =0.006
UMGs	0 _a (0.0)	14 _a (9.2)	62 _b (40.5)	67 _b (43.8)	10 _a (6.5)	153(100.0)	3.48	

1: totally disagree; 2: disagree; 3: neutral; 4: agree; 5: totally agree. Each identical letter indicates no significant difference between column proportions at the 0.05 significance level.

demand a more excellent value from urban leisure spaces, which constitutes part of their motivations for urban gardening. Specifically, due to low education levels, job instability, and low income levels, UMGs want to meet their needs for food production and increase family income while getting leisure and recreation through urban gardening. (2) They have a demand for larger spaces in urban gardening. As they demand food production and family income generation through urban gardening, UMGs are willing to spend more time commuting from where they live to their gardening spaces to pursue a larger size and plant vegetables to produce food and bring more income to the household.

4.2 Shared needs of UNGs and UMGs

Urban gardening is often seen as an essential means of promoting community interaction and improving social cohesion while protecting the urban ecosystem (Clark and Nicholas, 2013; Speak et al., 2015; Falkowski et al., 2022), but common attitudes towards urban gardening among both UNGs and UMGs suggest that the social interaction value of urban gardening is not currently recognized in China, while gardeners have reservations about the ecological protection function. The possible reasons may be: (1) In informal urban gardening, third-party management is usually absent. Gardeners often face a game of demarcation, using fences and barriers to determine the border of their space, resulting in fragmented use of growing areas. As an old Chinese

saying goes, “Everyone sweeps the snow in front of their door and does not care about the frost on other people’s roofs,” which may indicate the relationship between most gardeners in informal urban gardening spaces. On the other hand, in formal community gardens, community managers and informal organizations are the dominant forces in the gardening process (Lu, 2022; Mai et al., 2023) compared to the lack of autonomous participation of the residents. Therefore, the role of urban gardening as a hub of neighborhood interactions is not fully recognized, and there is a lack of related activities in some circumstances. (2) Most gardeners lack knowledge about organic gardening and eco-protection (Bon et al., 2010). We found in the survey that for most gardeners, eco-protection was a synonym for “no pesticides” or “green is eco.” A vacuum of guidance and training existed on eco-friendly practices and input in environmentally friendly facilities. Moreover, gardeners had no systematic understanding of the ecological value of urban gardening.

4.3 Urban gardening strategy recommendations targeting differentiated gardeners in China

Given the differences and similarities between UNGs and UMGs in Chinese cities, we propose targeted strategies in three areas: planning and design of urban gardening spaces, operation and management, and organization of activities (see Figure 5). (1) Space

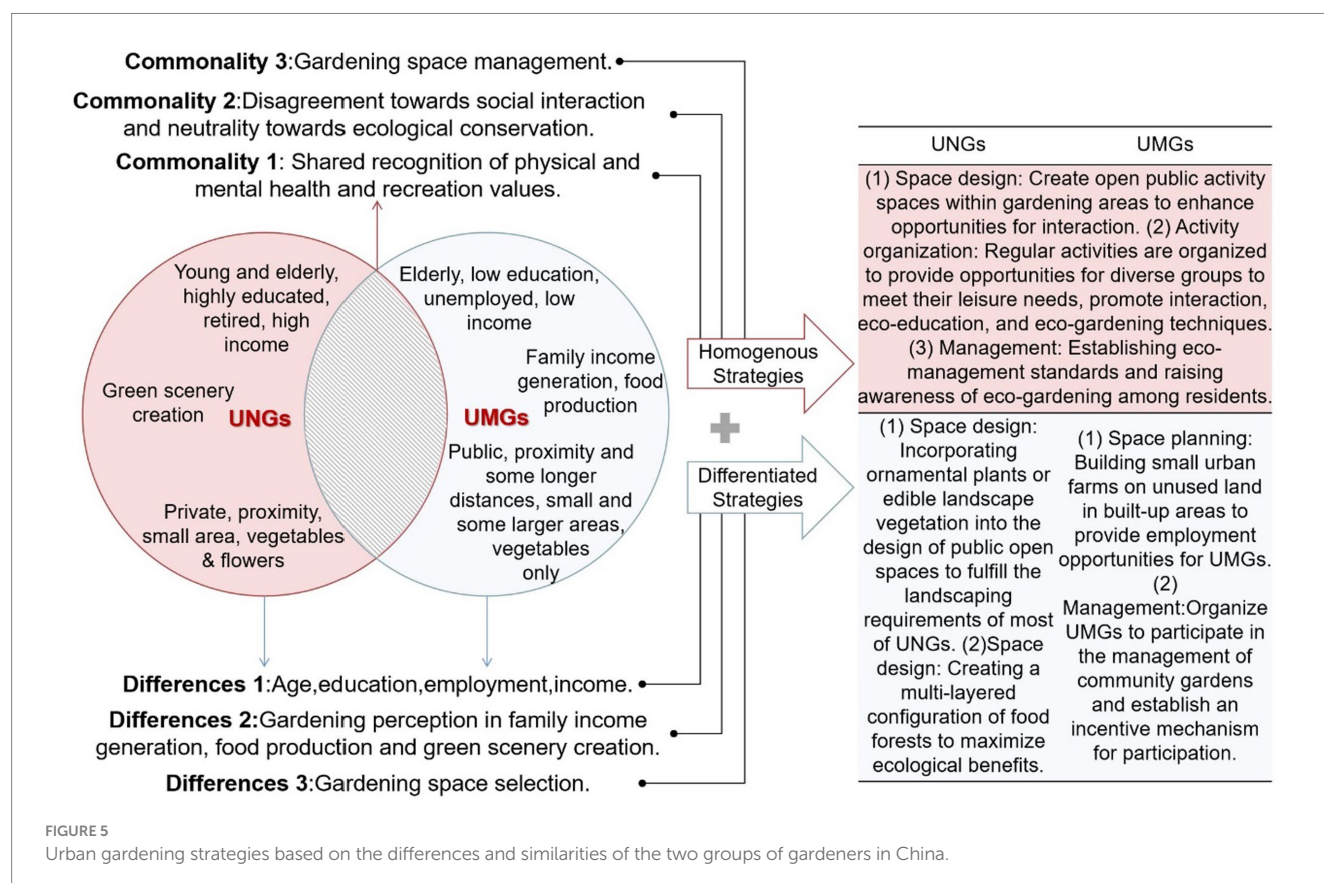
TABLE 4 Gardening behavior and differences in UMGs and UNGs.

Indicators	UNGs(N/%)	UMGs(N/%)	Statistical significance
Type of gardening space			
Private gardening	19 _a (38.8)	27 _b (17.6)	$\chi^2(2, n = 202) = 17.843; p < 0.001$
Community gardening	18 _a (36.7)	37 _a (24.2)	
Other urban gardening	12 _a (24.5)	89 _b (58.2)	
Traffic (min)			
Walk<10	43 _a (87.8)	103 _b (67.3)	$p = 0.011$
Walk 10–30	4 _a (8.2)	38 _b (24.8)	
Walk>30	0 _a (0.0)	8 _a (5.2)	
Vehicle<30	2 _a (4.1)	4 _a (2.6)	
Vehicle>30	0 _a (0.0)	0 _a (0.0)	
Size (m ²)			
≤10	24 _a (49.0)	47 _b (30.7)	$\chi^2(4, n = 202) = 9.857; p = 0.043$
11–66	18 _a (36.7)	64 _a (41.8)	
67–333	7 _a (14.3)	23 _a (15.0)	
334–666	0 _a (0.0)	11 _a (7.2)	
≥667	0 _a (0.0)	8 _a (5.2)	
Type of vegetation			
Only vegetables	14 _a (28.6)	88 _b (57.5)	$\chi^2(4, n = 202) = 17.410; p = 0.002$
Veg. and grains	8 _a (16.3)	25 _a (16.3)	
Veg. and fruit or herb medicine	3 _a (6.1)	9 _a (5.9)	
Veg. and flower	18 _a (36.7)	23 _b (15.0)	
Veg. and two more other types	6 _a (12.2)	8 _a (5.2)	
Pesticide application			
No	35 _a (71.4)	109 _a (71.2)	$\chi^2(1, n = 202) = 0.001; p = 0.98$
Yes	14 _a (28.6)	44 _a (28.8)	
Chemical fertilizer use			
No	26 _a (53.1)	68 _a (44.4)	$\chi^2(1, n = 202) = 1.108; p = 0.293$
Yes	23 _a (46.9)	85 _a (55.6)	
Composting or ecological nutrient supplementation			
No	25 _a (51.0)	78 _a (51.0)	$\chi^2(1, n = 202) = 0.000; p = 0.996$
Yes	24 _a (49.0)	75 _a (49.0)	
Self-construction of equipment			
No	45 _a (91.8)	126 _a (82.4)	$\chi^2(1, n = 202) = 2.569; p = 0.109$
Yes	4 _a (8.2)	27 _a (17.6)	

Each identical letter indicates no significant difference between column proportions at the 0.05 significance level. Sixty-six square meters≈1 Fen (分) of land; 666 square meters≈1 Mu (亩) of land.

planning and design: in response to the demand of some of UMGs for growing vegetables and income-generation, small-scale urban farms should be planned and built using unused or abandoned land within the built-up area. These farms differ from community gardens, China's mainstream urban gardening spaces. The purpose of these small-scale urban farms is to provide some UMGs with nearby gardening spaces and, at the same time, meet their needs for employment and livelihood subsidies. Moreover, in response to the fact that most gardeners still need to recognize the function of urban gardening in social interaction sufficiently, open public spaces for public activities should be added in

conjunction with the gardening spaces to make public interactions possible in terms of space. Given the shared interest of UMGs and UNGs in creating green scenery, as well as the integration of traditional garden aesthetics in urban gardening in other Asian countries (Amani-Beni et al., 2021; Khalilnezhad et al., 2022), we suggest the utilization of ornamental plants in public open areas. This approach is also advantageous for improving the attractiveness of urban gardening areas (Amani-Beni et al., 2021). In addition, incorporating edible flowering plants is also a great way to balance aesthetics and practicality (Lu et al., 2021). To maximize the ecological



benefits of urban gardening, vegetation selection can be based on the multi-layered configuration of food forests (Clark and Nicholas, 2013). The case of agroforestry in South Asia illustrates the advantages of using a multilayered vegetation configuration strategy with woody crops to enhance food production and preserve biodiversity (Kumar et al., 2012).

(2) Organization of activities: First, organizing regular gardening-related activities that cater to the diverse needs of gardeners across different age groups and, at the same time, provide opportunities for residents to interact with each other to realize the social interaction benefits of urban gardening. Such activities include nature education activities for children, sports and leisure activities for young gardeners, interactive planting activities for core family gardeners, and leisure and sports activities for older people. Secondly, in response to the lack of recognition of the ecological function of urban gardening, eco-gardening activities can also be planned to improve their ecological gardening skills through eco-education.

(3) Operation and management: In response to the more substantial food needs of UMGs, it is possible to organize migrant gardeners' management groups and increase the possibility of obtaining material products for UMGs through the establishment of participation incentive mechanisms such as the "management time for vegetables: time-food exchange system." In addition, as gardeners generally lack an understanding of the eco-values of urban gardening, it is possible to raise awareness of the eco-value through setting ecological management standards for the facilities and eco-friendly gardening practices.

5 Conclusion

This paper proposes a typology for classifying Chinese urban gardeners based on their urban–rural life experiences to develop a corresponding urban farming strategy amid China's urbanization. Research reveals distinctions between Chinese UNGs and UMGs in motivations and behaviors. Recognizing shared needs for physical and mental health, leisure, and recreation, some UMGs also maintain a strong need for urban gardening to produce food and generate family income. Therefore, the study recommends a shift from the "one-size-fits-all" policy strategy of promoting community gardens and banning informal gardening to a more adaptable framework to address the needs of both types of gardeners, from space planning and design to the operation and management of the spaces and the organization of activities. Such a revised framework should also include the planning of small-scale urban farms, the creation of small public open spaces with ornamental plants to enhance the aesthetic appeal of urban gardening, and the establishment of an incentive mechanism to meet the diverse needs of urban gardeners and fully realize the value and benefits of urban gardening in promoting social cohesion and protecting the urban ecosystem.

Data availability statement

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

Author contributions

YX: Data curation, Writing – original draft. ZX: Funding acquisition, Supervision, Writing – review & editing.

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References

- Adams, D., Hardman, M., and Larkham, P. (2014). Exploring guerrilla gardening: gauging public views on the grassroots activity. *Local Environ.* 20, 1231–1246. doi: 10.1080/13549839.2014.980227
- Ainembabazi, J. H., and Mugisha, J. (2014). The role of farming experience on adopting agricultural technologies: evidence from smallholder farmers in Uganda. *J. Dev. Stud.* 50, 666–679. doi: 10.1080/00220388.2013.874556
- Amani-Beni, M., Xie, G., Yang, Q., Russo, A., and Khalilnezhad, M. R. (2021). Socio-cultural appropriateness of the use of historic Persian gardens for modern urban edible gardens. *Land* 11:38. doi: 10.3390/land11010038
- Armstrong, D. (2000). A survey of community gardens in upstate New York: implications for health promotion and community development. *Health Place* 6, 319–327. doi: 10.1016/S1353-8292(00)00013-7
- Askerlund, P., and Almers, E. (2016). Forest gardens – new opportunities for urban children to understand and develop relationships with other organisms. *Urban For. Urban Green.* 20, 187–197. doi: 10.1016/j.ufug.2016.08.007
- Beavers, A. W., Atkinson, A., Ma, W., and Alaimo, K. (2021). Garden characteristics and types of program involvement associated with sustained garden membership in an urban gardening support program. *Urban For. Urban Green.* 59:127026. doi: 10.1016/j.ufug.2021.127026
- Bendt, P., Barthel, S., and Colding, J. (2013). Civic greening and environmental learning in public-access community gardens in Berlin. *Landsc. Urban Plan.* 109, 18–30. doi: 10.1016/j.landurbplan.2012.10.003
- Bon, H., Parrot, L., and Moustier, P. (2010). Sustainable urban agriculture in developing countries. A review. *Agron. Sustain. Dev.* 30, 21–32. doi: 10.1051/agro:2008062
- Booth, J. M., Chapman, D., Ohmer, M. L., and Wei, K. (2017). Examining the relationship between level of participation in community gardens and their multiple functions. *J. Community Pract.* 26, 5–22. doi: 10.1080/10705422.2017.1413024
- Castro, D. C., Samuels, M., and Harman, A. E. (2013). Growing healthy kids: a community garden-based obesity prevention program. *Am. J. Prev. Med.* 44, S193–S199. doi: 10.1016/j.amepre.2012.11.024
- Chan, K. W., and Buckingham, W. (2008). Is China abolishing the Hukou system? *China Q.* 195, 582–606. Available at: <http://www.jstor.org/stable/20192236>
- Chen, Y., Li, X., Tian, Y., and Tan, M. (2009). Structural change of agricultural land use intensity and its regional disparity in China. *J. Geogr. Sci.* 19, 545–556. doi: 10.1007/s11442-009-0545-7
- Chen, W., Wang, Q., Li, Q., Wang, Y., and Zheng, W. (2022). Exploring the impact of rural labor transfer on the production and ecological sustainability of crop planting structure in China. *Environ. Sci. Pollut. Res.* 30, 22668–22685. doi: 10.1007/s11356-022-23613-5
- China Daily (2021). Master plan for economic circle unveiled. Available at: http://english.www.gov.cn/policies/policywatch/202110/22/content_WS6171fb03c6d0df57f98e3a78.html (Accessed November 20, 2023)
- China National Bureau of Statistics (2020). The seventh national population census. Available at: http://www.stats.gov.cn/sj/tjgb/rkpcgb/qgrkpcgb/index_1.html (Accessed November 20, 2023).
- Chongqing Municipal Bureau of Statistics (2022). Chongqing statistical yearbook. Available at: https://tjj.cq.gov.cn/zwgk_233/tjnj/tjnj.html?url=https://tjj.cq.gov.cn/zwgk_233/tjnj/2022/zk/indexch.htm (Accessed November 20, 2023).
- Chongqing Urban Management Bureau (2023). Governance of the destruction of greenery and planting of vegetables. Available at: <https://cgj.cq.gov.cn/cqs/searchResultPC.html?tenantId=84&configTenantId=84&areaCode=500000125&searchWord=%E8%8F%9C%E5%9C%B0> (Accessed November 20, 2023).
- Clark, K. H., and Nicholas, K. A. (2013). Introducing urban food forestry: a multifunctional approach to increase food security and provide ecosystem services. *Landsc. Ecol.* 28, 1649–1669. doi: 10.1007/s10980-013-9903-z
- Clarke, L. W., Jenerette, G. D., and Bain, D. J. (2015). Urban legacies and soil management affect the concentration and speciation of trace metals in Los Angeles community garden soils. *Environ. Pollut.* 197, 1–12. doi: 10.1016/j.envpol.2014.11.015
- Department of Agriculture and Markets (2023). Farm-to-school. Available at: <https://agriculture.ny.gov/farming/farm-school#:~:text=The%20New%20York%20State%20Farm-to-School%20Program%20was%20created,State%20schools%20through%20New%20York%20State%E2%80%99s%20Farm-to-School%20program> (Accessed November 20, 2023).
- Ding, X., Zhao, Z., Zheng, J., Yue, X., Jin, H., and Zhang, Y. (2022). Community gardens in China: spatial distribution, patterns, perceived benefits and barriers. *Sustain. Cities Soc.* 84:103991. doi: 10.1016/j.scs.2022.103991
- Djokić, V., Ristić Trajković, J., Furundžić, D., Krstić, V., and Stojiljković, D. (2018). Urban garden as lived space: informal gardening practices and dwelling culture in socialist and post-socialist Belgrade. *Urban For. Urban Green.* 30, 247–259. doi: 10.1016/j.ufug.2017.05.014
- Egerer, M., Lin, B. B., and Diekmann, L. (2020). Nature connection, experience and policy encourage and maintain adaptation to drought in urban agriculture. *Environ. Res. Commun.* 2:041004. doi: 10.1088/2515-7620/ab8917
- Eigenbrod, C., and Gruda, N. (2014). Urban vegetable for food security in cities. A review. *Agron. Sustain. Dev.* 35, 483–498. doi: 10.1007/s13593-014-0273-y
- Falkowski, T. B., Jorgensen, B., Rakow, D. A., Das, A., Diemont, S. A. W., Selfa, T., et al. (2022). “Connecting with good people and good plants”: community gardener experiences in New York state during the COVID-19 pandemic. *Front. Sustain. Food Syst.* 6:854374. doi: 10.3389/fsufs.2022.854374
- Fisher, R. A. (1922). On the interpretation of χ^2 from contingency tables, and the calculation of P. *J. R. Stat. Soc.* 85, 87–94. Available at: <http://www.jstor.org/stable/2340521>
- Gaston, K. J., Warren, P. H., Thompson, K., and Smith, R. M. (2005). Urban domestic gardens (IV): the extent of the resource and its associated features. *Biodivers. Conserv.* 14, 3327–3349. doi: 10.1007/s10531-004-9513-9
- Ge, Y., Kiminami, L., and Furuzawa, S. (2021). Perception and behavior of residents towards community gardens and satisfaction of local life: empirical analysis on the case of Shanghai, China. *Asia-Pac. J. Reg. Sci.* 6, 141–158. doi: 10.1007/s41685-021-00219-2
- Golledge, R. G., Brown, L. A., and Williamson, F. (2007). Behavioural approaches in geography: an overview. *Aust. Geogr.* 12, 59–79. doi: 10.1080/00049187208702613
- Golledge, R. G., and Timmermans, H. (1990). Applications of behavioural research on spatial problems I: cognition. *Prog. Hum. Geogr.* 14, 57–99. doi: 10.1177/030913259001400104
- Górna, A., and Górny, K. (2020). Urban agriculture in Havana – evidence from empirical research. *Misc. Geogr.* 24, 85–93. doi: 10.2478/mgrsd-2020-0012
- Hardman, M., Chipungu, L., Magidimisha, H., Larkham, P. J., Scott, A. J., and Armitage, R. P. (2018). Guerrilla gardening and green activism: rethinking the informal urban growing movement. *Landsc. Urban Plan.* 170, 6–14. doi: 10.1016/j.landurbplan.2017.08.015
- He, B., and Zhu, J. (2018). Constructing community gardens? Residents’ attitude and behaviour towards edible landscapes in emerging urban communities of China. *Urban For. Urban Green.* 34, 154–165. doi: 10.1016/j.ufug.2018.06.015
- Hemmelgarn, H. L., and Munsell, J. F. (2021). Exploring ‘beyond-food’ opportunities for biocultural conservation in urban forest gardens. *Urban Agric. Region. Food Syst.* 6:e20009. doi: 10.1002/uar2.20009

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- Jahrl, I., Moschitz, H., and Cavin, J. S. (2021). The role of food gardening in addressing urban sustainability – a new framework for analysing policy approaches. *Land Use Policy* 108:105564. doi: 10.1016/j.landusepol.2021.105564
- Khalilnezhad, M. R., Russo, A., and Jannatifar, M. A. (2022). Forgotten edible heritage: the case study of the UNESCO site of Akbarieh garden in Iran. *Arboric. J.* 44, 234–247. doi: 10.1080/03071375.2022.2085942
- Kirby, C. K., Specht, K., Fox-Kämper, R., Hawes, J. K., Cohen, N., Caputo, S., et al. (2021). Differences in motivations and social impacts across urban agriculture types: case studies in Europe and the US. *Landsc. Urban Plan.* 212:104110. doi: 10.1016/j.landurbplan.2021.104110
- Kou, H., Zhang, S., Li, W., and Liu, Y. (2021). Participatory action research on the impact of community gardening in the context of the COVID-19 pandemic: investigating the seeding plan in Shanghai, China. *Int. J. Environ. Res. Public Health* 18:6243. doi: 10.3390/ijerph18126243
- Kou, H., Zhang, S., and Liu, Y. (2019). Community-engaged research for the promotion of healthy urban environments: a case study of community garden initiative in Shanghai, China. *Int. J. Environ. Res. Public Health* 16:4145. doi: 10.3390/ijerph16214145
- Kumar, B. M., Singh, A. K., and Dhyani, S. K. (2012). "South Asian agroforestry: traditions, transformations, and prospects" in *Agroforestry – the future of global land use*. eds. P. K. R. Nair and D. Garrity (Dordrecht: Springer Netherlands), 359–389.
- Lafontaine-Messier, M., Gélinais, N., and Olivier, A. (2016). Profitability of food trees planted in urban public green areas. *Urban For. Urban Green.* 16, 197–207. doi: 10.1016/j.ufug.2016.02.013
- Lee, J. H., and Matarrita-Cascante, D. (2019). The influence of emotional and conditional motivations on gardeners' participation in community (allotment) gardens. *Urban For. Urban Green.* 42, 21–30. doi: 10.1016/j.ufug.2019.05.006
- Lewis, O., Home, R., and Kizos, T. (2018). Digging for the roots of urban gardening behaviours. *Urban For. Urban Green.* 34, 105–113. doi: 10.1016/j.ufug.2018.06.012
- Li, Y., Zhang, S., and Zhu, D. (2023). Co-creation of community micro-renewals: model analysis and case studies in Shanghai, China. *Habitat Int.* 142:102951. doi: 10.1016/j.habitatint.2023.102951
- Liere, H., Egerer, M., Sanchez, C., Bichier, P., and Philpott, S. M. (2020). Social context influence on urban gardener perceptions of pests and management practices. *Front. Sustain. Food Syst.* 4:547877. doi: 10.3389/fsufs.2020.547877
- Lin, B. B., Philpott, S. M., and Jha, S. (2015). The future of urban agriculture and biodiversity-ecosystem services: challenges and next steps. *Basic Appl. Ecol.* 16, 189–201. doi: 10.1016/j.baec.2015.01.005
- Lindemann-Matthies, P., and Brieger, H. (2016). Does urban gardening increase aesthetic quality of urban areas? A case study from Germany. *Urban For. Urban Green.* 17, 33–41. doi: 10.1016/j.ufug.2016.03.010
- Lindemann-Matthies, P., and Marty, T. (2013). Does ecological gardening increase species richness and aesthetic quality of a garden? *Biol. Conserv.* 159, 37–44. doi: 10.1016/j.biocon.2012.12.011
- Lohr, V. I., and Pearson-Mims, C. H. (2005). Children's active and passive interactions with plants influence their attitudes and actions toward trees and gardening as adults. *HortTechnology* 15, 472–476. doi: 10.21273/horttech.15.3.0472
- Lu, D. (2022). Cultivating vibrant gardens in urban communities: success factors of community gardens in Beijing and Shanghai. *J. Undergraduate Ethnogr.* 12, 106–125. doi: 10.15273/jue.v12i2.11413
- Lu, S., Wu, F., Wang, Z., Cui, Y., Chen, C., and Wei, Y. (2021). Evaluation system and application of plants in healing landscape for the elderly. *Urban For. Urban Green.* 58:126969. doi: 10.1016/j.ufug.2020.126969
- Macdonald, T., and Winklerprins, A. M. G. A. (2019). Searching for a better life: peri-urban migration in Western Para state, Brazil. *Geogr. Rev.* 104, 294–309. doi: 10.1111/j.1931-0846.2014.12027.x
- Mackiewicz, B., Szczepanska, M., Kacprzak, E., and Fox-Kaemper, R. (2021). Between food growing and leisure: contemporary allotment gardeners in Western Germany and Poland. *Erde* 152, 33–50. doi: 10.12854/erde-2021-502
- Mai, X., Xu, Y., and Liu, Y. (2023). Cultivating an alternative subjectivity beyond neoliberalism: community gardens in urban China. *Ann. Am. Assoc. Geogr.* 113, 1348–1364. doi: 10.1080/24694452.2023.2187337
- Matsumoto, D. (2007). Culture, context, and behavior. *J. Pers.* 75, 1285–1320. doi: 10.1111/j.1467-6494.2007.00476.x
- Menconi, M. E., Heland, L., and Grohmann, D. (2020). Learning from the gardeners of the oldest community garden in Seattle: resilience explained through ecosystem services analysis. *Urban For. Urban Green.* 56:126878. doi: 10.1016/j.ufug.2020.126878
- Newell, J. P., Foster, A., Borgman, M., and Meerow, S. (2022). Ecosystem services of urban agriculture and prospects for scaling up production: a study of Detroit. *Cities* 125:103664. doi: 10.1016/j.cities.2022.103664
- Pearsall, H., Gachuz, S., Rodriguez Sosa, M., Schmook, B., Wal, H., and Gracia, M. A. (2019). Urban community garden agrodiversity and cultural identity in Philadelphia, Pennsylvania, U.S. *Geogr. Rev.* 107, 476–495. doi: 10.1111/j.1931-0846.2016.12202.x
- Pennsylvania Department of Agriculture (2023). Farm to school grant program. Available at: <https://www.agriculture.pa.gov/Funding/FarmBill/Pages/Farm-to-School-Grant.aspx> (Accessed November 20, 2023).
- Petrovic, N., Simpson, T., Orlove, B., and Dowd-Urribe, B. (2019). Environmental and social dimensions of community gardens in East Harlem. *Landsc. Urban Plan.* 183, 36–49. doi: 10.1016/j.landurbplan.2018.10.009
- Philpott, S. M., Egerer, M. H., Bichier, P., Cohen, H., Cohen, R., Liere, H., et al. (2020). Gardener demographics, experience, and motivations drive differences in plant species richness and composition in urban gardens. *Ecol. Soc.* 25:8. doi: 10.5751/es-11666-250408
- Qiu, P. (2013). Awareness and understanding of "Citizenship of the Agricultural Transfer Population". Available at: <http://theory.people.com.cn/n/2013/0313/c40537-20778267.html#:~:text=%E6%8D%A2%E5%8F%A5%E8%AF%9D%E8%AF%B4%E5%BC%8C%E5%86%9C%E4%B8%9A%E8%BD%AC,%E5%8F%97%E7%9A%84%E8%BF%87%E7%A8%8B%E5%92%8C%E7%BB%93%E6%9E%9C%E3%80%82> (Accessed November 20, 2023).
- Ryan, C. (2021). Atlanta creates the nation's largest free food forest with hopes of addressing food insecurity. Available at: <https://edition.cnn.com/2021/02/22/us/atlanta-free-food-forest-trnd/index.html> (Accessed November 20, 2023).
- Sanyé-Mengual, E., Specht, K., Vávra, J., Artmann, M., Orsini, F., and Gianquinto, G. (2020). Ecosystem services of urban agriculture: perceptions of project leaders, stakeholders and the general public. *Sustainability* 12:10446. doi: 10.3390/su122410446
- Schoen, V., Blythe, C., Caputo, S., Fox-Kämper, R., Specht, K., Fargue-Lelièvre, A., et al. (2021). "We have been part of the response": the effects of COVID-19 on community and allotment gardens in the global north. *Front. Sustain. Food Syst.* 5:732641. doi: 10.3389/fsufs.2021.732641
- Shanghai Urban Management and Law Enforcement Bureau (2023). Governance of deforestation and vegetable cultivation. Available at: <https://cgzf.sh.gov.cn/websearch/index.html#search/query=%E7%A7%8D%E8%8F%9C> (Accessed November 20, 2023).
- Song, S., Lim, M. S., Richards, D. R., and Tan, H. T. W. (2022). Utilization of the food provisioning service of urban community gardens: current status, contributors and their social acceptance in Singapore. *Sustain. Cities Soc.* 76:103368. doi: 10.1016/j.scs.2021.103368
- Speak, A. F., Mizgajski, A., and Borysiak, J. (2015). Allotment gardens and parks: provision of ecosystem services with an emphasis on biodiversity. *Urban For. Urban Green.* 14, 772–781. doi: 10.1016/j.ufug.2015.07.007
- Statistical Bureau of the People's Republic of China (2021). China Statistical Yearbook. Available at: <http://www.stats.gov.cn/sj/ndsj/2021/indexch.htm> (Accessed November 20, 2023).
- Suto, M. J., Smith, S., Damiano, N., and Channe, S. (2021). Participation in community gardening: sowing the seeds of well-being. *Can. J. Occup. Ther.* 88, 142–152. doi: 10.1177/0008417421994385
- Teuber, S., Schmidt, K., Kühn, P., and Scholten, T. (2019). Engaging with urban green spaces – a comparison of urban and rural allotment gardens in southwestern Germany. *Urban For. Urban Green.* 43:126381. doi: 10.1016/j.ufug.2019.126381
- Triandis, H. C. (1989). The self and social behavior in differing cultural contexts. *Psychol. Rev.* 96, 506–520. doi: 10.1037/0033-295X.96.3.506
- Van den Berg, A. E., and Custers, M. H. (2011). Gardening promotes neuroendocrine and affective restoration from stress. *J. Health Psychol.* 16, 3–11. doi: 10.1177/1359105310365577
- Van den Berg, A. E., van Winsum-Westra, M., de Vries, S., and van Dillen, S. M. E. (2010). Allotment gardening and health: a comparative survey among allotment gardeners and their neighbors without an allotment. *Environ. Health* 9, 1–2. doi: 10.1186/1476-069x-9-74
- Wei, Y., and Jones, P. (2022). Emergent urban agricultural practices and attitudes in the residential area in China. *Urban For. Urban Green.* 69:127491. doi: 10.1016/j.ufug.2022.127491
- Wen, C. (2023). Shenzhen: the gateway to the "we garden", where even "small patches of land" hold "poetry and distant lands". Available at: https://mp.weixin.qq.com/s?__biz=MzIzOTcyNDZMg==&mid=2247790688&idx=1&sn=6c574d1b5904c82c723e2971238deb89 (Accessed November 20, 2023).
- Wu, C., Li, X., Tian, Y., Deng, Z., Yu, X., Wu, S., et al. (2022). Chinese residents' perceived ecosystem services and disservices impacts behavioral intention for Urban Community garden: an extension of the theory of planned behavior. *Agronomy* 12:193. doi: 10.3390/agronomy12010193
- Xinhua News Agency (2022). China's efforts to promote citizenship among the agricultural migrant population. Available at: https://www.gov.cn/xinwen/2022-03/17/content_5679597.htm (Accessed November 20, 2023).
- Yuelai Liu, K. Y., Sun, Z., Hai, Y., and Mao, J. (2022). Cooperative landscape—a case study of the experiment of integrating public space renewal and social governance of community gardens in Shanghai. *Architect. J.* 3, 12–19. doi: 10.19819/j.cnki.ISSN0529-1399.202203002

Yufeng Wang, J. Z., and Wang, S. (2023). Discover the beauty of Chongqing, where vegetable plots are transformed into eco-friendly houses. Available at: https://wap.cqcb.com/shangyou_news/NewsDetail?classId=7821&newsId=5194605 (Accessed November 20, 2023).

Zhang, X., Pan, D., Wong, K., and Zhang, Y. (2022). A new top-down governance approach to community gardens: a case study of the “we garden” community experiment in Shenzhen, China. *Urban Sci.* 6:41. doi: 10.3390/urbansci6020041

Zhang, K. H., and Song, S. (2003). Rural–urban migration and urbanization in China: evidence from time-series and cross-section analyses. *China Econ. Rev.* 14, 386–400. doi: 10.1016/j.chieco.2003.09.018

Zhu, J., He, B.-J., Tang, W., and Thompson, S. (2020). Community blemish or new dawn for the public realm? Governance challenges for self-claimed gardens in urban China. *Cities* 102:102750. doi: 10.1016/j.cities.2020.102750



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Using the Net-Map tool to analyze stakeholder networks in the city region food systems of seven European cities

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The current global food system is characterized by anonymity in the value chain, global food trade, loss of knowledge about food sources, and a distant producer-consumer relationship. In addition, the negative environmental impacts of the agricultural sector, such as pollution, degradation of soil and water quality, loss of biodiversity, and significant greenhouse gas emissions, make this sector a major driver of climate change. In contrast, the city region food system (CRFS) approach captures the complexity of a food system and its actors at the local level. It aims to meet the requirements of sustainable transformation along the food value chain and offers an alternative approach to the challenges of the global food system. However, the actors and their relationships in CRFS are rarely analyzed. To fill this gap, this study focuses on analyzing CRFSs as networks using the Net-Map tool to study different CRFS in seven European cities (Bologna, Naples, Lansingerland, Tenerife, Oslo, Dortmund, and Romainville). The aim of this paper is to concentrate on the method and to show how the Net-Map tool can effectively support the evaluation of the CRFS by identifying different actor roles, recognizing patterns of relationships. Additionally, the strengths and weaknesses of the network can be assessed by a strengths, weaknesses, opportunities and threats (SWOT) analysis. The paper highlights the limitations, advantages, and practical use of the Net-Map tool and discusses potential transferability to other case studies.

KEYWORDS

city region food system, Net-map tool, social network analysis, food system, food network

1 Introduction

In today's world, the food system operates at the global level. In the past, it operated on a smaller, more local scale, and the various steps and activities involved in producing and distributing food were closely connected. Producers and consumers interacted directly with each other. The current food system is characterized by anonymity in the value chain, global food trade and competition, loss of knowledge about the food that is available for wholesale purchase and the elimination of a close producer-consumer relationship (Clapp, 2015; Heuser et al., 2017; Tucci, 2020; Säumel et al., 2022). Due to the destruction and pollution of soil and water quality, declining air quality from pesticides (UBA—Umweltbundesamt, 2019), and loss of biodiversity caused by present-day agricultural practices (IPBES, 2019), the food system has negative impacts on the environment and people. The agricultural sector is responsible for 1/3 of global greenhouse gas emissions and is considered one of the main contributors to climate change (FAO, 2022).

Given these negative factors, the need for an immediate and urgent transformation of the local food system has become evident. According to Blay-Palmer et al. (2018), ensuring an explicit “city focus” is crucial for developing a sustainable food system. The reasons lie in urbanization and the resulting increasing concentration of people in cities. This development creates local opportunities to generate social, environmental, and economic benefits within the context of the food system, promoting positive synergies in food access, livelihoods, and the environment. At the local level, spatial distances can be reduced, economic activities can be embedded in social and ecological contexts, and a direct connection can be established between consumers, producers, and other relevant stakeholders (Schmied, 2018). In urban society, there are growing demands for a shift in food practices and implementation at the local level. Simultaneously, there is an increasing willingness among citizens to contribute to the sustainable development of this issue (Tucci, 2020). Civil society initiatives such as food policy councils are emerging with the goal of transforming urban food systems (Bassarab et al., 2019; Trivette, 2019; Kropp and Da Ros, 2021; Michel et al., 2022). This exerts pressure on local policies and signals a movement toward integrating the topic of food into city administration (Morgan, 2015). However, a challenge lies in the fact that in municipal policies, the topic of food is often not anchored and defined as a political issue due to its cross-cutting nature, lacking concrete responsibilities (Schanz et al., 2020).

The Milan Urban Food Policy Pact (MUFP), established by the Food and Agriculture Organization of the United Nations (FAO), represents a significant milestone to solve the mentioned challenges. This political consolidation of grassroots initiatives and the integration of the food issue into municipal policies highlights the substantial potential for transforming urban food systems (UBA—Umweltbundesamt, 2019; Carey and Cook, 2021; Milan Urban Food Policy Pact, 2021).

There is a growing body of research focused on alternative food systems and solutions (Feagan, 2007; Biel, 2016; Blay-Palmer et al., 2018; Baldy and Kruse, 2019; Doernberg et al., 2019; Mastronardi et al., 2019; Tucci, 2020). While most research on local food systems has traditionally focused on product flows, quantity, and spatial origin, actor structures at the local level have often been overlooked (Sipple and Schanz, 2019). Additionally, previous research has attempted to improve our understanding of the complexity of food systems and the

concept of food democracy (Lohest et al., 2019; Tucci, 2020) and examined the importance of stakeholders within the food system (Sonnino and Marsden, 2006).

According to the findings of Baldy et al. (2020), to reach a transformation of the food system, it is very important for policymakers to involve and link the many stakeholders in the complex food system. It is necessary to consider who the actors are in order to jointly develop goals and visions for a sustainable local food network. This should be done in an exchange of information about preconditions, contexts and common or different. The new and holistic city region food system (CRFS) approach is employed to delineate the actors under consideration (FAO, 2022). It captures the complexity of the topic by addressing the urban region and the food system together. The CRFS includes all the actors, processes, and relationships involved in the food chain from production to processing to the distribution, marketing, and consumption of food in a given geographic region. However, the actors and their relationships in CRFS are rarely analyzed. In their typology for stakeholder analysis, Reed et al. (2009) propose three different methods for investigating relationships between stakeholder: actor-linkage matrices, Social Network Analysis and knowledge mapping.

There are few studies that examine local food systems using SNA (Freedman and Bess, 2011; Christensen and O'Sullivan, 2015; Trivette, 2019; Brinkley et al., 2021; Bruce et al., 2021; Levkoe et al., 2021; Li et al., 2022). All of them use standardized surveys for data collection. We are not aware of any study that employs social network analysis using a participatory tool. Some highlight the possible additional value of qualitative interview data to their studies (Christensen and O'Sullivan, 2015; Brinkley et al., 2021; Levkoe et al., 2021). Levkoe et al. (2021) explicitly state that “SNA results can and should be explored interactively with network members to gain further insights from the statistical analysis and visualizations relative to a member's position within the network” (Levkoe et al., 2021, p.74).

One way to engage stakeholder is to gather SNA data in a participatory manner with the Net-Map tool. This is a relatively new approach that differs from “traditional” SNA in that the results are visualized participatively during the process, whereas in traditional network analysis data are gathered with a standardized survey and visualization is performed at the end of the data collection (Schönhuth, 2013). The tool was developed by Eva Schiffer and was first applied in 2006 in a partnership between the Challenge Program for Water and Food and the White Volta Basin Board (WVBB), a local multistakeholder organization, in Northern Ghana (Schiffer and Hauck, 2010).

With regard to previous studies, testing the Net-Map tool for CRFSs network analysis fills a research gap.

To fill this gap, this paper pioneers the application of the Net-Map tool to examine CRFS networks in seven European cities (Bologna, Naples, Lansingerland, Tenerife, Oslo, Dortmund, and Romainville). The analysis demonstrates the suitability of the tool for generating pertinent results tailored to the distinctive attributes of each examined case in terms of

- o displaying the roles of actors;
- o revealing relationship patterns between actors;
- o illustrating the strengths and weaknesses of the network; and
- o defining solutions for strengthening the CRFS in each case.

Furthermore, we aim to evaluate the suitability of the method in a more general, transferable sense through

- o evaluating and discussing the method's limitations and benefits; and
- o developing recommendations for the practical uses of Net-Map and potential transferability to other case studies

The remainder of this paper is structured as follows. In order to address the analytical aspects described, we first explain the Net-Map tool and its procedure as well as the SWOT analysis used and its implementation methodology in the Methods section. In the result section, we then use the results from the seven European cities as examples in regard to the roles and relationships of the actors in the network and for the initial solutions for strengthening the CRFS. We present the findings which identify the roles of the actors, showing the motivations and influences of the actors, taking into account the socio-economic context, followed by the results of the visualization of relationship patterns between actors, with network maps showing the relationships investigated. In the discussion section, we discuss the benefits and limitations of the methodology for Network Analysis in CRFS Transformation and reflect on the practical use and the transferability of our results to other cases before we end with concluding remarks. The results of the analysis can also be found in the FoodE project deliverable (Wissmann et al., 2023).

2 Methods

2.1 Introduction of the Net-Map tool

The Net-Map tool¹ is an interview-based mapping tool that combines the empirical research of narrative interviews and participant observation so that the interviewer, in addition to conducting interviews, observes the expressed reflections of the interviewees and the process of map creation (Schönhuth, 2013).

The Net-Map tool is used with the aim of clarifying individual perspectives in the network of actors and analyzing the structures that are not based on physical infrastructures but are hidden in social networks (Hauck, 2012). Based on these insights, the tool promotes dialogue and helps to develop approaches to the problem under investigation. Through the entire process of the Net-Map design, the interviewees have the opportunity to name important key persons, relationship patterns, and influences, or power structures of actors in the network (Cassaniti, 2021). Thus, the Net-Map tool can capture the existing value chain in the local food system and represents the actual state of active stakeholders in the network, their relationship patterns, and existing gaps but also potential improvements in the network (Schiffer and Hauck, 2010). The end product is a visual network map created through a participatory process that allows social relationships to be surveyed and analyzed (Lelong, 2015).

Although the Net-Map tool was originally intended as a paper-to-pen method (Lelong et al., 2016), it allows a certain flexibility in the choice of formats and interview forms, which

have already been implemented in different ways in other research, e.g., using online tools (Lelong et al., 2016; Sattler et al., 2022; Schröter, 2022a). Considering individual factors such as the size of the study area, the number of interviewees, and their time and financial resources (for example, travel to the interview location, etc.), the flexibility justifies a high tolerance for implementing this method (Sattler et al., 2022). To investigate the social network dynamics within this process, data capturing the relational patterns among actors are collected. While the material of the narratives can be analyzed qualitatively, the actors and their links can be analyzed quantitatively using graph theory (Lelong et al., 2016). Thus, the Net-Map tool is a hybrid tool that follows the mixed-method approach (Lelong et al., 2016), meaning that both qualitative and quantitative data are collected and combined in the chosen research design (Kuckartz, 2014).

A Net-Map interview consists of an overall Net-Map question asking who are the important actors in a defined network at a certain time and several consecutive interview steps (Schiffer, 2007):

1. Which actors are included? (Actors).
2. In what ways are these actors linked? (Relationships).
3. How influential are these actors in the network? (Influence).
4. What are their goals or motivations in this context? (Motivations).

2.2 Interview preparation

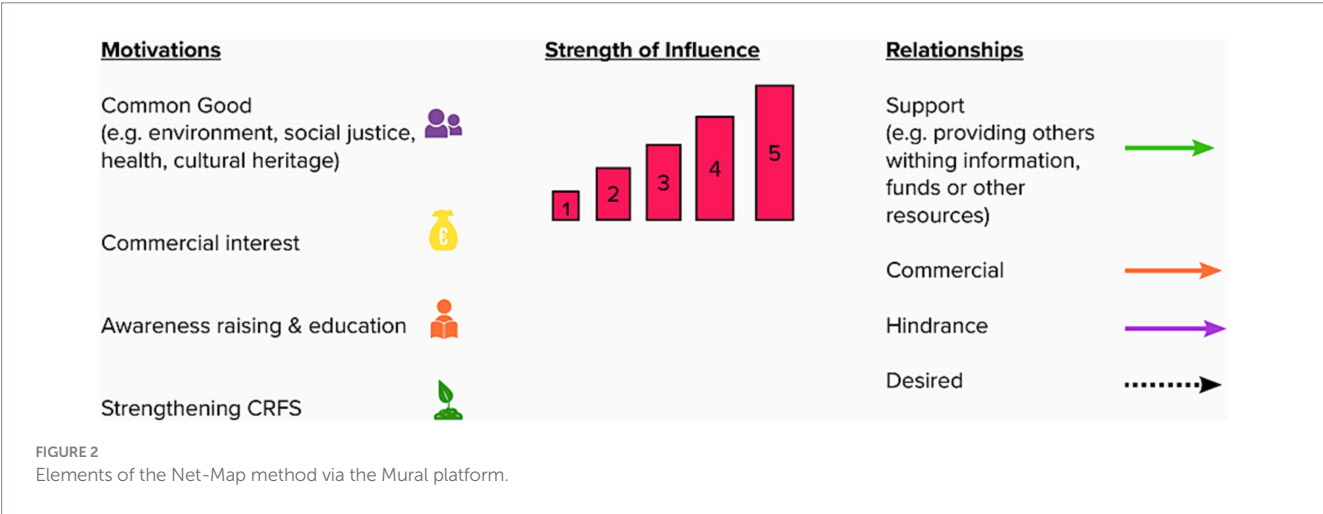
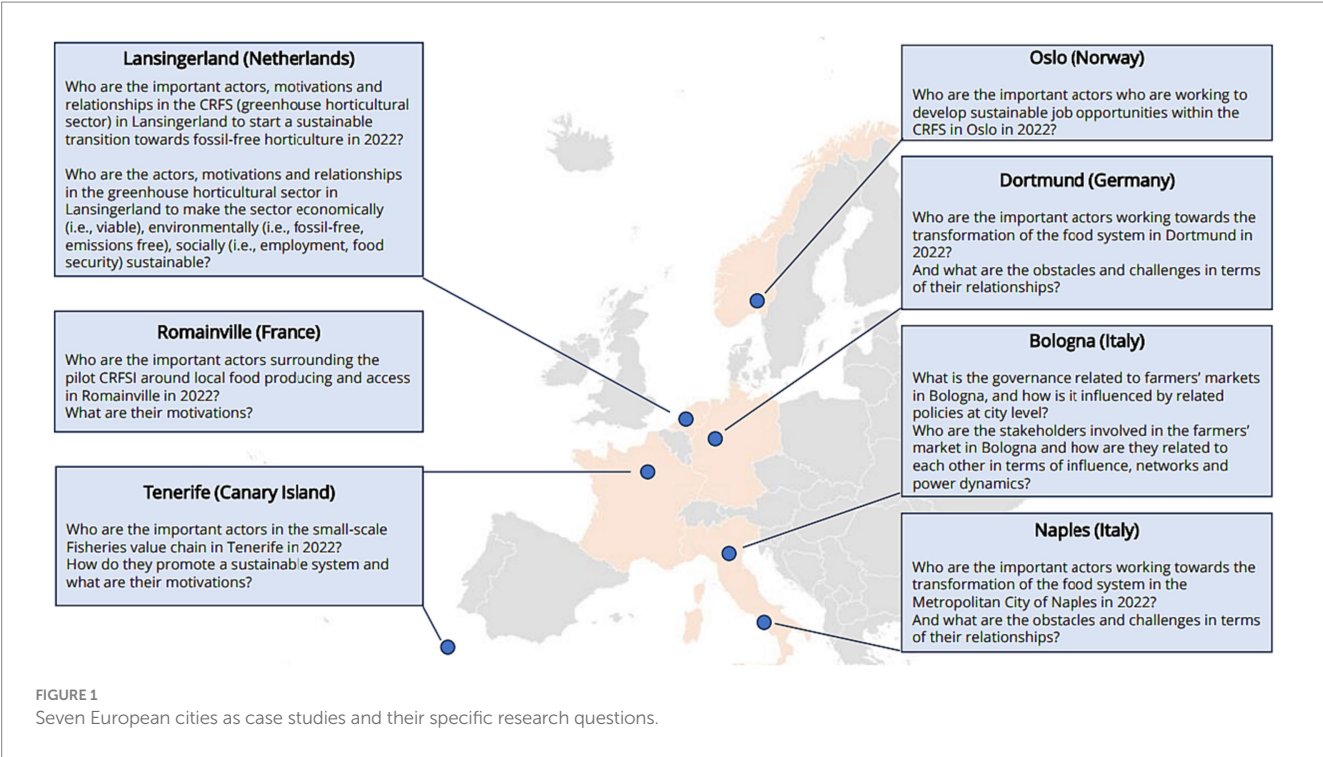
To define the interview framework, the third coauthor hosted a 2-day online workshop with the project team to introduce the Net-Map tool to all participating case studies in September 2022. In the workshop, the rules and implementation of the tool were presented and the Net-Map research questions for the CRFS in each of the seven European cities were defined (Figure 1).

Furthermore, which relationships between the actors would be gathered were defined, and the motivations that drove individual initiatives to participate in food system transformation were investigated. As a result, four different relationship categories—support, commercial, hindrance, and desired—were broadly defined and further differentiated in the cases, as elaborated in the results section. In addition, four motivations—common good, commercial interest, awareness raising, and CRFS education and strengthening—were captured during the workshop. Finally, the strength of perceived influence was delineated on a scale from one (lowest influence) to five (highest influence) for each case study (Figure 2). We also decided to distinguish the actors in the three groups—food economy, civil society, and public administration/government—that make up the CRFS.

2.3 Data collection

The within the workshop jointly developed interview framework ensured a consistent data generation process across all case studies (Annex 2). The next step was the respective research teams conducting the interviews, focusing on their individual research questions but following the same Net-Map interview

¹ More information at <https://netmap.wordpress.com/about/>



process. The teams also chose between in-person or online interviews, depending on their resources.

The interviewees were generally six to eight key actors so that at least two key persons were represented from each of the three stakeholder groups (civil society, public administration, and food economy) (see Table 1).

The interviewees were selected through intensive research by the research teams with the aim of interviewing individuals who were actively involved in the network and had a good overall understanding of its actors. Subsequently, face-to-face interviews were conducted with the selected individuals in either an online or on-site setting.

During the interviews, large sheets of paper were utilized to create network maps, while actor cards and Post-it notes were employed to designate the identities and motivations of the actors. To depict the relationships, pens in four different colors were used, and influence

tower disks were created to determine the level of influence of each actor. In the online interviews, the Mural online platform (Mural, 2022) was used to visually represent the network maps.

First, the actors involved in the networks were identified. To provide quick access to the food network interviews, the research teams selected 20–40 actors based on prior research and close examination of the CRFS networks. These 20–40 actors were then described to the respondents. The respondents were then asked to name additional actors, if needed. In some cases, a minimum number of 5–10 actors was selected before beginning the Net-Map process, while in other cases, no strict minimum number was specified. The limited number of actors was an attempt to streamline the length of the interviews and keep the complexity of the network manageable. However, it is worth noting that in some cases, the number of actors mentioned far exceeded the 10-actor limit.

TABLE 1 Overview over interviewees in each case study.

Case study city	Interviewed organizations	Type of stakeholder group
Dortmund (Germany)	1. Food Policy Council	1. Civil society
	2. Environmental Agency	2. Public administration/Government
	3. Office for International Relations	3. Public administration/Government
	4. Organic Food Shop	4. Food economy
	5. Educational Farm	5. Food economy
	6. Participatory Urban Development NGO	6. Civil society
	7. Social Enterprise	7. Food economy
Bologna (Italy)	1. Agricultural representatives	2. Public administration/Government
	2. Food-related association 1	1. Civil society
	3. Food-related association 2	2. Civil society
	4. City Commerce Department	3. Civil society
	5. City Agricultural Department	4. Public administration/Government
	6. FMs organizers 1	5. Public administration/Government
	7. FMs organizers 2	6. Food economy
	8. FMs organizers 3	7. Food economy
	9. FMs organizers 4	8. Food economy
Naples (Italy)	1. Urban farmer	9. Food economy
	2. Farmer's union organizations	1. Food economy
	3. NGO managing a farm, confiscated from the "Camorra" in the metropolitan area of Naples	2. Food economy
	4. NGO working with psychiatric patients in farming activities	3. Civil society
	5. Slow Food Campania	4. Civil society
	6. Representative of the Municipality of Naples	5. Civil society/food economy
Oslo (Norway) ¹		6. Public administration/Government
Romainville (France)	1. Vertical and educational greenhouse	1. City administration
	2. Supermarket	2. Food economy
	3. Intermunicipality	3. Intermunicipal administration
	4. Allotments gardens	4. Civil society
	5. Restaurant	5. Food economy
	6. Food bank	6. Civil society
	7. Vertical and educational greenhouse	7. City administration
Lansingerland (Netherlands)	1. Knowledge institution	1. Education
	2. Trade association in which 75% of Dutch greenhouse growers are organized	2. Food economy
	3. Regional government	3. Public administration/Government
	4. Commercial company/supplier	4. Food economy
	5. Commercial company/supplier	5. Food economy
Tenerife (Canary Island)	1. Cabildo de Tenerife. Área de Pesca	1. Public administration/Government
	2. Cofradía de Pescadores (Fishers' guild)	2. Civil society
	3. Universidad de La Laguna. Fisheries research group	3. Civil society
	4. Wholesaler/ producer	4. Food Economy
	5. Producer organization (cooperative)	5. Food Economy
	6. Poacher	6. Food Economy

¹This data is no longer available.

To collect data on how the actors were connected to each other in supportive, desired, hindering and commercial relationships, arrows that were color-coded to indicate specific connections were drawn

between actors (Figure 3). The arrows indicated a resource flow from one actor to another. If there was a mutual exchange, the arrows pointed in both directions (Schiffer and Hauck, 2010; Schröter, 2022a).

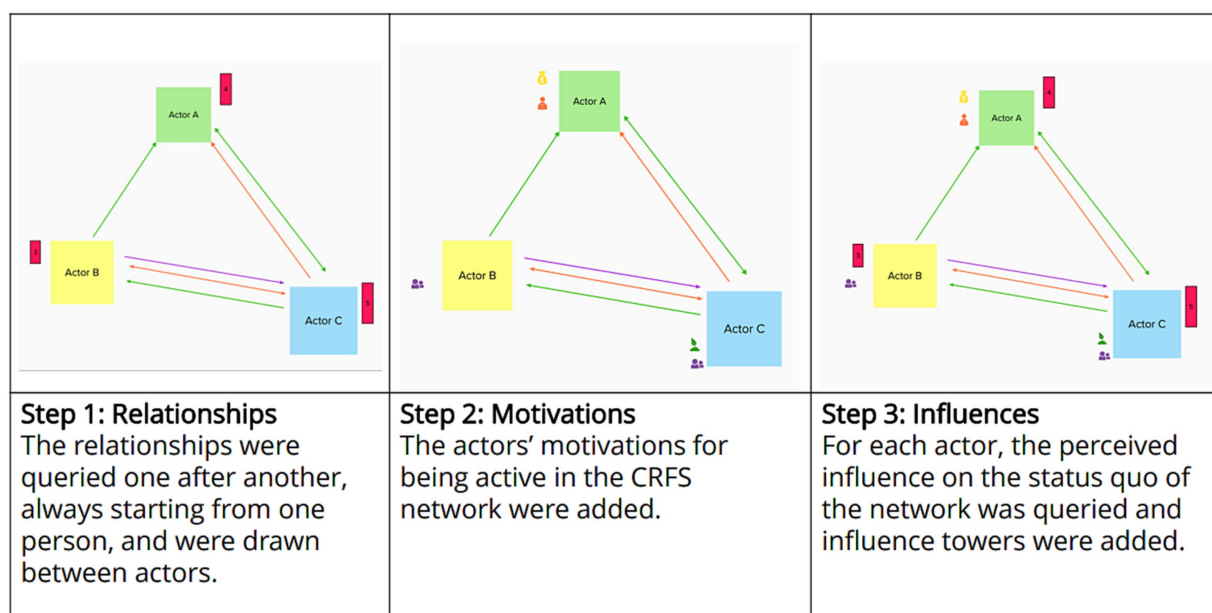


FIGURE 3
The three main steps for drawing Net-Maps via Mural.

In addition, the motivations (see Figure 2) were placed next to the actor maps as icons (Schiffer and Hauck, 2010, Schröter, 2022a). Furthermore, the interviewees were asked who had how much influence in the network, and the influence towers were then placed next to the actor cards (Figure 3). The higher a tower was at the end, the stronger the influence of that actor (Schiffer and Hauck, 2010, Schröter, 2022a).

Together with the perceived motivations, the information on influences was helpful for the interviewees to identify which actors they could strengthen in the future and which potential conflicts of interest they should be aware of (Schiffer and Hauck, 2010).

2.4 Data processing and analysis

2.4.1 Quantitative data analyzed by SNA measures

The final CRFS maps can be read using graph theory. The visualized actors and relationships are referred to as “nodes” and “edges.” Here, the nodes represent the individual actors in the network, which can be individual or collective (Borgatti et al., 2018). Connections are mapped between the actors and can be of different types, such as social relationships or resource flows. The nodes and edges form the output of the SNA, that is, the network (Borgatti et al., 2018).

The individual Net-Maps were analyzed mathematically by transferring and accumulating matrices in Excel spreadsheets. The relationships of the actors were detected in adjacency matrices where the rows and columns each represented an actor in the network (Fuhse, 2018). To capture the relationships, a “0” was inserted for no connection, and a “1” was inserted for an existing relationship. This created an Excel spreadsheet for each interview and each connection

category, and the results for each connection category were then added together (Schröter, 2022b).

The quantitative data generated through the Net-Map process were analyzed using SNA measures.

To convey all the information about the overall structure of the network, e.g., how influential individual nodes are within the network, it helps to represent different “centralities.” These can be measured in different ways (Fuhse, 2018). In this study, degree centrality was used. Degree centrality shows the number of incoming, as well as outgoing, connections and indicates nodes that are relevant for the flow of information (Cherven, 2015). Nodes with high degree centrality can be considered key actors, as they receive and transmit a larger amount of information or influence. This can aid in identifying important actors in the network and comprehending which nodes are particularly influential within the CRFS network.

Another measure that was calculated is reciprocity. A simple way to measure reciprocity is to count the number of reciprocal connections and divide it by the total number of connections. In directed networks, reciprocity occurs when an actor receives a connection from another actor and then returns a connection to that same actor (Borgatti et al., 2018). In networks that are inherently symmetric, full reciprocity exists by definition, meaning that both parties affirm the relationship equally. An example is a mutually supportive relationship through networking that is undirected and therefore reciprocal (Schönhuth, 2013). Reciprocity is useful for understanding how information or decisions circulate within a CRFS network and which nodes are particularly closely connected.

2.4.2 Visualization of the network

A map was visualized with Gephi software (Gephi, 2022) for each connection, resulting in a total of four network maps:

1. Net-Map of the supporting relationship.
2. Net-Map of the desired relationship.
3. Net-Map of the hindering relationship.
4. Net-Map of the commercial relationship.

Additionally, the three different actor spheres were distinguished by color coding when visualizing the maps (civil society actors in green, local food actors in blue, and public administration/government in yellow).

The relationships between actors were represented by edges, which indicate connections. The thickness of an edge and the intensity of its color between two actors illustrate the strength of the connection. Here, arrows at the end of the connection lines show the direction of the relationship and indicate whether it is reciprocal or one-sided. A larger arrow indicates that the flow of information is more often directed from one actor to the other. The node size is depicted depending on actors' calculated degree centrality.

For visualization, the Force Atlas algorithm was chosen for the layout of the graphs. This algorithm follows a twofold linear model in which the attraction and repulsion of the nodes are calculated proportionally to their distance. With this layout, the attraction of the nodes can be represented (Jacomy et al., 2014).

The Net-Maps visualized the density of the network, which provided initial information about the network structure. In this way, the number of actual relationships among potential connections in the network was determined. This concept of density provides insight into the overall connectivity of the network (Schönhuth, 2013).

Along with the layout, density, degree centrality, and reciprocity, we interpreted the roles of actors in the CRFS network. This allowed us to identify who were the central actors, intermediaries, or those not in focus within the CRFS network.

2.4.3 Analysis of motivations and influence towers

Influences and motivations were elaborated in the diagram representations. The motivations and influences of each actor were captured in an Excel file. The results of the individual network maps were entered along the four types of motivations on a scale of 0–2 (0 = not present, 1 = present, 2 = main motivation). Finally, the results were summed up in a separate spreadsheet. Regarding influence, values from 1 to 5 of the influence markers assigned to actors in the interview were assigned to the corresponding actors. The results for influence were also summed up. The influence and motivations assigned to the actors were visualized with simple bar charts. Together with the perceived motivations, the information about the influences is helpful for the interviewees to identify which actors they could strengthen in the future and which potential conflicts of interest they should be aware of (Schiffer and Hauck, 2010).

2.4.4 Analysis of the narratives

The qualitative analysis involved the examination of the narrative data from the interviews (Steinbrink et al., 2012). The interviews were transcribed and coded using both indicative and deductive categories (Flick, 2021). The results also captured information “between the lines” and revealed the individual perceptions of interviewees within the actor network (Küsters, 2009). The narratives provided greater

clarity regarding the nature of these relationships, allowing us to identify specific aspects within the categories.

Supportive relationships: these predominantly involve information exchange, networking, cooperation, and promotion.

Desired relationships: these mainly encompass the desire for new or increased information exchange, networking, the alignment of interests, financial and material support, and the creation of synergies.

Hindering relationships: these represent weaknesses, obstacles, and conflicts within the network and between actors.

Commercial relationships: these reveal which actors are engaged in business dealings with one another.

2.5 Strengths, weaknesses, opportunities and threats analysis

Based on the results of the final network maps, a SWOT analysis was carried out for each CRFS as a final step. This made it possible to identify strengths and weaknesses of the current network and, on this basis, to record opportunities and threats for the future.

The SWOT analysis was conducted by the case study research team itself in most of the case studies, based on the qualitative analysis of the individual interview transcripts, with the exception of the SWOT analysis in Dortmund. There, a stakeholder workshop was held online with one key person per stakeholder group in the network, and the results were discussed and elaborated together. The participants were presented with the four final Net-Maps of supportive, desired, hindering and commercial relationships in the food network in Dortmund and diagrams that showed the influences and motivations of the actors on a Mural board. The participants were asked for their impressions of these results, and they had the opportunity to examine the maps and diagrams in more detail. This created the opportunity to express new ideas and problems and to discuss possible solutions. Through the ideas and suggestions summarized in the SWOT table, the stakeholder workshops provided the opportunity to collect further aspects that would contribute to the improvement of the CRFS. This process was designed to be interactive, and the participants themselves formulated their thoughts in digital notes, which were then discussed in plenary.

3 Results

In the following section, the results from the seven European cities are used as examples to provide insights into the results that can be achieved through the Net-Map tool in regard to analyzing the roles and relationships of the actors in the network and developing initial solutions for strengthening the CRFS.

3.1 Insights for identifying the roles of actors

The results of the Net-Map interviews enabled us to identify the roles of the actors in each CRFS. Due to the specific research questions and the different individual situation of each case study and specific changes or problems in the cases for transformation of the food

system, the roles of the actors in each CRFS network differed (Table 2). By identifying the degree centrality, reciprocity, and density and using the Force Atlas algorithm, it was possible to illustrate which actors were key persons, which played an intermediary role and through which information flows at the shortest distance and which were perceived little or not at all (see section 2.5). As shown in Table 2, it is evident that each city had very different main actors (actor focus) for the transformation of its CRFS, including in the three different actor groups. For example, in Dortmund, the Food Policy Council as a civil society initiative was seen as the driver of food transformation in the city, whereas in Tenerife, the focus was on the economic actors in the local fisheries value chain in regard to driving change in the network. In Oslo, the city was seen as the most important transformer. The actors' roles could be captured by the Net-Map tool in the context of each CRFS.

In addition, the results generated from the sum of the influence towers were relevant to the roles of the actors. These show how individual actors and their influences are perceived in the CRFS network and how the actor groups and their influence are distributed. The results show that all three actor groups were present with high influence values. It became clear that the distributions differed in each case study and that the actors with the highest values also differed in their functions, ranging from farmers to the Food Policy Council to universities and research institutions (Table 3).

By capturing the motivations of the actors in the CRFS networks, it is possible to identify what drives the actors to be active. It turns out that the strengthening of CRFSs is highly relevant in all CRFS networks and that commercial intentions relate only to the food economy, but these relationships are not truly relevant for the functioning of the network itself (Table 4).

TABLE 2 Context and focus of each CRFS network in the seven different European cities.

Case study City	Research question for city-specific framework	Network focus	Specific change or problem in the city for transforming the food system
Dortmund (Germany)	Who are the important actors working toward the transformation of the food system in Dortmund in 2022? What are the obstacles and challenges in their relationships?	Actors around a newly formed Food Policy Council in Dortmund.	Action program "Klima-Luft 2030" with master plan about food and future staff position for supporting Food Policy Council.
Bologna (Italy)	What is the governance of farmers markets in Bologna, and how is it influenced by related policies at the city level? Who are the stakeholders in the farmers market in Bologna, and how are they related to each other in terms of influence, networks and power dynamics?	Actors around the farmers market network in Bologna	City Council approved a new regulation on farmers markets ("Regulations for conducting direct sales markets of → agricultural products"), which are characterized through direct selling without middlemen, allowing the connection between farmers and citizens.
Naples (Italy)	Who are the important actors working toward the transformation of the food system in the metropolitan city of Naples in 2022? What are the obstacles and challenges in their relationships?	Actors working toward the transformation of the CRFS in the Metropolitan City of Naples.	
Oslo (Norway)	Who are the important actors who are working to develop sustainable job opportunities within the CRFS in Oslo in 2022?	Actors working to develop sustainable job opportunities within the CRFS in Oslo (main focus City of Oslo).	Sprouting Oslo Strategy→ from City of Oslo for funding to help start and support urban agriculture projects.
Romainville (France)	Who are the important actors surrounding the pilot CRFS around local food production and access in Romainville in 2022? What are their motivations?	Actors surrounding the pilot Cité Maraîchère (municipal facility for urban agriculture, a vertical farm that hosts a series of facilities and activities under one roof) around local food production and access in Romainville.	The Cité Maraîchère aims to develop an environmental education program alongside sustainable food, promoting access to fresh, healthy and seasonal produce.
Lansingerland (Netherlands)	Who are the important actors and what are their motivations and relationships in the CRFS (greenhouse horticultural sector) in Lansingerland to start a sustainable transition toward fossil-free horticulture in 2022 and to make the sector economically (i.e., viable), environmentally (i.e., fossil-free, emissions free), and socially (i.e., employment, food security) sustainable?	Actors in the greenhouse horticultural sector at regional and national levels [Municipality of Lansingerland and world, Wageningen University & Research (WUR) (Business Unit Greenhouse Horticulture)].	Transition toward fossil-free greenhouse horticulture with a realistic road map and clear guidance that accounts for the needs and challenges of the actors involved.
Tenerife (Canary Island)	Who are the important actors in the Small-Scale Fisheries value chain in Tenerife in 2022? How do they promote a sustainable system, and what are their motivations?	Actors in the Small-Scale Fisheries value chain in Tenerife.	Local artisanal fishers struggle in a market with an increasing number of operators.

TABLE 3 Actors with the highest influence in each CRFS separated into the three actor groups: civil society (CS), public administration (PA), and food economy (thick letters show the actor with the highest general influence).

Case	Number of actors included in each case	Civil society	Public administration	Food economy	General influence (CS = Civil society; PA = Public administration; E = Food economy)
Dortmund	25	Food Policy Council	Environmental agency, City Council	<i>Educational farm Schulte-Tigges</i>	Highest influence belongs to CS and PA
Bologna	54	<i>Food-related associations (Slow Food)</i>	City Commerce Department, City Council, City Agricultural Department	Farmers/Agricultural enterprises; Consumers/Citizens	Influence belongs to E and PA
Naples	18	Universities and research institutions	Municipality	Professional associations, business of 0 km products	Highest influence belongs to C
Oslo	10	REKo RIngen	Communal administration of Oslo	<i>UReist</i>	Highest influence belongs to PA and CS
Romainville	25	Inhabitants	Schools, City Maraichère	<i>Central supermarket</i>	Highest influence belongs to PA and CS
Lansingerland	10	Greenhouse farming	Government	Primary producers	Highest influence belongs to PA, SC, E
Tenerife	40	<i>Small intermediary</i>	Productive units	Wholesalers, illegal fishers	Highest influence belongs to E, CS

TABLE 4 Motivation of actors per case study (x = not mentioned).

Motivation	Dortmund	Bologna	Naples	Oslo	Romainville	Lansingerland	Tenerife
Strengthening the CRFS	Relevant for all actors, especially CS	x	Relevant especially for CS	Major focus of food economy followed by CS	Relevant for all actors, especially for PA and food economy	Relevant for all actors	Relevant for PA, food economy
Common good	Relevant for all actors, especially public administration	Highly relevant for all actors	Relevant especially for CS	Relevant especially for food economy and CS	Relevant for all actors, especially PA, CS	Relevant for all actors, especially for food economy	Major focus of PA
Knowledge and awareness	Relevant for all actors, especially CS	x	Relevant especially for CS	Major focus of food economy followed by CS	Major focus of PA	Major focus of PA, followed by CS	Not relevant
Commercial	Major focus only for economic actors	Relevant just for economic actors	Major focus only for food economy	Major focus for food economy, followed by CS	Major focus for food economy	Major focus for food economy	Major focus for food economy
Information sharing	x	Relevant for all actors, especially public administration	x	x	x	x	x

In the context of motivations, the distribution and function of the three actor groups, civil society, food economy and city government, as well as the identification of key actors provided insights into the CRFSs and identified the main drivers of each network.

3.2 Insights for visualizing relationship patterns between actors

To portray the supportive, desired, hindering and commercial relationships, the connections among actors in the food network were illustrated in the Net-Map interviews. Subsequently, the individual network maps of relationship categories were aggregated into a final map.

3.2.1 Supportive relationships

The network maps of the supportive relationships illustrated which actors in each CRFS network had reciprocal or unilateral relationships, who occupied key positions in the network and thus represented intermediaries in the support network and who did not. Both individual actors and entire groups of actors and their support functions were analyzed.

Through the layout interpretation of density and the intensity of interconnectedness through the measures reciprocity and degree centrality, conclusions could be drawn about the willingness to support and the degree of awareness and activity of the actors in the network.

The analyses of the interview narratives revealed that supporting relationships primarily involved information exchange, networking, cooperation, and promotion. In all seven case studies, all actor spheres were interconnected, forming dense networks. This indicated a strong willingness among the participants to support each other within the CRFS network. Moreover, it was observed that central actors, who had the most connections, also had the strongest influence on transforming the CRFS. For each specific network, it was possible to identify its support dynamics.

To provide an example, the Net-Map for Dortmund (Figure 4) shows a dense support network among the actors in the CRFS. The green arrows between the nodes (actors) represent the supported relationships, indicated by their thickness and intensity of color. The map primarily shows mutual relationships, as indicated by arrows that point in both directions. All actor groups are strongly represented in the relationships, as is evident from the nodes in yellow (public administration), green (civil society), and blue (food economy). What stands out in the map is the high level of support from the city administration (yellow nodes), which also has a significant influence on transforming the CRFS. The Food Policy Council has the highest degree centrality, holds the largest node in the map and is centrally positioned with numerous relationship ties. The clear results demonstrate that the Food Policy Council plays the most important support role and is perceived as a point of contact for civil society regarding food matters, serving as an essential link for all three stakeholder groups. These results with the information generated in the qualitative interviews while drawing the Net-Map underline the strong commitment to transformation

in Dortmund from all actor groups facilitated by mutual support within the CRFS.

In comparison to Dortmund, in the Net-Map of Bologna (Figure 5), many more relevant actors are visible. As shown on the map, a dense network with a high number of supportive relationships is also evident here. The strongest supportive relationship, between farmers and citizens, is represented by the thickest edge with the darkest green color. Not only does this connection have the highest level of support, but the actors also have the strongest influence on the CRFS network. This relationship makes visible how closely connected citizens and farmers are with each other in the CRFS and highlights the importance of this relationship. In the interviews, the respondents pointed out that this connection can create a community that helps to create awareness among future consumers.

3.2.2 Desired relationships

The Net-Maps with desired relationships show which connections did not exist in the status quo in the network but would be desirable for the CRFS or which connections should be expanded more strongly. This mostly encompassed new or increased information exchange, networking, bundling interests, financial and other material support, and the creation of synergies. In contrast to the support network, the case studies revealed varying levels of density within the desired networks, ranging from frequently drawn connections to highly dense networks. Notably, support was the network with the highest density, but in all cases, the actors also wanted more relationships in the future, especially with the municipality and with the key actors of the CRFS.

For example, the Net-Map of Oslo (Figure 6) shows that the actors had no great size differences in their nodes and thus no highly fluctuating degree centrality. Incoming and outgoing relationships were therefore more equally represented among the actors, which also expressed a high desire for relationships among all actors in the network. However, dark red edges can be seen, especially toward the municipality of Oslo, which was also centrally located in the network, indicating a high level of magnetism.

Using Oslo as an example, the Net-Map shows that participants mostly wanted the city of Oslo, which had the strongest influence and potential to transform the CRFS, to strengthen relationships with other actors in the future. Statements from the interviews revealed that the desired relation was perceived as not strong enough and not always reciprocal. In addition, stronger coordinated cooperation with other actors in the network was desired.

In the desired relationships in the CRFS in Naples (Figure 7), the Net-Map shows that there are main actors located in the center of the map, with high degree centrality and a high number of incoming and outgoing relationships. To the left and right of this density are individual strands of connections in the network. While these may not be the central focus, they hold significance for comprehending the relationships depicted in this map, enriched by additional insights provided in the interviews.

The Net-Map shows that it is not the city but the civil society initiatives that form the core of the desired network relationships. The highest degree centrality is mainly that of the farmers' associations, especially Coldiretti. In relation to families, individuals or communities of citizens, the need for a stronger relationship with the

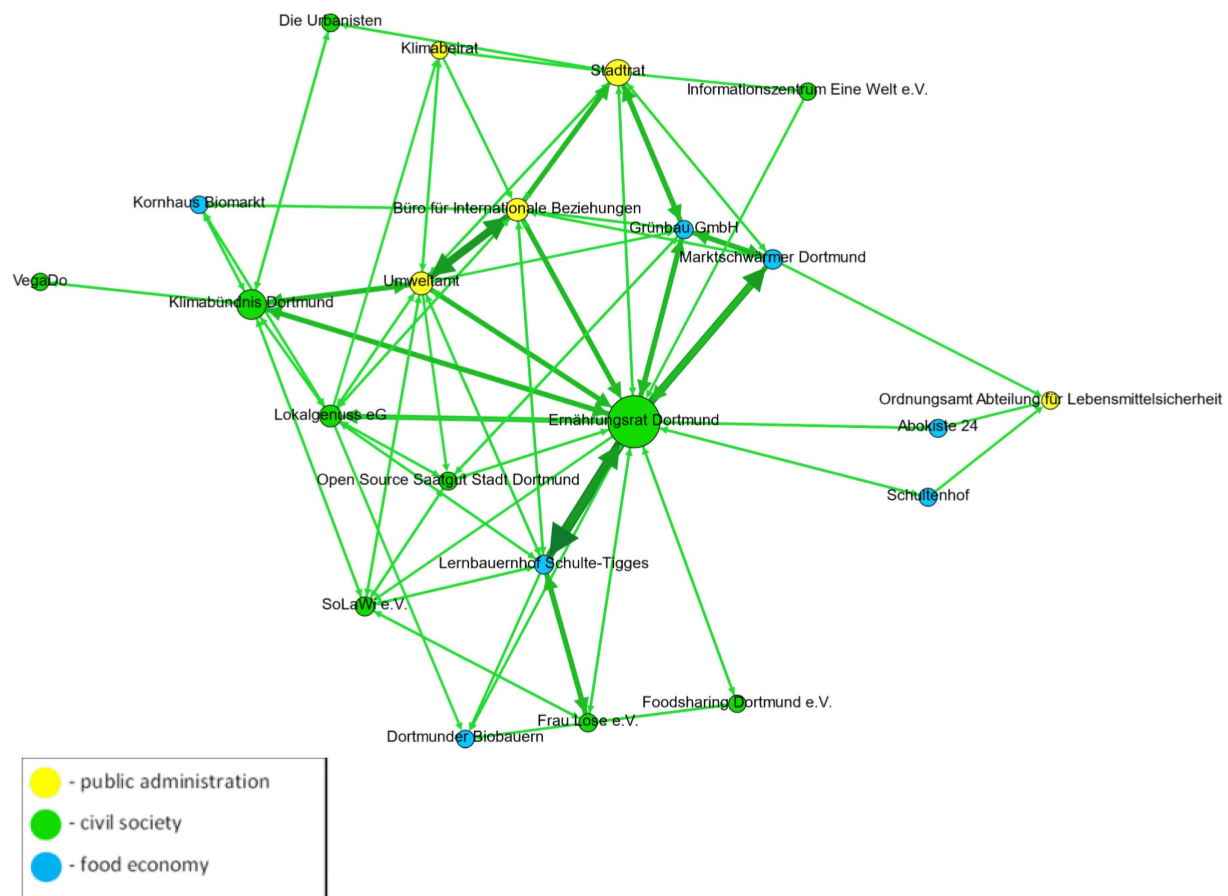


FIGURE 4

Net-Map of supportive relationships of the relevant actors of all three actor groups, food economy (blue), civil society (green), and public administration (yellow), in the CRFS in Bologna. All ties depicted. Node size according to degree centrality. Node color intensity according to betweenness centrality. The direction of the arrow indicates the direction of the relationship, as well as one-sided or two-sided relationships. (ILS/FoodE).

European Union was highlighted in the interviews, as this institution and its actions were perceived as far removed from the needs of the people.

3.2.3 Hindering relationships

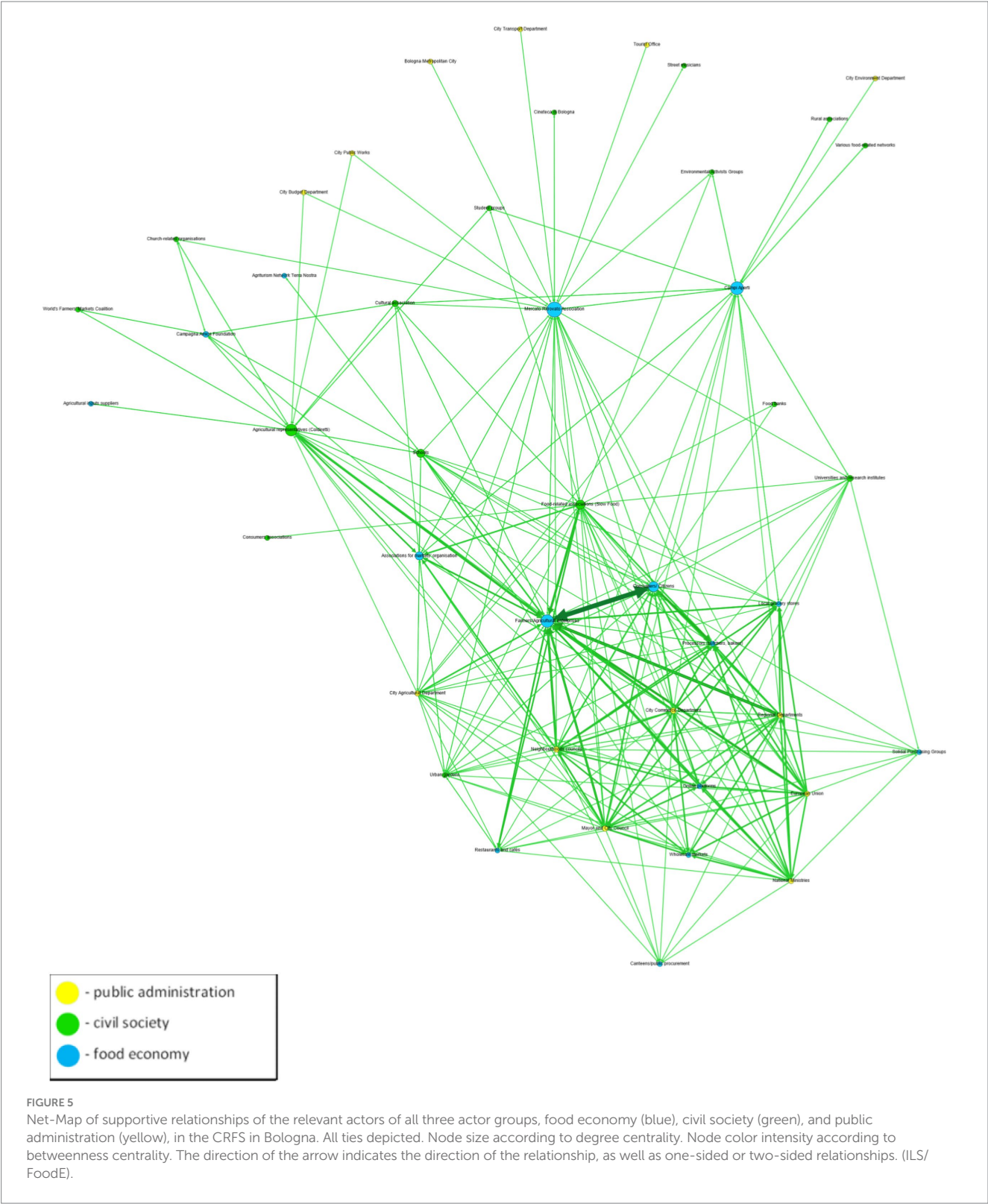
For hindering relationships, the Net-Map reveals weaknesses, hurdles, and conflicts that exist within the network and between the actors. The case studies show that there were mostly fewer hindering relationships than supportive relationships.

In the CRFS in Tenerife (Figure 8), illegal fishermen had a particularly strong obstructive relationship with the legitimate producers of the fisheries sector and with the public administration. The Net-Map of Tenerife shows that the illegal fishermen (poachers) were the central actors in the hindering relationships, with the highest degree of centrality. Imported and illegal products hindered fair trade in local catches, sometimes representing strong unfair competition with local producers. The public administration's decision-making position was perceived as being hindered by rules, boundaries, and laws, as well as bureaucratic hurdles and a lack of resources to implement a regulated framework and reduce the activities of illegal fishers.

The Net-Map of hindering relationships in the CRFS in Romainville (Figure 9) shows that few actors played a role here and that there were only hindering relationships with the Cité Maraîchère. The interviewees mentioned the perception of a lack of support on the part of the public administration in the form of financial assistance as an obstacle.

3.2.4 Commercial relationships

Commercial relationships show which actors are in a business relationship with each other. The example of the CRFS in Lansingerland (Figure 10), which is concerned primarily with the energy transition, shows that these relationships existed primarily among the food economy and public administration. The map shows the interrelationships between food economy actors and civil society actors through the triangles in the center of the map, which thus also illustrate a high level of interdependent dynamics among the actors. Primary producers had well-established (and mutual) connections with private investors, energy suppliers, general suppliers, and research institutions. In this case, research institutions played a key role as connectors for the network as a whole and especially served as a bridge with the sphere of civil society.



3.3 Insights for determining strengths and weaknesses and elaborating solutions in the network

Based on the results obtained through the Net-Map tool, the researchers then conducted a SWOT analysis themselves and

summarized weaknesses and potential improvements in the CRFS network, drawing conclusions from these findings for potential improvements, solutions or even risks in the future. Table 4 presents the results for the city of Dortmund for illustration. In this case, the analysis was developed by the researchers together with key persons from the CRFS in a group discussion.

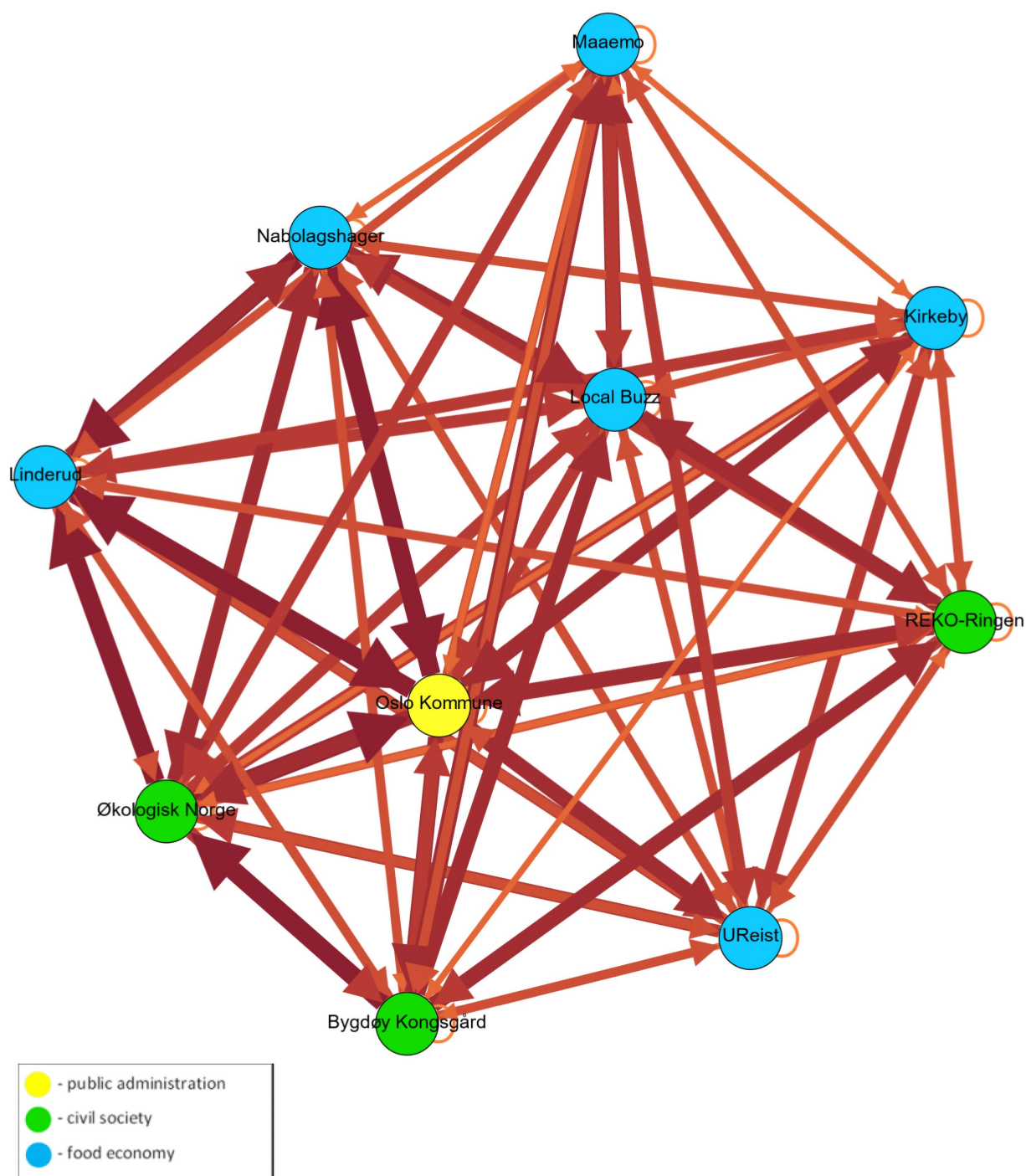


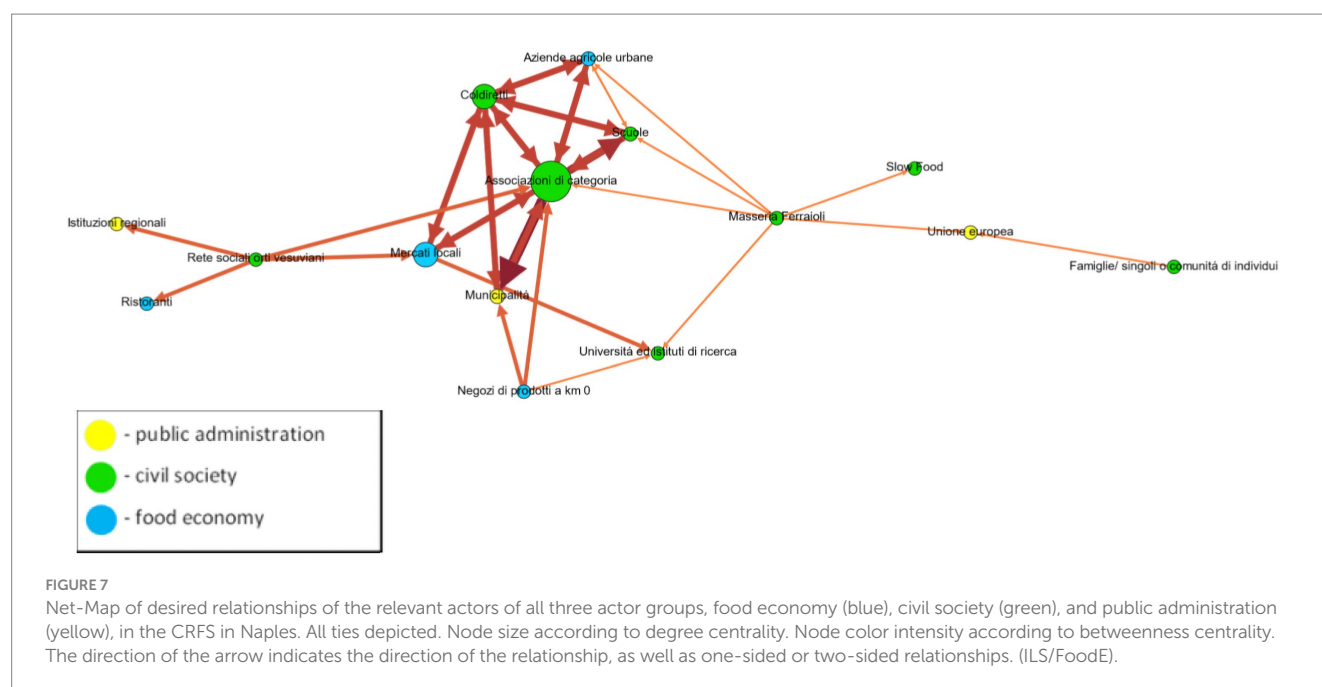
FIGURE 6

Net-Map of desired relationships of the relevant actors of all three actor groups, food economy (blue), civil society (green), and public administration (yellow), in the CRFS in Oslo. All ties depicted. Node size according to degree centrality. Node color intensity according to betweenness centrality. The direction of the arrow indicates the direction of the relationship, as well as one-sided or two-sided relationships. (ILS/FoodE).

The results for Dortmund show that activities in the network were primarily person-centered. The network exhibited a certain instability that could be remedied by stronger institutionalization. The person-based activities in the food network resulted in information being transmitted over a short distance and exchanges being based on personal, trust-building relationships. If individual key figures were to disappear, the network could be weakened or

even collapse. Solutions for institutionalization were mentioned in the group discussion.

For example, the food-relevant civil society and food economy in Dortmund lacked the bundling of interests and the visualization of their goals and challenges. The Food Policy Council was the actor that was supposed to work out this bundling. Due to its form of a voluntary initiative and due to the workload involved in establishing the



association, there were deficiencies in time, personnel, and financial resources.

The results of the SWOT analysis generated insights and showed what solutions are crucial for the development of the CRFS in each case study (Table 5).

4 Discussion and recommendations

The Net-Map tool provides a snapshot of an actor network identifying the roles, relationship patterns, and influences of the individual actors. This reveals dynamics between actors that are not based on physical infrastructures but are hidden in social networks (Hauck, 2012). The tool made it possible to show how actors were perceived in the CRFSs of the seven European cities. It also identified who was noticed as being present in the network and how these actors related to each other. When analyzing the interview data and the perceptions conveyed by the interview participants during the Net-Map interviews, we were able to contextualize an understanding of the dynamics and roles of the actors within the network within the specific situations in which these network participants were engaged. This allowed complex relationships to be understood with the addition of SWOT analysis. It also allowed weak points in the CRFS network to be identified.

4.1 Benefits of the Net-map tool for social network analysis in CRFS transformation/strengthening in European cities

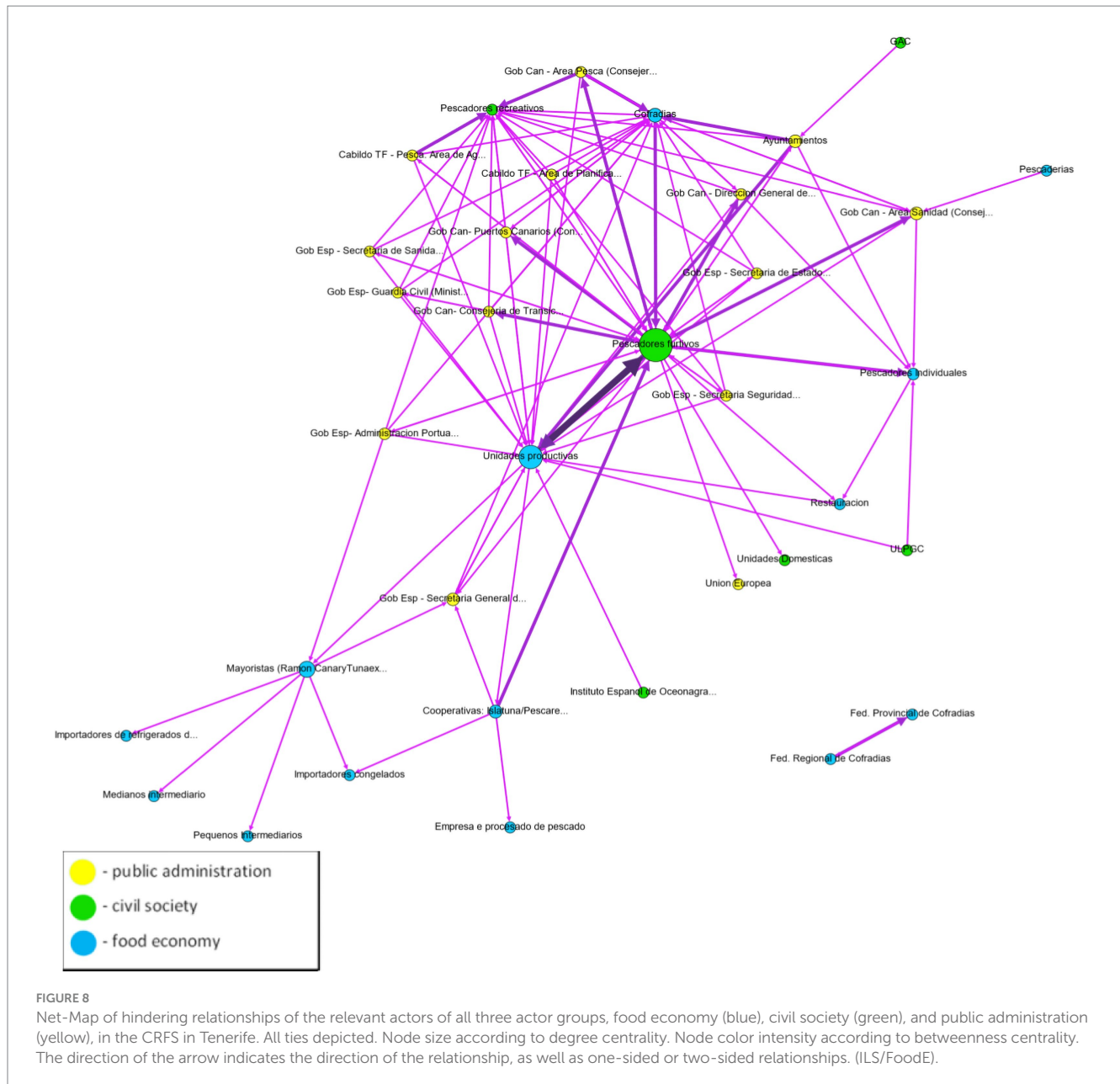
The Net-Map tool allows a certain flexibility in the choice of formats and interview forms, which have already been implemented differently in other research (Lelong et al., 2016; Sattler et al., 2022; Schröter, 2022a). Considering individual factors such as the size of the study area, the number of interview partners, and their time resources

and financial expenditures (for example, travel to the interview location), the flexibility justifies a high implementation tolerance of this methodological tool (Sattler et al., 2022). This flexibility was advantageous in this study because each city was able to act individually with its time and personnel capacities and implement the method with the resources it had available. Additionally, the situation of the COVID-19 pandemic could be weighed individually, and an implementation option could be chosen on that basis.

A familiar atmosphere was created in the interviews, and the open-ended questions placed the focus on the opinions and perceptions of the interviewees, who could simultaneously follow their spoken words visually via network drawings. Thus, learning effects occurred immediately (Schröter et al., 2018). This also led to participants' understanding of the current situation of their CRFS, and on this basis, shared visions for sustainable CRFSs were developed. During the interview process, the interviewees could qualitatively evaluate what they had said, visualize it, and reflect on it together with the researcher (Lelong et al., 2016). Therefore, connection between the researchers and the actors could be established, as the encounters took place in an informal way and insights into individual thoughts about the network could be revealed.

4.2 Limitations of the Net-map tool for analyzing CRFSs and limitations of the study in general

A disadvantage of the method is that it is time-consuming. The reason is the time needed for the individual Net-Map interviews as well as the further processing of the network maps and the interview material. The subsequent transfer of the data into an SNA and visualization program as well as the preparation, implementation, and analysis take considerable time. As a result, the interviewees' concentration sometimes waned toward the end of the interviews,



and the answers became shorter, which meant that less information could be gathered in the final steps.

Another obstacle regarding the collection of scientific data is the strict categorization of relationship types, which reduces complexity and does not reflect the nuanced nature of human interactions. Nevertheless, this specification ensured that each case study could depict the same relationships and also made it possible to create a clear time and evaluation framework. Furthermore, the participants did not encompass all perceptions within the network and lacked complete knowledge of individual characteristics. Achieving this level of information would theoretically entail conducting interviews with every individual involved in the CRFS network. To address this challenge, we grouped the actors into three actor categories: food economy, civil society and public administration. Another limitation of the tool is that the results are subjective and show the perceptions

of the participants. Therefore, some information could have been omitted because some participants did not know every specific relationship to other actors, which also influenced the results of the Net-Maps. The study area was also limited due to time constraints. The scope of the investigation was limited primarily to the city itself, and as a result, several relevant actors from surrounding areas were not included. The method may not capture all relevant stakeholders, especially those who are marginalized or have limited involvement in the CRFS. Furthermore, the actors in the network were defined differently in different cases. In some cases, general actors were used, such as *schools* or *city administration*, which included several institutions or specialized offices, or specific actors were named, such as “Frau Lose” (a café in Dortmund) or environmental department. In addition, the interviewees sometimes misattributed relationships or roles to higher-level actors, leading to potential data inaccuracies.

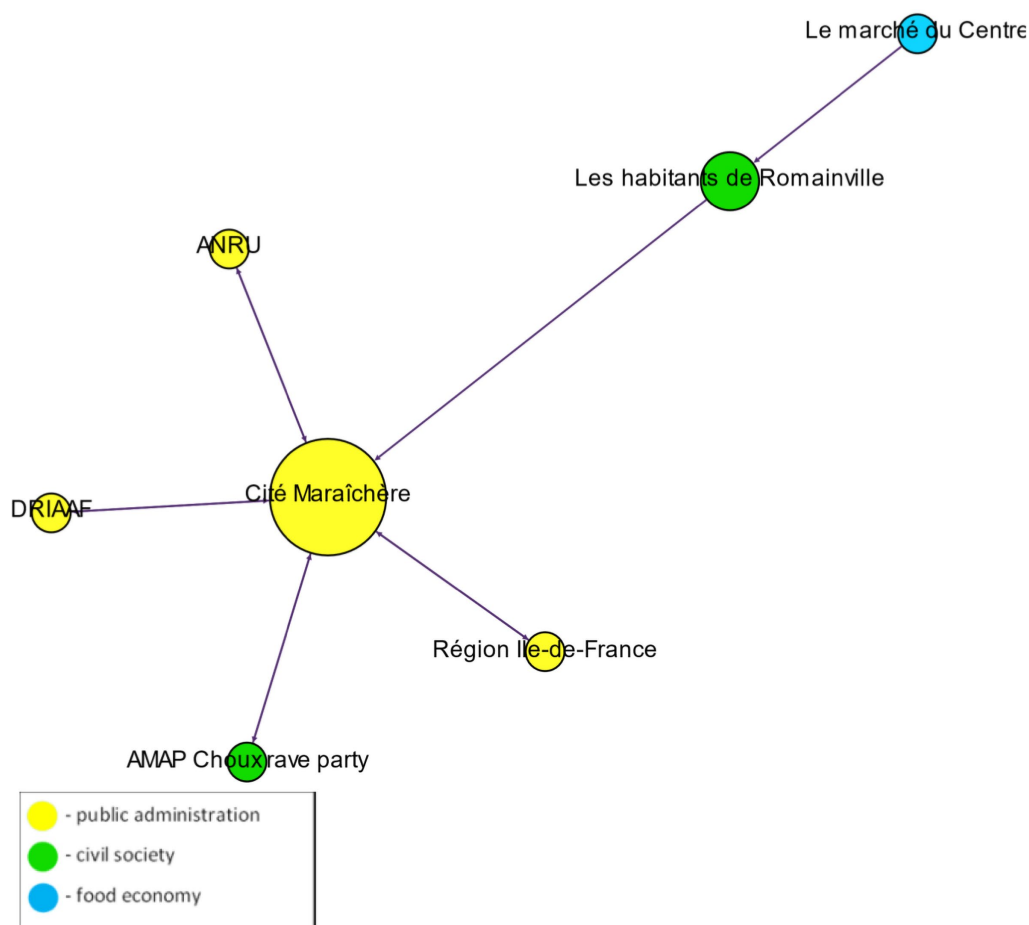


FIGURE 9

Net-Map of hindering relationships of the relevant actors of all three actor groups, food economy (blue), civil society (green), and public administration (yellow), in the CRFS in Romainville. All ties depicted. Node size according to degree centrality. Node color intensity according to betweenness centrality. The direction of the arrow indicates the direction of the relationship, as well as one-sided or two-sided relationships. (ILS/FoodE).

4.3 Practical uses of the tool in policy making

The CRFS approach is designed not only to ameliorate the food system within urban locales but also to extend its impact into neighboring rural regions. This approach carefully considers various pivotal facets, including infrastructure, logistics, public procurement, licensing, and land-use planning. Equally crucial is the active engagement of governmental bodies at different levels alongside participants from civil society and the private sector (RUAF, 2017).

To gain a comprehensive understanding of the complexity of the entire food system and craft effective solutions, it is prudent to build upon existing knowledge and incorporate rural areas into the examination.

The Net-Map tool made it possible to address the complexity of CRFSs. It facilitates an all-encompassing analysis and the involvement of additional pertinent stakeholders. Consequently, it fosters a holistic strategy for enhancing food security, sustainability, and food system quality in both urban and rural settings. The results of different situations in the specific networks show that completely different actors act as key figures and that specific challenges exist. The tool is well suited for a truly deep dive into these individual structures and

for visibly presenting them in the context of each network as demanded by Brinkley et al. (2021), Christensen and O'Sullivan (2015), and Levkoe et al. (2021). It provided information on the effectiveness of existing governance structures, resource management practices, and marketing channels. Deconstructing relationships with regional and local stakeholders makes it possible to assess which resources are currently being leveraged and identify opportunities for collaboration that have yet to be explored.

This information can inform decision-making processes to transform and strengthen CRFSs as they “determine which personnel or departments are engaging in local food activities, what those activities are, and how the personnel or departments are interacting.” (Christensen & O'Sullivan, 2015, 126). All type of actors that want to implement or improve a CRFs and use SNA results as a kind of consultancy how to proceed.

In addition, the visual results can be used for discussion (Christensen and O'Sullivan, 2015) and increase motivation to drive the transformation of a CRFS. Showing processes and relationships that are already operating well or that are having less of an impact can improve the understanding the needs of each actor and actor group, resulting in increased clarity among all the actors involved and promoting appropriate developments and actions from within the

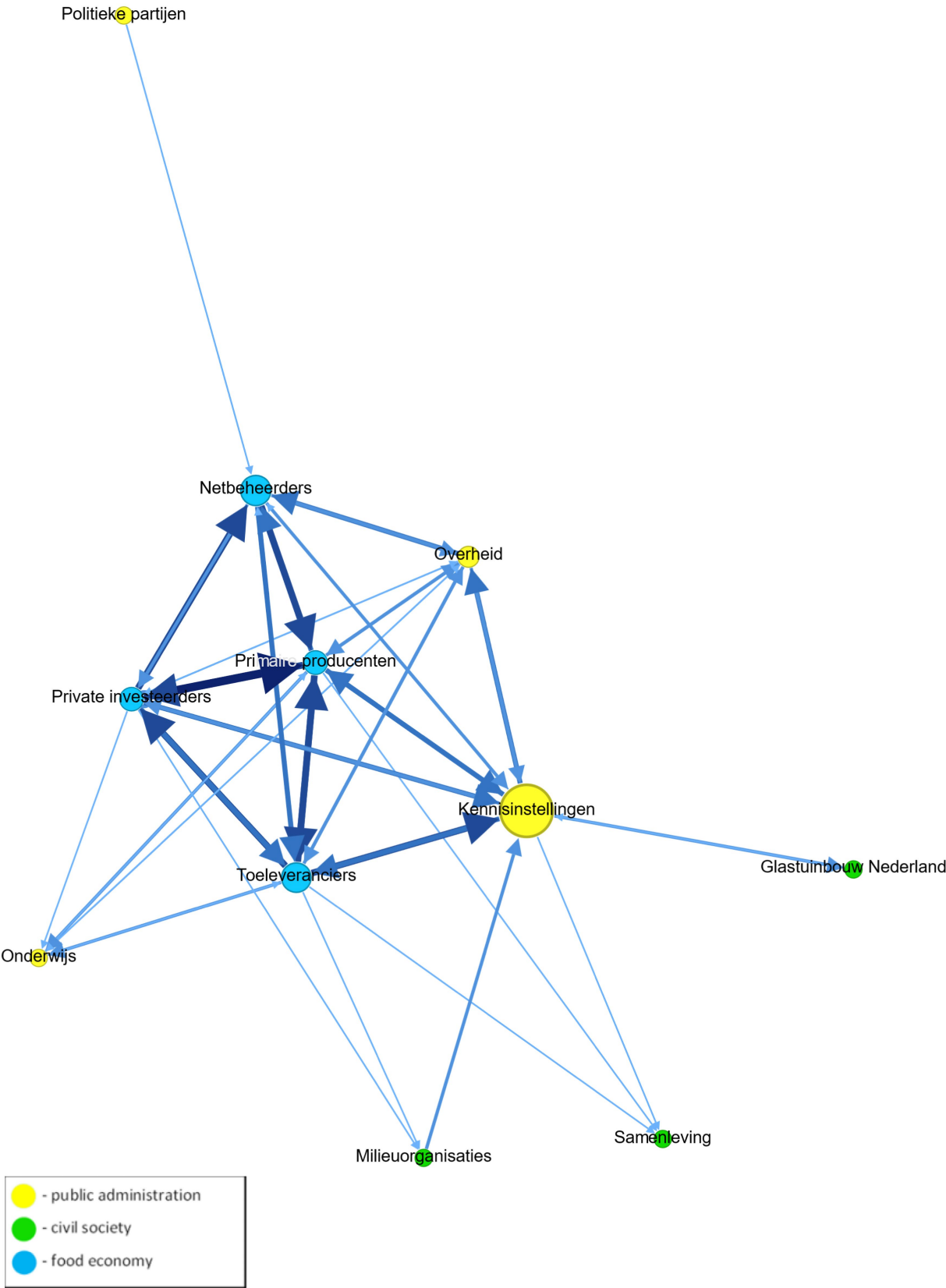


FIGURE 10
Net-Map of commercial relationships of the relevant actors of all three actor groups, food economy (blue), civil society (green), and public administration (yellow), in the CRFS in Lansingerland. All ties depicted. Node size according to degree centrality. Node color intensity according to betweenness centrality. The direction of the arrow indicates the direction of the relationship, as well as one-sided or two-sided relationships. (ILS/ FoodE).

TABLE 5 Example of a SWOT analysis generated from the Net-Map results in the Dortmund case study (ILS/FoodE).

Strengths of the stakeholder network	Weaknesses of the stakeholder network
- High level of mutual support among the actors in the network.	- Network relies in many places on personal connections
	- Lack of institutional capacity of the Food Policy Council
- Awareness among the actors active in the food system.	- No unified definition of the concept of “food system transformation”
- Events promote networking—High degree of consistency in the commitment of the actors.	- Lack of coordination—Lack of visibility
	- Lack of funding
- The Food Policy Council is seen as a key player.	- Food Policy Council wishes to be seen as a partner on an equal footing with the city administration
- Confidence in the city administration/policy—Active municipal administration—Personal active network.	- Not all actors link up with the Food Policy Council
- Actors have knowledge of each other and are partly in exchange with each other.	- Lack of overview of members still needed in the food policy council
	- Lack of time of the actors
- Potential and solutions/Opportunities of the stakeholder network.	Threats/Risks of the stakeholder network
- Strengthening the Food Policy Council in its central position.	- Network relies in many places on personal connections and could break if a main actor left the network.
- Establishment of a coordination body—Initiation of committee (public administration, civil society and food economy).	
- Platform for stakeholders to come together—Consolidation of smaller projects.	
- Strengthen the political presence of the Food Policy Council.	

network itself. This is important both for the participants themselves, who gain a better understanding of the stakeholders whom they are connected with, and for policymakers, who can implement specific policies.

The results of the Net-Map interviews can be integrated into policy debates and influence future decisions on food in the city. The network maps can motivate members of civil society to participate in the network. They can create awareness of the topic in the city, bring actor groups closer together, and offer a structured basis for further steps that can be carried out with further participatory processes on site. For this purpose, it was important in the study to present the results to the stakeholders in the CRFS network. Based on the results, further moderated discussion rounds and workshops can be used to define common goals and guide visions. On this basis, a strategy can then be developed to record the goals, plans and projects for sustainable CRFSs.

The Net-Map tool complements other tools for gathering data on food systems. For instance, the visual aspect of the maps and the involvement of various stakeholders in their development will enhance stakeholders' engagement in discussions of the current situation, in contrast to traditional long-term fieldwork techniques. While it may not introduce a significant amount of new information after extensive on-site research, this tool can contribute to the collective development of plans for change.

For a whole participatory learning process, a group discussion is helpful, or at the presentation with a final discussion of the Net-Maps in each case study with all relevant actors. The case of the city of Dortmund showed that the group discussion had an effective impact on further solutions and local participants.

The results are very specific to each CRFS and offer the possibility of addressing individual factors and specific situations of networks in both geographical and socioeconomic contexts in the CRFS. This is particularly advantageous for the complexity of food systems and the diversity of urban structures in Europe. The tool shows highly transferable implementation for the analysis of CRFSs in different contexts. As it can be implemented so flexibly, this article will serve as inspiration to show the usefulness of analyzing CRFS networks in their specific contexts to determine the gaps and potential improvements and to develop sustainable CRFSs.

5 Conclusion

Local actors with their relationships, dynamics, roles, and motivations hidden within the operating network are the drivers of the transformation of CRFSs. To uncover this information, identify barriers and potential improvements, and develop solutions on this basis, it is essential to make the network visible. This is made possible

through the Net-Map tool, with learning processes for both local actors and researchers, generating visualizations of relationships, roles, influences, and motivations within the network and capturing individual perceptions through qualitative interviews. The tool therefore overcomes limitations of existing SNA of food systems.

The research demonstrates the relevance of using the Net-Map tool to understand local food networks, allowing local actors to be seen and understood, promoting mutual understanding among them and providing visibility into the dynamics of their operation. Equipped with this knowledge, actors in these networks can better connect, particularly when facing similar situations. Additionally, local city administrations can gain a better understanding of how to approach the topic of food within the city by integrating economic and civil actors with knowledge of how best to engage and support them and what their needs are.

As the study only presents a snapshot of the CRFS networks at a certain point of time, future research may conduct longitudinal social network to understand changes in actors' constellations and shifts in their relations (Christensen and O'Sullivan, 2015; Brinkley et al., 2021). The evaluation of these results could show the actors the extent to which the stabilization of the goals has progressed and what has changed in the network structures over time.

Furthermore, in addition to evaluating the availability and accessibility of resources such as land, water, seeds, and financial support for farmers, future research could analyze the transport infrastructure for food distribution from rural to urban centers as well as food processing and distribution mechanisms. An additional salient aspect is the potential challenges and opportunities associated with social integration and the engagement of rural communities in decision-making processes and initiatives aimed at enhancing the food system. The Net-Map Tool could be a valuable visualization tool for illuminating these aspects and in this way advance the transformation of urban food systems into sustainable and resilient CRFS.

Data availability statement

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

Author contributions

ML: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Resources, Validation, Visualization, Writing – original draft, Writing – review & editing. KS: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Project administration, Resources, Supervision, Validation, Writing – review & editing, Funding acquisition, Writing – original draft. BS: Conceptualization, Data curation, Methodology, Supervision, Writing – review & editing, Writing – original draft. AW: Conceptualization, Investigation, Writing – review & editing, Formal analysis, Methodology. CI: Conceptualization, Writing – review & editing, Formal analysis, Investigation. RF-K: Conceptualization, Supervision, Writing

– review & editing, Funding acquisition, Project administration. A-KS: Conceptualization, Visualization, Writing – review & editing. FM: Conceptualization, Writing – review & editing, Formal analysis, Investigation. AS: Conceptualization, Writing – review & editing, Formal analysis, Investigation. GM: Conceptualization, Writing – review & editing, Formal analysis, Investigation. LR-D: Conceptualization, Writing – review & editing, Formal analysis, Investigation. AC: Conceptualization, Writing – review & editing, Formal Analysis, Investigation. IR: Conceptualization, Writing – review & editing, Formal analysis, Investigation. MD'O: Conceptualization, Writing – review & editing, Formal analysis, Investigation. JR: Conceptualization, Writing – review & editing, Formal analysis, Investigation. SA: Conceptualization, Data curation, Writing – review & editing. JP-F: Conceptualization, Data curation, Writing – review & editing, Investigation.

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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.

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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.2024.1315399/full#supplementary-material>

References

- Baldy, J., Eckardt, T., and Kruse, S. (2020). "Wie lassen sich Beteiligungsprozesse organisieren, um eine nachhaltige Gestaltung des kommunalen Ernährungssystems zu befördern?" DStGBDokumentation (153), pp. 18–19. Available at: <https://d-nb.info/120525692X/34> (Accessed January 1, 2022).
- Baldy, J., and Kruse, S. (2019). Food democracy from the top down? State-driven participation processes for local food system transformations towards sustainability. *Politics Govern.* 7:2019. doi: 10.17645/pag.v7i4.2089
- Bassarab, K., Clark, J. K., Santo, R., and Palmer, A. (2019). Finding our way to food democracy: Lessons from US food policy council governance. *Politics Govern.* 7, 32–47. doi: 10.17645/pag.v7i4.2092
- Biel, R. (2016). "Sustainable Food Systems. The Role of the City." London: UCL Press
- Blay-Palmer, A., Santini, G., Dubbeling, M., Renting, H., Taguchi, M., and Giordano, T. (2018). Validating the City region food system approach: enacting inclusive, Transformational City region food systems. *Sustain. For.* 10:1680. doi: 10.3390/su10051680
- Borgatti, S. P., Mehra, A., Brass, D. J., and Labianca, G. (2018). Network analysis in the social sciences. *Science* 323, 892–895. doi: 10.1126/science.1165821
- Brinkley, C., Manser, G. M., and Pesci, S. (2021). Growing pains in local food systems: a longitudinal social network analysis on local food marketing in Baltimore County, Maryland and Chester County, Pennsylvania. *Agric. Hum. Values* 38, 911–927. doi: 10.1007/s10460-021-10199-w
- Bruce, A., Jackson, C., and Lamprinoupolou, C. (2021). Social networks and farming resilience. *Outlook Agri.* 50, 196–205. doi: 10.1177/0030727020984812
- Carey, J., and Cook, B. (2021). "The Milan Urban Food Policy Pact monitoring framework." Available at: <https://www.fao.org/3/cb4181en/cb4181en.pdf> (Accessed December 7, 2023).
- Cassaniti, J. (2021). Influence networks relating to health knowledge among Nairobi's Micro-retailers and their clients. *EJMKM* 18, 302–324. doi: 10.34190/ejkm.18.3.2068
- Cherven, K. (2015). "Mastering Gephi network visualization: produce advanced network graphs in Gephi and gain valuable insights into your network datasets." Birmingham. Available at: <https://learning.oreilly.com/library/view/mastering-gephi-network/9781783987344/ch01s02.html> (Accessed October 30, 2022).
- Christensen, L. O., and O'Sullivan, R. (2015). Using social network analysis to measure changes in regional food systems collaboration: a methodological framework. *J. Agric. Food Syst. Commun. Dev.* 5, 113–129. doi: 10.5304/jafscd.2015.053.013
- Clapp, J. (2015). Distant agricultural landscapes. *Sustain. Sci.* 10, 305–316. doi: 10.1007/s11625-014-0278-0
- David, S., and Heine, S. (2019). "Nachhaltige Stadtentwicklung über kommunale Ernährungssysteme: Marktakteursnetzwerke als Ansatzpunkte zur Gestaltung und Steuerung," *Zeitschrift für Wirtschaftsgeographie*, 63, 1–22. doi: 10.1515/zfw-2018-0024
- Doernberg, A., Horn, P., Zasada, I., and Piorr, A. (2019). Urban food policies in German city regions: an overview of key players and policy instruments. *Food Policy* 89:101782. doi: 10.1016/j.foodpol.2019.101782
- EIT Food (2020). "EcoFoodMap Leuven mapping the food system in and around Leuven." Available at: <https://www.eitfood.eu/projects/ecofoodmap-leuven-mapping-the-food-system-in-and-around-leuven>
- FAO (2022). "The CRFS approach | Food for the cities programme | Food and Agriculture Organization of the United Nations." Available at <https://www.fao.org/in-action/food-for-cities-programme/overview/crfs/en/> (Accessed November 28, 2022).
- Feagan, R. (2007). The place of food: mapping out the 'local' in local food systems. *Progress Hum. Geography* 31, 23–42. doi: 10.1177/0309132507073527
- Flick, U. (2021). Qualitative Sozialforschung. Eine Einführung. 10. Auflage, Originalausgabe. Reinbek bei Hamburg: rowohlt's enzyklopädie im Rowohlt Taschenbuch Verlag (Rowohlt's Enzyklopädie, 55694).
- Freedman, D. A., and Bess, K. D. (2011). Food systems change and the environment: local and global connections. *Am. J. Commun. Psychol.* 47, 397–409. doi: 10.1007/s10464-010-9392-z
- Fuhse, J. (2018). "Soziale Netzwerke. Konzepte und Forschungsmethoden." 2., überarbeitete Auflage. Konstanz, München: UVK Verlagsgesellschaft mbH; UVK/Lucius (UTB Sozialwissenschaften, 4563). Available at <http://www.blickinsbuch.de/item/5e5a-aa998e5cd8cc3bdd31c1e69cad6a> (Accessed November 11, 2022).
- Gephi (2022). "Gephi—The Open Graph Viz Platform." Available at: <https://gephi.org/> (Accessed October 30, 2022).
- Hauck, J. (2012). "Between Intuition and Indicators—Using Net-Map for Visual and Qualitative Social Network Analysis." doi: 10.14361/transcript.9783839419274.231
- Heuser, A., Pohl, C., Urhahn, J., and Buron, S. (2017). "Unser Essen Mitgestalten. Ein Handbuch zum Ernährungsrat." Berlin: INKOTA-netzwerk e.V.
- IPBES (2019). "Global assessment report on biodiversity and ecosystem services of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (Version 1)." Zenodo.
- Jacomy, M., Venturini, T., Heymann, S., and Bastian, M. (2014). ForceAtlas2, a continuous graph layout algorithm for handy network visualization designed for the Gephi software. *PLoS One* 9:e98679. doi: 10.1371/journal.pone.0098679
- Kropp, C., and Da Ros, C. (2021). "Alternative Food Politics." (eds.) I Antoni-Komar and C Cropp, Sage, C. doi: 10.4324/9781003131304-4.
- Kuckartz, U. (2014). *Mixed Methods. Methodologie, Forschungsdesigns und Analyseverfahren* Wiesbaden: Springer Fachmedien Wiesbaden.
- Küsters, I. (2009). "Narrative Interviews: Grundlagen und Anwendungen" 2. Aufl. Wiesbaden: VS, Verlag für Sozialwissenschaften (Lehrbuch)
- Lelong, B. (2015). "Durchsetzungsprozesse in der Stadtentwicklungspolitik." Wiesbaden: Springer Fachmedien Wiesbaden
- Lelong, B., Stark, M., Hauck, J., Leuenberger, T., and Thronicker, I. (2016). "A visual network perspective on social interaction and space: using net-map and wennmaker in participatory social-spatial research." *Europa Regional* 23.2015, pp. 5–19. Available at <https://nbn-resolving.org/urn:nbn:de:0168-ssoar-51684-3> (Accessed October 15, 2022).
- Levkoe, C. Z., Schiff, R., Arnold, K., Wilkinson, A., and Kerk, K. (2021). Mapping food policy groups: understanding cross-sectoral network building through social network analysis. *Canad. Food Stud. Rev.* 8, 48–79. doi: 10.15353/cfs-rcea.v8i2.443
- Li, Y., Si, Z., Miao, Y., and Zhou, L. (2022). How does the concept of Guanxi-circle contribute to community building in alternative food networks? Six case studies from China. *Behav. Sci.* 12:432. doi: 10.3390/bs12110432
- Lohest, F., Bauler, T., Sureau, S., van Mol, J., and Achten, W. M. J. (2019). Linking food democracy and sustainability on the ground: learnings from the study of three alternative food networks in Brussels. *Politics Govern.* 7, 21–31. doi: 10.17645/pag.v7i4.2023
- Mastronardi, L., Marino, D., Giaccio, V., Giannelli, A., Palmieri, M., and Mazzocchi, G. (2019). Analyzing alternative food networks sustainability in Italy: a proposal for an assessment framework. *Agric. Econ.* 7:21. doi: 10.1186/s40100-019-0142-8
- Michel, S., Wiek, A., Bloemert, L., Bornemann, B., Granchamp, L., Villet, C., et al. (2022). Opportunities and challenges of food policy councils in pursuit of food system sustainability and food democracy—a comparative case study from the upper-Rhine region. *Front. Sustain. Food Syst.* 6:916178. doi: 10.3389/fsufs.2022.916178
- Milan Urban Food Policy Pact (ed.) (2021). "Milan Urban Food Policy Pact." Available at <https://www.milanurbanfoodpolicypact.org/>, updated on 7/19/2021 (Accessed November 30, 2022).
- Morgan, K. (2015). Nourishing the city: the rise of the urban food question in the global north. *Urban Stud.* 52, 1379–1394. doi: 10.1177/0042098014534902
- Mural (ed.) (2022). "Work better. Work anywhere." Available at: <https://www.mural.co/> (Accessed October 1, 2023).
- Reed, M., Graves, A. R., Dandy, N., Posthumus, H., Klaus, H., Morris, J., et al. (2009). Whos In and Why? a typology of stakeholder analysis methods for natural resource management. *Journal of Environmental Management.* 90, 1933–49. doi: 10.1016/j.jenvman.2009.01.001
- RUAF (2017). *City region food systems. Waht and why.* Available at: <https://ruaf.org/document/city-region-food-systems-what-and-why/>
- Sattler, C., Rommel, J., Chen, C., García-Llorente, M., Gutiérrez-Briceño, I., Prager, K., et al. (2022). Participatory research in times of COVID-19 and beyond: adjusting your methodological toolkits. *One Earth* 5, 62–73. doi: 10.1016/j.oneear.2021.12.006
- Sämel, I., Reddy, S., Wachtel, T., Schlecht, M., and Ramos-Jiliberto, R. (2022). How to feed the cities? Co-creating inclusive, healthy and sustainable city region food systems. *Front. Sustain. Food Syst.* 6:909899. doi: 10.3389/fsufs.2022.909899
- Schanz, H., Pregering, M., and Kruse, S. (2020). "Warum sollten sich Kommunen mit dem Thema Ernährungsräte beschäftigen? Umfassende Nachhaltigkeits- und Stadtentwicklung." DStGB Dokumentation (153), 8–9. Available at: https://www.dstgb.de/aktuelles/archiv/archiv-2020/Kommunen%20gestalten%20Ern%C3%A4hrung/Doku_153_FINAL_Web.pdf?cid=5yr (Accessed March 8, 2022).
- Schiffer, E. (2007). "Net-Map toolbox: Influence Mapping of Social Networks." Available at: https://netmap.files.wordpress.com/2008/04/netmap_manual.pdf
- Schiffer, E., and Hauck, J. (2010). Net-map: collecting social network data and facilitating network learning through participatory influence network mapping. *Field Methods* 22, 231–249. doi: 10.1177/1525822X10374798
- Schmied, D. (2018). *Nahrungsgeographie. Druck A1.* Braunschweig: Westermann (Das geographische Seminar). Online available at: <https://elibrary.utb.de/doi/book/10.5555/9783141603866>.
- Schröter, B. (2022a). "Workshop 2: Einführung in die Net-Map-Methode." Workshop zur Net-Map-Methode. Zoom (online). Accessed September 9, 2022.
- Schröter, B. (2022b). "Workshop 2: Einführung in die Visualisierungstechniken." Workshop zur Net-Map-Methode. Zoom (online). Accessed October 10, 2022.

- Schönhuth, M., Gamper, M., Kronenwett, M., and Stark, M. (2013). *Visuelle Netzwerkforschung: Qualitative, quantitative und partizipative Zugänge*, Bielefeld: transcript Verlag. doi: 10.1515/transcript.9783839422571
- Schröter, B., Sattler, C., Graef, F., Chen, C., Delgadillo, E., Hackenberg, I., et al. (2018). Strengths and weaknesses of the Net-Map tool for participatory social network analysis in resource management: experience from case studies conducted on four continents, in *Methodological Innovations* 11, 205979911878775. doi: 10.1177/2059799118787754
- Sipple, D., and Schanz, H. (2019). “Nachhaltige Stadtentwicklung über kommunale Ernährungssysteme: Marktakteursnetzwerke als Ansatzpunkte zur Gestaltung und Steuerung” *Zeitschrift für Wirtschaftsgeographie*, 63, 1–22.
- Steinbrink, M., Zigmann, F., Ehebrecht, D., Westholt, F., Schmidt, Jan-B., Stockmann, A., et al. (2012). Netzwerk(analys)e in der deutschen Humangeographie *Berichte zur deutschen Landeskunde* 86, 309–358.
- Sonnino, R., and Marsden, T. (2006). Beyond the divide: rethinking relationships between alternative and conventional food networks in Europe. *Journal of Economic Geography*, 6, 181–199, doi: 10.1093/jeg/lbi006
- Trivette, S. (2019). The importance of food retailers: applying network analysis techniques to the study of local food systems. *Agric. Hum. Values* 36, 77–90. doi: 10.1007/s10460-018-9885-1
- Tucci, G. (2020). “From the global food system to the local dimension: the urban food strategies” (eds.) J. Schröder, E. Sommariva and S. Sposito. Hannover: Gottfried Wilhelm Leibniz Universität Hannover
- UBA—Umweltbundesamt (2019). “Transformation des Ernährungssystems: Grundlagen und Perspektiven”. Texte 84/2019, Dessau-Roßlau: Umweltbundesamt. Available at: <https://www.umweltbundesamt.de/publikationen/transformation-des-ernaehrungssystems-grundlagen>
- Wissmann, A., Iodice, C., Leimkühler, M., Specht, K., Fox-Kämper, R., Amghar, S., et al. (2023). FoodE deliverable 6.2 analysis of the roles and relationships of different actors in the food chain.



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Home food gardening in modern cities: advances, issues, and future perspectives

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Against the backdrop of the unexpected COVID-19 epidemic, governments are facing significant challenges in mobilizing food resources, particularly fresh products. It is inevitable that there will be intermittent shortages of food during the pandemic. As a result, home food gardening has gained considerable attention from city residents and policymakers in modern cities. This is due to its potential to provide food during humanitarian emergencies and lockdown. Moreover, home food gardening is increasingly becoming a popular recreational activity in many countries, offering therapeutic benefits such as fostering social bonds through knowledge-sharing and fruit-sharing, improving mental and psychological well-being, promoting outdoor physical exercise, and strengthening the connection between humans and nature. This review provides a comprehensive summary of the latest advancements in home food gardening, including cultivated species, devices, technologies, and current issues. It also proposes perspectives based on current researches to serve as a reference for future research and development.

KEYWORDS

home food gardening, urban agriculture, self-provisioning, COVID-19, horticulture

1 Introduction

The 21st century is characterized by rapid urbanization (Lal, 2020). While urban development brings benefits, it also poses certain challenges. At present, agricultural production ability is becoming increasingly vulnerable due to diminishing availability of productive land in a majority of highly urbanized regions in China over the past two to three decades (Li et al., 2023). It is projected that by 2030, two-thirds of the world's population (about 5 billion people) will be living in urban areas, and this proportion is expected to increase to approximately 68% (about 6.7 billion people) by 2050 (Lal, 2020; Richardson and Arlotta, 2022). Fresh products, which refer to unprocessed or minimally processed fruits and vegetables, play a crucial role in human diets as they are rich in dietary fibers, essential minerals, and vitamins (Romero et al., 2022; Zhang et al., 2023). With the ongoing urbanization and unprecedented demographic pressure in cities, the availability of fresh products in urban areas heavily relies on peri-urban and adjacent rural areas, as well as external supply chains. This trend is observed globally (Zasada et al., 2019; Diehl et al., 2020; Dorr et al., 2023; Li et al., 2023).

Home food gardening (HFG), also known as residential food gardening or household food gardening, involves creating small-scale farms and growing edible or medicinal plants with some decorative value in private residential backyards, front yards, balconies, kitchen windowsills, bay windows, patios, terraces, rooftops, and other marginal lands next to a dwellings. Actually, HFG is a kind of small-scale farming implemented within the urban areas or rural areas, and its products are mainly used for self-consumption rather than for profit. Additionally, there is a cross relationship between HFG and indoor farming, because HFG can be carried out indoors (e.g., kitchen windowsills, and bay windows) or in open spaces (e.g., backyards, and rooftops) (Ghosh, 2014; Degefa et al., 2021; Mullins et al., 2021; Hong and Zimmerer, 2022; Richardson and Arlotta, 2022; Baliki et al., 2023; Cruz et al., 2023; Ma et al., 2023; Ezzeddin et al., 2024).

In the early colonial periods of the New World, carrying out HFG to supply the home diet was a requisite of life for most colonizers (Burgin, 2015). Even today, in developing countries like Bangladesh, Cambodia, Indonesia, Rwanda, Sri Lanka, and Tanzania, the availability of daily food *per capita* is below international health standards, HFG is still of great necessity (Thamilini et al., 2019; Baliki et al., 2022; Depenbusch et al., 2022; Ichinose et al., 2023; Issahaku et al., 2023; Suwardi et al., 2023).

Against the background of global city densification as well as geopolitical tensions currently, HFG has the latent capacity to be an effectual nature-based solution for mitigating food security issues (Lal, 2020; Li et al., 2023).

The COVID-19 pandemic is one global public health emergency that poses mass hospitalization and the death of countless people (Marques et al., 2021; Wu et al., 2022). Since the outbreak of COVID-19, in an attempt to effectively suppress the dissemination of the highly contagious coronavirus, on a global scale, most governments have implemented strict epidemic prevention policies, for instance, imposing longstanding mobility restrictions and social distancing measures (Erokhin and Gao, 2020; Laborde et al., 2020; Basu et al., 2021; Cerda et al., 2022; Godrich et al., 2022; Turnšek et al., 2022). However, these containment countermeasures have had a significant impact on the social life of citizens, causing a great deal of discomfort. Furthermore, they have exposed the fragility of food supply chains and highlighted the shortcomings of long food mileage in urban and urbanizing areas, thereby profoundly derailing civic sustenance availability worldwide (Erokhin and Gao, 2020; Laborde et al., 2020; Basu et al., 2021; Cerda et al., 2022; Godrich et al., 2022; Turnšek et al., 2022). Especially in populous cities, the availability of fresh and nutritious vegetables has become a major concern for urban inhabitants, especially those belonging to marginalized and mid- to low-income populations (Theodorou et al., 2021; Baliki et al., 2023; Ma et al., 2023). The precarious or totally disrupted food supply chains caused huge panic among urban denizens, stimulating them to empty municipal grocery stores or supermarket shelves in proximity (Cattivelli, 2022). Consequently, fresh food supplies frequently fell short of meeting local demands, which in turn led to triggering price boom and worsened the challenges of unequal access and distribution of fresh products among vulnerable groups amid the strain of the COVID-19 pandemic (Cattivelli, 2022).

The unexpected epidemic brought HFG to the public's attention (Music et al., 2022). Numerous urban residents and policymakers

are deeply aware of the significance and necessity of self-sufficiency of inexpensive sources of high quality and nutritious produce in closed urban residential areas for emergencies (Aditya and Zakiah, 2022; Cattivelli, 2022; Turnšek et al., 2022; Baliki et al., 2023; Perez-Lugones et al., 2023). Within this crisis, peoples' interest and participation in HFG that is lack of focus prior to the COVID-19 pandemic has substantially enhanced, making HFG are becoming trendy on residential compounds and apartment blocks in many countries or territories like China, American, Indonesia, Canada, Slovenia, Norway, Estonia, Switzerland, Iceland and others (Mullins et al., 2021; Aditya and Zakiah, 2022; Kim et al., 2022; Music et al., 2022; Turnšek et al., 2022; Ma et al., 2023; Perez-Lugones et al., 2023). A survey showed that 17.4% of respondents in Canada and the United States started carrying out HFG in 2020 during COVID-19 pandemic (Mullins et al., 2021). Another study in Europe revealed that an approximately 10% increase in HFG during COVID-19 pandemic in the sample population (Turnšek et al., 2022). As a result, there has been an exponential increase (in some cases up to 450%) in the demand for gardening products related to HFG, including seeds, pots, trowels, pruning shears, trellis, yellow sticky traps, sprinklers, garden gloves, fertilizers, and substrates (Mullins et al., 2021). Additionally, sales of handbooks on this subject have also seen a significant boost (Mullins et al., 2021). Notably, a significant portion of these escalating orders came from novices on gardening, interestingly, mainly Millennials, while the remaining portion has been from growers with revival in interest in HFG (Mullins et al., 2021).

In actuality, HFG effectively reduces "food miles", decreases the demand for logistics processes, conserves more fossil fuels, lowers transportation emissions, minimizes perishable food losses during transportation, contributes to a partial improvement of food sovereignty, and tackles starvation and malnutrition caused by delays in long-distance fresh products transportation owing to a pandemic and other forms of traffic congestion or major disruption (Richardson and Arlotta, 2022; Li et al., 2023; Ma et al., 2023).

In addition to serving as a means of self-provisioning food during initial pandemic-related home confinement or other similar special periods (such as wars and geological disasters), HFG also holds significant social relevance (Larder et al., 2014). Participating in HFG enables urban dwellers to forge stronger social connections with their neighbors, thereby increasing the cohesion of gated communities. This is achieved through the distribution or bartering of excess homegrown fresh food. Additionally, individuals engaging in HFG experience direct pleasure and find relief from mental or psychological health problems through the cultivation process (Machida, 2019; Diekmann et al., 2020; Corley et al., 2021; Mullins et al., 2021; Cerda et al., 2022; Sia et al., 2022, 2023). In reality, HFG has an irreplaceable role in horticultural therapy. Engaging in HFG, for instance, can effectively alleviate loneliness, bolster mental resilience, and cultivate tranquility to reduce the incidence of depression and anxiety for the elderly who adore horticulture but lost their arable patches in emigration or urban sprawl, as well as substantial contemporary young white-collar workers with extremely fast-paced lives and chronically high-pressure jobs but do not have access to affordable pastime in densely populated metropolitan areas (Abass et al., 2018; Burgin, 2018).

Gaining delight and achieving sense of accomplishment via growing horticultural crops for aesthetic purposes, helping parents educate their children about agricultural production and bridge the

Abbreviations: Bt, *Bacillus thuringiensis*; EM, effective microorganism; HFG, home food gardening; IoT, internet of things; WBEEP, whole-body edible and elite plant.

gap between kids and nature, as well as harvesting edible horticultural crops for domestic consumption are the prime motivator to engagement in HFG before, during, and after the COVID-19 pandemic (Taylor et al., 2017; Diekmann et al., 2020; Lal, 2020; Chalmin-Pui et al., 2021; Perez-Lugones et al., 2023). A varied and colorful home garden decorated with various vegetables and fruits may be turning into a common sight in the future (Santos et al., 2022). In addition, from an ecological perspective, HFG can lessen the impact of heat islands, ameliorate residential microclimate, as well as contribute to conservation and maintenance of diversity of plants with local characteristics (Furlan et al., 2017; Saroinsong et al., 2021; Hong and Zimmerer, 2022; Patel et al., 2022; Humaida et al., 2023; Korpelainen, 2023; Visvanathan et al., 2023).

The primary focus of this review is to gather and discuss the most recent reports on the developments and problems related to HFG found in the scientific literature. It also suggests viewpoints based on the state of the field in order to serve as a guide for future HFG research and development.

2 Advances

2.1 Cultivated species for HFG

In comparison to seeds grown in farmlands, seeds grown in home gardens should exhibit greater in variety, be easier to cultivate, adapt well to residential environments (e.g., tolerate urban heat), wrapped in smaller packages, and not require large spaces (Richardson and Arlotta, 2022; Cruz et al., 2023). Urban farmers who are disconnected from the land often turn to the Internet for advice on cultivating plants. As a result, many content creators and Internet celebrities who are knowledgeable about HFG (HFG-savvy) share their extensive experience and suggestions through various social media platforms such as YouTube, Bilibili, TikTok, RED, Twitter, and Facebook. These HFG-related works cover a wide range of edible plants, including root vegetables and crops (e.g., onion, turnip, radish, potato, sweet potato, carrot, and ginger), liana and fruit vegetables (e.g., melon, watermelon, cucumber, tomato, eggplant, chili pepper, and Japanese pumpkin), leafy vegetables (e.g., basil, rosemary, thyme, coriander, romaine lettuce, spinach, water spinach, cabbage, savoy, kale, garlic seedling, spring onion, Chinese chive, and scallion), sprouts (e.g., mung bean sprout, soybean sprout, pea sprout, and broccoli sprout), berry fruits (e.g., strawberry, blueberry, and raspberry), and citrus fruits (e.g., kumquat and lemon).

Additionally, the selection of HFG varieties depends on climates, seasons, available spaces and other conditions (Baliki et al., 2023; Cruz et al., 2023). For instance, some heat-tolerant vegetables like water spinach (*Ipomoea aquatica* Forssk.) (Khosa et al., 2023), and okra (*Abelmoschus esculentus* L.) (Khan et al., 2022), can be cultivated during summer. During winter, hardy vegetables like spinach (*Spinacia oleracea* L.) (Yoon et al., 2017), and Chinese chive (*Allium tuberosum* Rottl. ex Spr.) (Wang et al., 2024) can be selected. In places with insufficient lighting, such as low-rise balconies, poor-light-tolerant vegetables such as Chinese chive (*Allium tuberosum* Rottl. ex Spr.) (Wang et al., 2024), and various sprouts are more appropriate for HFG (Le et al., 2021).

More than 100 edible plant taxa from 25 families which is suitable for HFG were identified previously (Taylor et al., 2017; Boneta et al.,

2019; Thamilini et al., 2019; Suwardi et al., 2023). In the following text, we will provide detailed introductions for a selected subset of these plants.

2.1.1 Potato

Potato (*Solanum tuberosum* L.) is considered one of the ideal staple foods for HFG due to its numerous merits. These include: (1) high harvest index, (2) high tuber production, (3) starchy tubers providing ample nourishment, (4) uncomplicated cultivation requirements, (5) adaptability to environmental stresses and low soil fertility, (6) relatively long shelf life, (7) simple food processing demands, and (8) asexual propagation through tubers for steady nutritional component regeneration (Wiersema and Booth, 1987; Coffin et al., 1993; Boivin et al., 2020; Devaux et al., 2021; Liu et al., 2021). Domestic potted potatoes are shown in Figure 1.

Potato is an important food security crop and has long been regarded as a “super food” (Devaux et al., 2021). In the science fiction film “The Martian”, the protagonist, an astronaut and botanist played by Matt Damon, grows potatoes to survive on Mars. This fictional scenario is now becoming a potential reality. Chinese scientists have been dedicated to biotechnological advancements in space agriculture and have proposed the Whole-Body Edible and Elite Plant (WBEEP) strategy for potato improvement. This strategy aims to address the inherent problem of toxic solanine in potato plants, specifically in the aerial portions such as stems, leaves, and berries, which are currently inedible (Liu et al., 2021). On the basis of genetic modification that can block the biosynthesis of solanine, the WBEEP-potatoes, whose whole bodies are edible, might be created in the future and subsequently applied in HFG.

2.1.2 Tomato

Tomato (*Solanum lycopersicum* L.), a staple of Italian and Latino cuisines, enriched with essential nutrients and bioactive antioxidant compounds, has become a worldwide vegetable (or fruit, as some insist) (Perveen et al., 2015). Statistically, in the United States, among all HFG vegetables, tomato is the most popular one (Cruz et al., 2023). Non-miniature tomatoes with indeterminate growth characteristics require the application of plant growth regulators (e.g., paclobutrazo) to achieve compact potted plants for HFG (Melo et al., 2018; Cruz and Gómez, 2022). In comparison to non-miniature counterparts, dwarf or miniature tomatoes (Figure 2) have smaller plant canopy diameters, shorter internodes, and pedicels. These features offer several advantages, including strong resistance to lodging damage, suitability for diminutive space, and the absence of pruning requirements, which are crucial for HFG (Melo et al., 2018; Zhao et al., 2023). Several dwarf and semi-dwarf tomato varieties with well-proportioned plant architectures and eaten fruits, such as “Micro Gold” (Zhao et al., 2023), “Micro Tom” (Ke et al., 2022), “Red Robin” (Richardson and Arlotta, 2022), “Sweet ‘n’ Neat” (Richardson and Arlotta, 2022), “Terenzo” (Richardson and Arlotta, 2022), “Tiny Tim” (Richardson and Arlotta, 2022), and “Tumbler” (Richardson and Arlotta, 2022), have been developed as HFG tomato varieties. In addition, a study demonstrated that “Terenzo” and “Tumbler” achieve the highest yield, while “Micro Tom” is the least productive variety among six dwarf tomato cultivars, including “Micro Tom”, “Red Robin”, “Sweet ‘n’ Neat”, “Terenzo”, “Tiny Tim”, and “Tumbler” (Richardson and Arlotta, 2022).

2.1.3 Leafy vegetables

Leafy vegetables have a short growth cycle and are essential sources of required vitamins and minerals for human beings (Yoon



FIGURE 1
Domestic potted potatoes.

et al., 2017). Figure 3 illustrates the abundant options of leafy vegetables used for HFG. As a layperson-friendly vegetable, romaine lettuce (*Lactuca sativa* L. var. *longifolia*) grows fast and can easily be cultivated in human settlements using soil culture, substrate culture, or hydroponics (Majid et al., 2021; Noh and Jeong, 2021). A handful of leafy vegetables used for spices are also suitable for HFG, for instance, basil (*Ocimum basilicum* L.) and rosemary (*Rosmarinus officinalis* L.) (Aditya and Zakiah, 2022; Kim et al., 2022). Basil, also referred to as “more precious than gold” or “nine-storey tower” in China, is the main ingredient of Chinese cuisine such as Three Cup Chicken and Italian Pesto sauce (Tanzilli et al., 2023), and rosemary is routinely used for shish kebabs and beef steaks.

2.1.4 Sprouts

Sprouts (i.e., microgreens), a novel class of edible veggies harvested and consumed at an immature stage (Teng et al., 2023). As shown in Figure 4, with small plant sizes, sprouts are advantageous when planted in tiny balcony, kitchen windowsill or other compact places because of their better spatial efficiency (Teng et al., 2023). Additionally, sprouts are non-polluting green foods produced directly from seeds, have no intricate cultivation demands, and can be grown in soil or hydroponically in both light and dark environments (Reed et al., 2018; Le et al., 2021; Xiao et al., 2022). Healthwise, as functional edibles with anti-oxidant powerhouse credited with preventing some diseases, sprouts deliver richer nutrition than seeds, since they contain high levels of carbohydrates, dietary fibers, amino acids and health-beneficial metabolites like polyphenols (Zhang et al., 2022; Nolasco et al., 2023; Suathong et al., 2024; Zhao et al., 2024). Moreover, nutrient-rich food sprouts have been found to grow faster and can be harvested earlier compared to other vegetables. This quality makes them particularly valuable during times of major disruptions in the

fresh product supply chain, as they effectively ensure the intake of required vitamins (Reed et al., 2018; Zhang et al., 2022). Hence, sprouts have captured more attention from HFG hobbyists with health consciousness (Supapvanich et al., 2019; Gilbert et al., 2023).

Traditional legume seed sprouts, such as pea sprouts (*Pisum sativum* L.), are widely consumed and highly popular in various regions around the world. They are particularly favored in Southwest China, including Sichuan Province and Guizhou Province, as well as in several Asian countries like Japan, Korea, and Thailand. This popularity can be attributed to their desirable qualities, including crispness, tenderness, fresh fragrance, and significant nutritional value (Lin et al., 2023; Suathong et al., 2024). In recent years, plentiful novel sprouts with functions differed from legume seed sprouts are emerging, such as the broccoli sprouts rich in glucosinolates and sulforaphane (Guo et al., 2016), the coriander sprouts rich in phyloquinone and tocopherols (Rajan et al., 2019), and the rapeseed sprouts rich in glucosinolates and selenium (Xiao et al., 2022), the presence of these sprouts greatly expands the choices for HFG, and provides urbanite with more comprehensive nutrition.

2.1.5 Strawberry

Fruits are an important component of the human daily diet, but HFG fruits available are obviously few compared with vegetables. Strawberry (*Fragaria × ananassa* Duch.), a perennial herb, cultivated worldwide due to the vibrant color, fragrant flavor, succulence, distinctive sweetness, high nutritional value (e.g., rich in minerals, vitamins, anthocyanins, carotenoids, and polyphenols) and health benefits, is ideally suited for HFG owing to their small size and relatively lower light requirements (Tulipani et al., 2011; Battino et al., 2021; Hardigan et al., 2021; Martín-Pizarro et al., 2021; Wang et al., 2022; Avendaño-Abarca et al., 2023; Zheng et al., 2023; Liu et al.,



FIGURE 2
Domestic potted dwarf tomatoes.

2024). Domestic potted strawberry cultivation is shown in Figures 5A,B. The trend of HFG opens a novel dimension to strawberry cultivation (Olbricht et al., 2014). Besides common white-flowered strawberries, there are also red-flowered and pink-flowered varieties that have been developed through distant hybridization (*Fragaria* × *Potentilla*), which have gained popularity among urban gardeners for their use in landscaping and potted viewing (Ding et al., 2019; Liu et al., 2021). A pink-flowered strawberry cultivar is shown in Figures 5C,D. As eye catchers, the red-flowered and pink-flowered strawberries with unique flower morphological characteristics (e.g., semi-double flowers in succession), diverse petal colors (i.e., covers the whole red series, flower colors range from light pink to deep red), relatively long florescence, strong ability to reproduce, edible and ornamental values are “add flowers to the brocade” for HFG, commanding a markedly higher selling price and economic value distinguished from common white-flowered strawberry varieties (Xue et al., 2016; Ding et al., 2019; Xue et al., 2019; Guan et al., 2023). Actually, there is an immense market potential for ornamental strawberries in the post-epidemic era (Guan et al., 2023).

With a history of over 60-year efforts in modern ornamental strawberry breeding, breeders have successfully developed a broad assortment of pink-flowered and red-flowered strawberry cultivars

with independent intellectual property rights (Mabberley, 2002; Khanizadeh et al., 2010; Xue et al., 2015; Ding et al., 2019; Bentvelsen and Vange, 2021; Yue et al., 2022; Guan et al., 2023). For instance, ABZ Seeds, a Dutch breeding company dedicated to the development of F1 hybrid seed-propagated strawberry cultivars, has delved into ornamental strawberry breeding and released a series of superior ornamental strawberry varieties full of aesthetic morphological attributes, such as “Summer Breeze Cherry Blossom”, “Summer Breeze Rose”, “Gasana” and “Toscana” in the market (Bentvelsen and Bouw, 2006; Bentvelsen and Vange, 2021). Table 1 provides an overview of the some institutions involved in ornamental strawberry breeding and the varieties they have developed.

2.2 Devices available for HFG

Actually, some kind of cultivation points, such as precise or appropriate fertilization, irrigation, temperature and light managements, are hard to novices of HFG. Thus, inexperienced urban gardeners require suitable equipment that is not difficult to utilize. Some novice-friendly cultivation systems, which can automatically and continuously adjust environmental conditions, including



FIGURE 3
Leafy vegetables cultivated in residences.



FIGURE 4
Self-production of sprouts at home.



FIGURE 5 Domestic potted strawberries (A) and (B), a pink-flowered strawberry cultivar (C) and (D).

photoperiod, light intensity, humidity, temperature, soil moisture level and nutrient solution irrigation. These systems help minimize environmental fluctuations and achieve precise control over the plant growth environment (Kim et al., 2022). Currently, there are four cultivation patterns of HFG, including soil culture, substrate culture, hydroponics, and aquaponics (Kyaw and Ng, 2017; Suárez-Cáceres et al., 2021; Richardson and Arlotta, 2022). In fact, almost all HFG plants can be grown in the soil and substrate. Some plants suitable for hydroponics at home and their cultivation points are shown in Table 2 (Baras, 2018). Plants suitable for hydroponic cultivation are also suitable for aquaponics.

2.2.1 Light supplementation equipment

Plant growth and development are significantly influenced by light since it has an impact on the energy metabolism of plants. Insufficient exposure to light during plant growth hinders carbon dioxide (CO₂) absorption and assimilation, which lowers photosynthetic efficiency and impacts agricultural productivity (Deng and Deng, 2018). However, a typical issue in HFG is inadequate lighting, especially on low-rise balconies where low-intensity scattered light is the norm, thus light supplementation is very important. Traditional light supplementation devices are considerably power-consuming. Daylight harvesting is a technique extensively utilized in protected agriculture, which can effectively modulate supplemental lighting been based upon sunlight (Bhuiyan and van Iersel, 2021). Some individuals interested in new things opt for high-end automated machines equipped with advanced features such as plant lighting devices with daylight harvesting capabilities. These devices have an intelligent adjustable light function that emits supplemental light

based on photosynthetic active radiation. They are particularly useful for HFG plants that are typically deprived of sunlight in balconies or other areas. For instance, a novel micro indoor smart hydroponics system, named Adpatalight, utilizes Internet of Things (IoT) technology. This system harvests ambient light by utilizing an inexpensive AS7265x IoT sensor to measure photosynthetic active radiation, resulting in a significant reduction in energy consumption (Stevens et al., 2022).

2.2.2 Substrate cultivation system

Soil-based HFG may pose a contamination risk due to urban soil, besides, low fertility, low organic matter, decreased activity and diversity of soil organisms, as well as high concentrations of stones, gravels, and artifacts are frequently found in urban soils. These elements may have a detrimental effect on horticultural crop productivity, rendering urban soils unsuitable for HFG, therefore, utilizing inert and clean substrates is an effective solution (Ercilla-Montserrat et al., 2018; Izquierdo-Díaz et al., 2023). Spanish researchers found that the output of an open-air rooftop soilless home food garden based on perlite bag culture, can achieve a high degree of self-provisioning for a two-member household (Boneta et al., 2019). Now in China, there are some substrate-based vertical system used for HFG, two of them are shown in Figure 6.

2.2.3 Hydroponic systems

The discrepancy between hydroponics and traditional cultivation is that hydroponics has no demand for plowing field and weeding, also, it can reduce even eliminate the application of pesticides, making HFG more feasible and convenient in urban settings where space is

TABLE 1 Some breeding institutions of ornamental strawberry and their bred varieties.

Breeding institutions	Varieties	References
ABZ Seeds	Florian	Bentvelsen and Vange (2021)
	Frisan	
	Gasana	
	Merlan	
	Pikan	
	Red Ruby (i.e., Feanor)	
	Roman	
	Ruby Ann	
	Summer Breeze Cherry Blossom	
	Summer Breeze Rose	
	Tarpan	
	Toscana	
	Tristan	
Agriculture and Agri-Food Canada, Horticulture Research and Development Center	Rosalyne	Khanizadeh et al. (2010)
	Roseberry	
Jiangsu Academy of Agricultural Sciences	Zijin Fenyu	Guan et al. (2023)
	Zijinhong	
Shenyang Agricultural University	Fenyun	Yue et al. (2022)
	Pink Beauty	Ding et al. (2019)
	Pink Princess	
	Pretty Beauty	
	Red Rose	Xue et al. (2015)
	Sijihong	Guan et al. (2023)
	Xiaotaohong	
University College London	Pink Panda (i.e., Frel)	Mabberley (2002)

TABLE 2 Some plants suitable for hydroponics at home and their cultivation points.

Plants	Optimum temperature (°C)			Optimum pH of nutrient solution	Optimum electrical conductivity of nutrient solution (ms/cm)
	Germination	Nutrient solution	Air		
Basil	18–24	21–24	21–27	5.5–6.0	1.8–2.3
Capsicum	24–27	18–21	24	5.5–5.8	1.4–1.8
Kale	24–30	15–24	15–33	5.5–6.5	1.2–2.3
Lettuce	15–21	18–21	18–24	5.5–6.0	1.8–2.3
Spinach	7–18	10–21	18–24	5.5–6.0	0.7–2.3
Strawberry	21	15–21	15–27	5.5–6.0	0.8–1.2
Tomato	24–27	18–24	15–24	5.5–6.0	1.2–2.5

limited (Solis-Toapanta et al., 2020; Noh and Jeong, 2021). In actuality, hydroponic systems include aeroponics, wick watering, DWC (Deep Water Culture), DFT (Deep Flow Technique), NFT (Nutrient Film Technique), and more. The wick watering system is the most basic and low-maintenance of all the hydroponic systems. Because of this, it works well for small plants like lettuces and strawberries and is therefore more appropriate for HFG. Furthermore, hydroponics combined with a vertical system can achieve higher yield of leafy vegetable production in a compact space (Rajan et al., 2019), two hydroponic systems are shown in Figure 7. In a recent development, Malaysian scientists have introduced a smart hydroponic system called SMART GROW, which utilizes Internet of Things (IoT) technology. This system offers several advantages, including minimal space requirement, cost-effectiveness, automated water level regulation, and the ability to cultivate various edible plants at home (Shin et al., 2024).



FIGURE 6
Two vertical substrate-based systems used for leafy vegetables.



FIGURE 7
Two vertical hydroponic systems used for leafy vegetables.

2.2.4 Aquaponics equipment

Aquaponics, considered as a bio-integrated system mimicking a complex ecosystem, is composed of beneficial bacteria (e.g., heterotrophic bacteria and nitrifying bacteria), recirculating aquaculture and hydroponic cultivation (Wongkiew et al., 2017). This environmentally friendly system utilizes the nitrogen in aquaculture effluent as nutrients for hydroponic plant growth. At the same time, the plants purify the water, creating a suitable environment for the culture of aquatic animals such as pearl gourami (*Trichogaster leerii*), carp (*Cyprinus carpio*), tilapia (*Oreochromis mossambicus*), catfish (*Clarias gariepinus*), and shrimp (*Litopenaeus vannamei*). By combining these elements, aquaponics effectively addresses the individual limitations of each component (Makhdom et al., 2017; Wongkiew et al., 2017; Pineda-Pineda et al., 2018; Goddek and Keesman, 2020; León-Cañedo et al., 2023). Aquaponics has gained rapid development and wide application in home food production due to its high resource utilization rate, absence of chemical fertilizers and

antibiotics, low consumption, high efficiency, and sustainability (Kyaw and Ng, 2017; Wongkiew et al., 2017; Li et al., 2018; Suárez-Cáceres et al., 2021). A study has shown that aquaponics can provide equal or higher nutrient content for lettuce compared to traditional hydroponics. Additionally, the highest lettuce yield was achieved when treating with 120% of the recommended fish diet (Pineda-Pineda et al., 2018).

A smart aquaponics system has been designed and developed by scientists in Singapore for HFG. The system is primarily used for producing water spinach and raising tilapia (Kyaw and Ng, 2017). Equipped with various sensors, actuators, microcontrollers, and microprocessors, the system is able to monitor and regulate water quality, light intensity, and aquatic animal feed (Kyaw and Ng, 2017). If any abnormal system state is detected by the sensors, the user will automatically receive early warnings from the system, and the actuators will rectify the abnormal conditions without any human intervention (Kyaw and Ng, 2017). The dispensing of aquatic animal

feed is done according to the user's preset timings (Kyaw and Ng, 2017). The extent of self-provisioning in aquaponic systems is heavily dependent on their size. In the past, achieving a high degree of self-sufficiency from a small-scale aquaponic system was considered nearly impossible due to space constraints and limited productivity. However, recent advancements have led to significant progress in this area. Researchers in Spain have successfully developed two micro-scale domestic aquaponic systems, which consist of a 4.56 m² cropping area and a 1 m³ fish tank. Excitingly, the results of their study demonstrated that these home-based aquaponic systems can annually produce 62 kg of tilapia and 352 kg of 22 different agricultural products, including tomatoes, peppers, melons, pumpkins, cucumbers, basil, broccoli, cabbage, Chinese cabbage, onions, chard, and lettuce (Suárez-Cáceres et al., 2021). The output can provide self-sufficiency along with dietary diversity for a four-member household throughout the year (Suárez-Cáceres et al., 2021). Compared to other cultivation patterns like the rooftop system mentioned earlier, aquaponics is more likely to have higher productive efficiency in supporting self-provisioning (Boneta et al., 2019).

2.2.5 Sprouts production devices

Paper-based sprout garden is a system suitable for home-grown sprout production, it is based on a piece of absorbent paper with watering at regular intervals and can harvest after 10 to 15 days of growth given the optimum environments. At present, there are multifarious grow plates and racks available for picking on the basis of spatial layout of residence (Li et al., 2023). Additionally, for those new to sprout cultivation, user-friendly microgreen growth kits like the one introduced by Hamama, Inc. are also recommended options (Teng et al., 2023).

2.3 Technologies available for HFG

2.3.1 Hydroponic technologies

The constituents of the nutrient solution have a significant impact on the yield and quality of hydroponic crops. Ssamchoo (*Brassica lee* ssp. *namai* cv. Ssamchoo) is a vegetable commonly used in Ssam, a Korean specialty food. However, cultivating Ssamchoo hydroponically poses challenges due to its sensitivity to the composition and concentration of the nutrient solution (Noh and Jeong, 2022). A research reported that nutrient solution (the ratio of NO₃⁻ to NH₄⁺ to urea is 50: 25: 25) combined with silicon (10.7 mmol L⁻¹) is suitable for planting Ssamchoo in a household hydroponic system. This optimized nutrient solution not only allows for achieving the highest yield but also effectively mitigates the harmful effects of ammonium on Ssamchoo (Noh and Jeong, 2022).

2.3.2 Ordinary home composting and black soldier fly larvae-based composting technologies

High-quality soils are often not readily available in urban residential areas. In addition, soilless substrates used for HFG typically lack sufficient nutrients. Therefore, it is essential to enhance soil fertility and functionality by applying some fertilizers, such as chemical fertilizers, homemade composts or commercial organic fertilizers (Lal, 2020; Shrestha et al., 2020; Dorr et al., 2023). For cutbacks in expense of chemical fertilizers and organic composts used

for HFG, many urban gardeners opt to prepare small-scale home composts themselves (Gao et al., 2022). Biodegradable kitchen waste, such as meat or fish scraps, and urban green waste, such as fallen leaves and chopped grasses, can be transformed into valuable assets through the production of home-made composts. This practice aligns with the principles of a circular economy and sustainable agriculture (Storino et al., 2016; Hou et al., 2024).

Effective Microorganism (EM), originated from Japan, is one of the useful additives for composting (Fan et al., 2018). A research revealed that the practice of home-scale composting inoculated with the activated EM, is able to significantly reduce the smelly odor during the decomposition, promote humification of raw composting materials, as well as increase the decomposition rate of fat (Fan et al., 2018). In another study, it was found that regular urban gardeners were able to effectively compost kitchen waste indoors by adding EM and lime at a rate of 1% of the wet weight of the feedstock. This homemade compost also led to improved seed germination for most families (Gao et al., 2022). *Bacillus thuringiensis* (Bt) is a pathogen with potent pesticidal activity (Jurat-Fuentes et al., 2021). More recently, Spanish researchers have presented an approach to produce Bt-enriched home-scale compost through an uncomplicated procedure and low-input process (Ballardo et al., 2020). The efficiency of home composting also need to be focused on. A study demonstrated that a period of 12 to 15 months may be suitable for the development of home composting (Tatano et al., 2015). However, another research reported that it only takes 21 days to convert food wastes to composts just with minor alkalinity (Margaritis et al., 2023). The discrepancy between these two studies could be attributed to the varied additives used.

Actually, compare to time-consuming composting, there is a more efficient approach to kitchen waste treatment—black soldier fly larvae-based composting (Nguyen et al., 2015). Black soldier fly (*Hermetia illucens* L.) is an insect commonly utilized for the bio-conversion of kitchen waste. Its larvae efficiently convert various organic wastes into nutritious insect proteins and fats, while also reducing the content of antibiotics and decreasing the abundance of resistance genes commonly found in ordinary home-produced composts (Liu et al., 2017; Cai et al., 2018; Liu et al., 2020). As a fat-rich and protein-rich feed source, black soldier fly larvae can be used for feeding aquatic animals if small-scale aquaponic systems are already equipped in the residence (Qiu et al., 2023).

2.3.3 Light and temperature management technology

Regulating photoperiod and temperature can be beneficial for urban gardeners in effectively controlling the growth and harvest time of HFG plants. According to Korean scientists, for romaine lettuce (*Lactuca sativa* L. var. *longifolia*), a temperature setting of 25/18°C together with a photoperiod of 14 h were the most suitable for hastened growth. On the other hand, a temperature of 20/15°C combined with an 18 h photoperiod was deemed suitable for delayed growth (Noh and Jeong, 2021).

2.3.4 Domestic sprouts production technology

While it is advisable to minimize the use of chemical agents, it is crucial to apply them judiciously in order to achieve high yields and ensure the safety of harvested produce in HFG systems (Gilbert et al., 2023). For instance, employing safe chemicals such as dilute domestic

bleach (0.6% sodium hypochlorite) and freshly generated hypochlorous acid (800 ppm chlorine) for seed disinfestation practices can effectively suppress seed-borne bacterial and fungal infections, thereby preventing food contamination (Ding et al., 2013; Gilbert et al., 2023).

3 Current issues

3.1 Space constraints

Actually, a substantial private backyard is an ideal place to implement HFG. However, with urban consolidation, more lands are being occupied, leading to a reduction or elimination of backyards. Consequently, the available space suitable for HFG has significantly decreased (Burgin, 2018). Deficiency of enough space outdoors has become the main barrier to implement home composting, thus, HFG are transferring indoors (Deng and Deng, 2018; Kunszabó et al., 2022; Cruz et al., 2023). Nonetheless, owing to the dramatically enhanced density of housing, along with the urban space is at a premium in megacities, a great deal of housing estate developers presently are apt to omit home gardening areas, mainly residential balconies and terraces. Instead, they allocate more space for other public landscapes like lawns for exercise and street trees, or for car-parking bays in new housing schemes, consequently potential spaces for HFG is more compact than some existing old residential quarters, and in some cases, there may be no space available at all (Burgin, 2018; Chalmin-Pui et al., 2021). A more demise of the spaces for HFG occurred worldwide, as a consequence, HFG is considered a luxury in particular in several megacities nowadays, as well as most often the purview of the “upper class” rather than the “middle class” and “working class”, simultaneously, making plant architecture that has excellent adaptability in a small volume space become the most ideal plant architecture and highest priority breeding objective for HFG (Burgin, 2018; Cruz et al., 2023; Ma et al., 2023). Besides, the demand of wall-type cultivation infrastructure used for HFG is also increasing because of space constraints.

3.2 Underlying harms for buildings

When implementing HFG, the construction of balconies and terraces in most buildings poses new challenges in terms of building loading capacity, leak proof systems, waterproofing, and drainage. This is mainly because these areas were not originally designed to accommodate the necessary supporting infrastructures for HFG. In other words, the planning field was previously unaware of the specific requirements of HFG (Burgin, 2018). In addition, there is a risk of soil and substrate leakage from planting containers, which can potentially cause blockages in residential drainage pipes.

3.3 Lack of government policy support

The initiatives for urban HFG have been predominantly driven by governments. Many countries, such as Australia, are addressing the lack of space for HFG with the support of governmental agencies (Burgin, 2018). However, in developing countries, government policy

support for HFG is rare. Interestingly, in Australia, certain local governments like Canberra, Brisbane, and Perth, are even permitting adjacent household owners to use street areas for HFG, which is hard to imagine and achieve elsewhere (Burgin, 2018). Actually, soil-based or substrate-based HFG heavily relies on compost-derived nutrients, with meat scraps being a crucial feedstock for homemade compost. However, it is important to note that in certain European countries, composting meat waste is prohibited due to regulations such as the Animal By-Products regulation (Storino et al., 2016).

3.4 Labor- and time-intensive procedures

Without a doubt, some HFG practices are labor- and time-intensive. These include pruning, weed removal, replacing soil, and providing ongoing care for HFG crops over their whole life cycle. For some leisurely people who embrace HFG and can allocate adequate time to tend to plants, like retired elderly people in good physical condition, it provides gentle exercise together with joy. However, for others who find it difficult to take time away from their regular housework or work, such as exhausted working mothers who wear two hats, HFG can be a source of real torture (Perez-Lugones et al., 2023). Obviously, it is not a consideration of busy people unless some of ones are obsessed with HFG.

3.5 Relatively high input costs

Throughout history, the main motivation for low-income home gardeners to grow agricultural products instead of purchasing in the market, increases substantially in times of economic crisis or situations with economic downturn (Burgin, 2018; Perez-Lugones et al., 2023). But more recently, a number of cases are against the original intention. Some newly designed devices used for HFG is costly with low efficiency. For example, micro indoor smart hydroponics systems designed by a research team consisting of scientists from United Arab Emirates and Australia, have the apparently prohibitive costs in power consumption and equipment expense (Stevens et al., 2022).

3.6 Deficiency of planting experience

In general, urban horticultural neophytes do not have much knowledge that how to carry out HFG in an appropriate approach (Oberholtzer et al., 2014; Kunszabó et al., 2022). Novice home gardeners frequently encounter issues such as root maceration due to excessive irrigation, seedling burn caused by overfertilization, and phytotoxicity resulting from improper pesticide and fungicide concentrations. Despite their efforts to learn various planting techniques, urban gardeners still face significant knowledge gaps. Certain crops, like tomatoes and eggplants, require complex pruning throughout their growth period to avoid a tangle of branches and leaves and to ensure optimal fruit yield (Srinivasan and Huang, 2009; Appolloni et al., 2023; Wang et al., 2023). While young city dwellers have relatively easy access to planting experience and techniques, the elderly, especially those without electronic equipment or proficiency in its use, struggle to obtain planting knowledge.



FIGURE 8
Collection of mystery box tomato fruits (primarily cherry tomatoes).

3.7 Unguaranteed seed quality, vanishing heirlooms, and scarcity of cultivar selection information

Contemporarily, a switch from a preference for inedible ornamental plants to fruit seedlings and vegetable seeds has occurred among urbanite (Perez-Lugones et al., 2023). However, there is a shortage of specialized varieties for HFG, which hinders its widespread adoption and application (Sykes et al., 2021). Mystery boxes are much the rage today in China. In the context of HFG upsurge, mystery seed boxes or blind seed boxes (i.e., randomly selected different seed varieties that are mixed in a package) have gripped consumers, becoming one of the bestsellers on e-commerce platforms due to the pleasure surprise. As shown in Figure 8, mystery box tomato fruits exhibit different phenotypes. However, there is a considerably obvious downside to mystery seed boxes purchased from some online stores. The pedigrees of these seeds are typically unknown, and they may consist of segregating individuals or hybrids. As a result, the taste, yield, tolerance against environmental stresses, and resistance to pathogens and pests cannot be guaranteed (Ma et al., 2023). Actually, there are two main reasons hindering the development of the seed industry for HFG, one significant constraint is that parts of the urban residents lean toward getting access to the seeds free of cost, and another is that the market size of HFG plants is not big enough (i.e., on small-scale) to give impetus to the research and development of HFG species (Ma et al., 2023).

In order to achieve commercialization, the majority of seeds available for sale are hybrid seeds. These seeds are unable to produce viable seeds in the second generation due to the presence of multiple divergent characteristics in the fruits, such as varied colors, shapes, sizes, flavors, and textures (Osmani et al., 2023). Therefore, growers are required to purchase new seeds every year, particularly in regions

with well-established formal seed systems (Osmani et al., 2023). In contrast, heirloom varieties can be preserved by seed owners for generations (Jordan, 2007). It is worth noting that while hybrid seeds are often favored for their resistance and productivity, there are some heirlooms that are widely grown and sold and are considered to have superior flavor compared to commercial hybrid varieties (Joseph et al., 2017; Tieman et al., 2017). From the perspective of some relatively nonwealthy or needy amateur gardeners apt to cut the cost of seeds and preserve seeds themselves, heirlooms can be excellent choices, albeit this may slightly dampen the breeding enthusiasm of some breeders. However, every coin has two sides, indeed, those heirloom varieties bearing a wide diversity of colors, shapes, resistances, flavors and other traits can be utilized by breeders targeting to improve crop properties, such as flavor, mouthfeel, appearance and other organoleptic traits (Jordan, 2007; Joseph et al., 2017). Nowadays, in several European countries, Australia and North America, heirloom varieties are ordinarily sold in the market, but in China, they are vanishing gradually (Joseph et al., 2017; Burgin, 2018; Constantino et al., 2022). Consequently, now there is before agriculture professionals an imperative than previously in collection, preservation, and resurgence of precious heirlooms for posterity. In addition to official efforts, a non-governmental team in China called Seed Hunter is dedicated to reviving heirlooms. In aggregate, more efforts are required for the preservation and utilization of heirlooms.

As is known to all, in different geographical settings, regionally-appropriate plants are varied. As a result, knowledge based on research on regionally-specific varieties is extremely valuable and may serve as a reliable source of reference for novices in HFG when they come to choosing and caring for plants (Sykes et al., 2021). However, regional performance assessment data of HFG plants are now extremely rare due to the high cost of experiments but lack of relevant financing and a scarcity of researchers in the unheeded field (Sykes et al., 2021).

3.8 Weak light and changing weather conditions

Photosynthesis is vital for plants, the stronger the light, within a certain range of light intensity, the higher the photosynthesis rate (Deng and Deng, 2018). However, poor light is a common hurdle in HFG, particularly on low-rise balconies where low-intensity scattered light predominates. This makes many crops less productive, including tomatoes, which need a much higher daily light integral than most leafy vegetables (Burgin, 2018). Compact pepper and tomato cultivars are widely used for HFG, however, research has shown that indoor UV radiation deficiency typically causes compact pepper cultivars to become susceptible to intumescence, significantly lowering the aesthetic value of pepper seedlings (Cruz et al., 2023; Suarez et al., 2023). Climate change has caused extreme weather to occasionally affect protected fields, not to mention HFG sites without shelter. Typhoons, frosts, hailstorms, and heat injuries have become commonplace, making it difficult for HFG to operate outdoors and ultimately leading to a failure to improve food self-provisioning (Du Toit et al., 2022; Darge et al., 2023).

3.9 Annoying pests, phytopathogens, and birds

Pests, phytopathogens and birds exact a toll on HFG (Scott et al., 2004; Depenbusch et al., 2022). For instance, vegetables and fruits,

especially with vibrant color, like tomatoes and strawberries grown in the open-air balconies and terraces without application of insect-proof screens, are frequently eaten by birds (Figure 9). Furthermore, pests like western flower thrips, aphids, spider mites, and leaf miners, as well as phytopathogens like *Botrytis cinerea* and *Alternaria solani*, can cause frustration for horticultural beginners (Perez-Lugones et al., 2023). The heavy soil and the relatively high cost of commercial substrate make many urban growers reluctant to replace them, leading to obstacles in continuous cropping unless comprehensive disinfection and appropriate crop rotation are implemented.

3.10 Poor quality of urban soils

In situations where space is no allotment, urban gardeners may resort to creating small-scale gardens like roof gardens, and implementing HFG with domestic cultivated containers (Burgin, 2018; Baliki et al., 2023). But urban individuals usually have no soil in their homes. Due to budget constraints, most of them are inclined to collect soil adjacent to residential dwellings. The proliferation of HFG is a contributing factor to paying close attention to urban soil quality by part of citizens. Urban soils are often characterized by compaction, low fertility, limited organic matter, reduced activity and diversity of soil organisms, and high levels of stones, gravels, and artifacts. These factors can negatively impact the productivity of horticultural crops, making urban soils unsuitable for home food production (Lal, 2020).



FIGURE 9
Tomatoes and strawberries pecked by birds.

3.11 Health risks, even life dangers

Sometime, HFG may result in some disease dissemination, for example, Australian scientists revealed that toxigenic *Clostridium difficile* present in the home garden environment (e.g., soil, compost, and manure) contributes to the *C. difficile* infection in the community, which may lead to diarrhea, and even severely result in death (Shivaperumal et al., 2020).

Ventilation can result in heat losses, especially on cold days (Tien et al., 2021). During winter, people often reduce the frequency of ventilation to maintain ambient temperature, particularly at night. However, indoor farming plants serve as effective air purifiers during the day, releasing oxygen and reducing air pollutants such as formaldehyde, toluene, and benzene from new furniture and household decorations. It is important to note that these plants also produce CO₂ at night (Deng and Deng, 2018; Kumar et al., 2023). Without or lack of periodic ventilation, combined with CO₂ generated by human respiration, CO₂ will accumulate soon in indoor space. Evidence showed that elevated concentration CO₂ in human-residing environment may result in attention deficit, fatigue, and drowsiness (Wyon, 2004). Indeed, as a crassulacean acid metabolism plant, aloe (*Aloe vera* L.) is one of ideal indoor HFG plants, which can continuously absorb CO₂ during the night (Winter et al., 2005).

As widely acknowledged, falling objects pose a significant threat, with severe cases even leading to fatalities (Grivna et al., 2015). In adverse weather conditions such as typhoons, potted plants lacking adequate stabilization are prone to toppling and causing potential hazards.

Urban soils in industrialized cities can contain high levels of contaminants, such as heavy metals and organic pollutants (e.g., petroleum hydrocarbons, antibiotics, microplastics), which can be emitted from sources like automotive exhaust. These contaminants have the potential to accumulate in the human body when consuming food grown in polluted soils, leading to various side effects, including carcinogenic risks (Gao et al., 2015; Manucharova et al., 2021; Nematollahi et al., 2022; Zhu et al., 2023; Lange et al., 2024). While food contamination from polluted urban soil can be addressed through the adoption of substrate culture or hydroponics, it is important to note that toxic heavy metals present in the atmosphere of densely populated areas may pose a threat to the safety of home-grown food (Izquierdo-Díaz et al., 2023). Fortunately, these toxic heavy metal particles primarily adhering to the leaf surface and that their absorption into the plant tissue is limited. Consequently, it is strongly advised to wash vegetables produced in urban gardens in order to minimize the possibility of ingesting toxins that may be adhered to surfaces (Izquierdo-Díaz et al., 2023).

Sprout production involves the seed germination process, which requires warm and moist conditions. However, these ideal conditions also create an optimal habitat for pathogens such as *Salmonella* and *E. coli* O157:H7 to proliferate. As a result, household sprout production is vulnerable to microbial contamination, which can lead to a certain probability of food poisoning and even pose a risk to life (Gilbert et al., 2023).

Nitrate is a main source of nitrogen for crops (Buoso et al., 2021). Excessive fertilization is a prevalent problem in HFG due to the lack of experience among urban inhabitants. In hydroponics, when the nutrient solution contains an excess of nitrate ions beyond the requirements of the crops, leafy species have the potential to accumulate excessive

amounts of nitrate ions (Bian et al., 2020). However, high nitrate content in edible portions of crop plants renders harm to people who consume them (Bian et al., 2020). Ironically, the original motivation of several urbanite for carrying out HFG is the ongoing scare that arose from food contamination (Boneta et al., 2019).

While home composting markedly reduces the costs associated with collecting, transporting, and treating kitchen waste, and the use of home-produced compost for soil and substrate amendment is effective, it is important to consider some drawbacks. Urban growers often face issues with foul odors and nauseous leachate during the composting process. Additionally, homemade composts may contain heavy metals and various substances that contribute to antimicrobial resistance, posing risks to human health (Vázquez and Soto, 2017; Kohli et al., 2022; Kunszabó et al., 2022; Hou et al., 2024).

3.12 Water eutrophication

From an ecological perspective, the application of domestic composts often results in an excessive amount of phosphorus being applied, surpassing the nutrient requirements of plants. This can lead to the potential loss of phosphorus through leachate and runoff, ultimately causing water eutrophication (Small et al., 2019; Shrestha et al., 2020).

4 Future perspectives

Historically, the practice of supplementing domestic meals with agricultural products from HFG has “waxed and waned”. In the post-epidemic era, the importance of HFG to support the household food self-sufficiency would have diminished in some countries or territories. HFG is no longer solely focused on food self-provisioning, it now encompasses various functions such as decoration, recreation, therapy, socialization, and education. Consequently, there continues to be a growing market and increased popularity of HFG, evident both in the media and real-life scenarios. However, it is important to acknowledge that there are still numerous unresolved issues that need to be addressed.

At present, one of the main obstacles to implementing HFG is the limited space available in residential areas or adjacent to living spaces, due to the increasing trend towards smaller allotments. For the encroachment on HFG spaces as well as omission of HFG spaces by property development, spaces available for HFG should be embedded in housing estates along with other system in building planning design, which requires valid government policy development. Besides, other HFG-related government policy support should be introduced and implemented. In addition, more cultivation facilities that can effectively improve space utilization efficiency should be studied and promoted in the future, such as various wall-type cultivation systems.

In order to cut down HFG expenses, smart devices can be equipped with multiple solar panels to harness solar energy and power the entire intelligent system. Additionally, it is crucial to continuously promote the development of low-cost equipment with highly efficient traits.

Some evidence has shown that addressing the lack of planting experience and techniques can be relatively easy through hands-on training in garden management. Therefore, neighborhood committees of residential compounds, apartments, and townhouses can consider inviting agricultural experts to give lectures for HFG greenhorns.

Besides, breeders could contribute to the welfare of citizens by donating various seeds during public activities. In addition to providing offline instruction, providing more expert online HFG platforms for exchanging problems and answers may be an efficient way to deal with the issue of insufficient planting experience, because online platforms can break the restrict of time and space.

The breeding of HFG special cultivars requires collaboration between breeders and the full utilization of existing plant resources. This is done to diversify horticultural plant genetic resources and continuously enhance the variety of plant species available for residential lots. This provides people with a wider range of colorful and diverse options to appreciate and consume. Similar to cultivation in space, the ideal crops for HFG should be able to provide much sustenance with minimal fertilizer inputs. Therefore, the WBEPP approach should be implemented on other plants, not just limited to potatoes.

In addition to utilization of insect-proof screens, urban gardeners can implement HFG in closed or semi-closed systems to successfully prevent losses in the face of horticultural products being pecked by birds and bitten by pests. Although carrying out HFG in closed systems or semi-closed systems may encounter the challenge of poor light, growers can use supplementary lighting equipment to mitigate this problem.

In aquaponics, the level of dissolved oxygen and nitrate concentration in water should be monitored by some sensors in real time to ensure the development of aquatic animals, and achieve safe home-grown vegetables with low nitrate content, because food safety issues should always be a key concern at all times.

Hygienic issues associated with HFG, such as operation involved in household composting, should be brought into sharp focus. Against the background of HFG boom, developing safe, affordable along with high-efficiency commercialized domestic composters and their accessories (e.g., compost accelerators compatible with the attributes of various types of waste) are of great importance and necessity.

5 Conclusion

As alluded to above, throughout human history, HFG has played a crucial role in self-provisioning, particularly during economic downturns and food shortages caused by emergencies. In an uncertain future marked by war, plague, oil embargo, climate change, and other catastrophic events, HFG is seen as a sustainable and viable approach to ensuring nutrition security. As citizens increasingly recognize the importance of HFG in the 21st century, it is expected to become integrated into their daily lives. Certainly, now HFG is not a silver bullet to cope with urban hunger yet, there are challenges and opportunities that need to be explored and developed further in the field of HFG.

References

- Abass, K., Adanu, S. K., and Agyemang, S. (2018). Peri-urbanisation and loss of arable land in Kumasi Metropolis in three decades: evidence from remote sensing image analysis. *Land Use Policy* 72, 470–479. doi: 10.1016/j.landusepol.2018.01.013
- Aditya, R. B., and Zakiah, A. (2022). Practical reflection and benefits of making a food garden at home during Covid-19 pandemic. *Int. J. Food Stud.* 11, 85–97. doi: 10.7455/ijfs/11.1.2022.a8
- Appolloni, E., Paucek, I., Pennisi, G., Manfrini, L., Gabarrell, X., Gianquinto, G., et al. (2023). Winter greenhouse tomato cultivation: matching leaf pruning and supplementary lighting for improved yield and precocity. *Agronomy* 13:671. doi: 10.3390/agronomy13030671
- Avendaño-Abarca, V. H., Alvarado-Camarillo, D., Valdez-Aguilar, L. A., Sánchez-Ortiz, E. A., González-Fuentes, J. A., and Cartmill, A. D. (2023). Response of strawberry to the substitution of blue light by green light in an indoor vertical farming system. *Agronomy* 13:99. doi: 10.3390/agronomy13010099
- Baliki, G., Schreinemachers, P., Brück, T., and Uddin, N. M. (2022). Impacts of a home garden intervention in Bangladesh after one, three and six years. *Agric. Food Secur.* 11, 1–9. doi: 10.1186/s40066-022-00388-z
- Baliki, G., Weiffen, D., Moiles, G., and Brück, T. (2023). Home garden interventions in crisis and emergency settings. *Front. Sustain. Food Syst.* 7:1138558. doi: 10.3389/fsufs.2023.1138558

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Conflict of interest

YX was employed by Taizhou Urban and Rural Planning Design Institute Co. Ltd.

The remaining 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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- Ballardo, C., Vargas-García, M. D. C., Sánchez, A., Barrena, R., and Artola, A. (2020). Adding value to home compost: biopesticide properties through *Bacillus thuringiensis* inoculation. *Waste Manag.* 106, 32–43. doi: 10.1016/j.wasman.2020.03.003
- Baras, T. (2018). *DIY hydroponic gardens. Cool springs: 401 second avenue north, suite 310, Minneapolis, MN 55401 USA*
- Basu, M., Das Gupta, R., Kumar, P., and Dhyani, S. (2021). Home gardens moderate the relationship between Covid-19-induced stay-at-home orders and mental distress: a case study with urban residents of India. *Environ. Res. Commun.* 3:105002. doi: 10.1088/2515-7620/ac2ab2
- Battino, M., Giampieri, F., Cianciosi, D., Ansary, J., Chen, X., Zhang, D., et al. (2021). The roles of strawberry and honey phytochemicals on human health: a possible clue on the molecular mechanisms involved in the prevention of oxidative stress and inflammation. *Phytomedicine* 86:153170. doi: 10.1016/j.phymed.2020.153170
- Bentvelsen, G., and Bouw, B. (2006). Breeding ornamental strawberries. *Acta Hort.* 708, 455–458. doi: 10.17660/ActaHortic.2006.708.80
- Bentvelsen, G., and Vange, A. V. D. (2021). Advances in F1 hybrid day-neutral strawberry breeding at ABZ seeds, Andijk, the Netherlands. *Acta Hort.* 1305, 241–246. doi: 10.17660/ActaHortic.2021.1309.35
- Bhuiyan, R., and van Iersel, M. W. (2021). Only extreme fluctuations in light levels reduce lettuce growth under sole source lighting. *Front. Plant Sci.* 12:619973. doi: 10.3389/fpls.2021.619973
- Bian, Z., Wang, Y., Zhang, X., Li, T., Grundy, S., Yang, Q., et al. (2020). A review of environment effects on nitrate accumulation in leafy vegetables grown in controlled environments. *Food Secur.* 9:732. doi: 10.3390/foods9060732
- Boivin, M., Bourdeau, N., Barnabé, S., and Desgagné-Penix, I. (2020). Sprout suppressive molecules effective on potato (*Solanum tuberosum*) tubers during storage: a review. *Am. J. Potato Res.* 97, 451–463. doi: 10.1007/s12230-020-09794-0
- Boneta, A., Rufi-Salis, M., Ercilla-Montserrat, M., Gabarrell, X., and Rieradevall, J. (2019). Agronomic and environmental assessment of a polyculture rooftop soilless urban home garden in a Mediterranean city. *Front. Plant Sci.* 10:341. doi: 10.3389/fpls.2019.00341
- Buoso, S., Tomasi, N., Said-Pullicino, D., Arkoun, M., Yvin, J., Pinton, R., et al. (2021). Characterization of physiological and molecular responses of Zea mays seedlings to different urea-ammonium ratios. *Plant Physiol. Biochem.* 162, 613–623. doi: 10.1016/j.plaphy.2021.03.037
- Burgin, S. (2015). Why the difference in the recreational hunting ethic between Australians and north Americans? An opinion with emphasis on furbearers. *Int. J. Environ. Stud.* 72, 770–783. doi: 10.1080/00207233.2015.1077592
- Burgin, S. (2018). Back to the future? Urban backyards and food self-sufficiency. *Land Use Policy* 78, 29–35. doi: 10.1016/j.landusepol.2018.06.012
- Cai, M., Ma, S., Hu, R., Tomberlin, J. K., Yu, C., Huang, Y., et al. (2018). Systematic characterization and proposed pathway of tetracycline degradation in solid waste treatment by *Hermetia illucens* with intestinal microbiota. *Environ. Pollut.* 242, 634–642. doi: 10.1016/j.envpol.2018.06.105
- Cattivelli, V. (2022). The contribution of urban garden cultivation to food self-sufficiency in areas at risk of food desertification during the Covid-19 pandemic. *Land Use Policy* 120:106215. doi: 10.1016/j.landusepol.2022.106215
- Cerda, C., Guenat, S., Egerer, M., and Fischer, L. K. (2022). Home food gardening: benefits and barriers during the COVID-19 pandemic in Santiago, Chile. *Frontiers in Sustainable Food Systems* 6:841386. doi: 10.3389/fsufs.2022.841386
- Chalmin-Pui, L. S., Griffiths, A., Roe, J., Heaton, T., and Cameron, R. (2021). Why garden?—attitudes and the perceived health benefits of home gardening. *Cities* 112:103118. doi: 10.1016/j.cities.2021.103118
- Coffin, R., Keenan, M. K., Lynch, D., McKeown, A., Wilson, J., Nelson, G. A., et al. (1993). Banana: a yellow-fleshed fingerling type potato for home garden production. *Am. Potato J.* 70, 1–5. doi: 10.1007/BF02848642
- Constantino, L. V., Shimizu, G. D., Macera, R., Fukui, A. S. S., Zeffa, D. M., Koltun, A., et al. (2022). Genetic diversity and selection of heirloom tomato accessions based on the physical and biochemical fruit-related traits. *Bragantia* 81:e1422. doi: 10.1590/1678-4499.20210193
- Corley, J., Okely, J. A., Taylor, A. M., Page, D., Welstead, M., Skarabela, B., et al. (2021). Home garden use during COVID-19: associations with physical and mental wellbeing in older adults. *J. Environ. Psychol.* 73:101545. doi: 10.1016/j.jenvp.2020.101545
- Cruz, S., and Gómez, C. (2022). Effects of daily light integral on compact tomato plants grown for indoor gardening. *Agronomy* 12:1704. doi: 10.3390/agronomy12071704
- Cruz, S., van Santen, E., and Gómez, C. (2023). Evaluation of compact pepper cultivars for container gardening indoors under light-emitting diodes and in a greenhouse under sunlight. *HortTechnology* 33, 317–324. doi: 10.21273/HORTTECH05194-23
- Darge, A., Haji, J., Beyene, F., and Ketema, M. (2023). Smallholder farmers' climate change adaptation strategies in the Ethiopian rift valley: the case of home garden agroforestry systems in the Gedeo zone. *Sustain. For.* 15:8997. doi: 10.3390/su15118997
- Degefa, B., Albedwawi, A. M. M., and Alazeezib, M. S. (2021). The study of the practice of growing food at home in the UAE: role in household food security & wellbeing and implication for the development of urban agriculture. *Emirates J. Food Agric.* 33, 465–474. doi: 10.9755/ejfa.2021.v33i6.2712
- Deng, L., and Deng, Q. (2018). The basic roles of indoor plants in human health and comfort. *Environ. Sci. Pollut. Res. Int.* 25, 36087–36101. doi: 10.1007/s11356-018-3554-1
- Depenbusch, L., Schreinemachers, P., Brown, S., and Roothaert, R. (2022). Impact and distributional effects of a home garden and nutrition intervention in Cambodia. *Food Secur.* 14, 865–881. doi: 10.1007/s12571-021-01235-y
- Devaux, A., Goffart, J., Kromann, P., Andrade-Piedra, J., Polar, V., and Hareau, G. (2021). The potato of the future: opportunities and challenges in sustainable Agri-food systems. *Potato Res.* 64, 681–720. doi: 10.1007/s11540-021-09501-4
- Diehl, J. A., Sweeney, E., Wong, B., Sia, C. S., Yao, H., and Prabhudesai, M. (2020). Feeding cities: Singapore's approach to land use planning for urban agriculture. *Glob. Food Sec.* 26:100377. doi: 10.1016/j.gfs.2020.100377
- Diekmann, L. O., Gray, L. C., and Thai, C. L. (2020). More than food: the social benefits of localized urban food systems. *Front. Sustain. Food Syst.* 4:534219. doi: 10.3389/fsufs.2020.534219
- Ding, H., Fu, T. J., and Smith, M. A. (2013). Microbial contamination in sprouts: how effective is seed disinfection treatment? *J. Food Sci.* 78, R495–R501. doi: 10.1111/1750-3841.12064
- Ding, Y., Xue, L., Guo, R., Luo, G., Song, Y., and Lei, J. J. (2019). De novo assembled transcriptome analysis and identification of genic SSR markers in red-flowered strawberry. *Biochem. Genet.* 57, 607–622. doi: 10.1007/s10528-019-09912-6
- Dorr, E., Hawes, J. K., Goldstein, B., Fargue-Lelièvre, A., Fox-Kämper, R., Specht, K., et al. (2023). Food production and resource use of urban farms and gardens: a five-country study. *Agron. Sustain. Dev.* 43:18. doi: 10.1007/s13593-022-00859-4
- Du Toit, M. J., Rondón, O., Cologna, V., Cilliers, S. S., and Dallimer, M. (2022). Why home gardens fail in enhancing food security and dietary diversity. *Front. Ecol. Evol.* 10:804523. doi: 10.3389/fevo.2022.804523
- Ercilla-Montserrat, M., Muñoz, P., Montero, J. I., Gabarrell, X., and Rieradevall, J. (2018). A study on air quality and heavy metals content of urban food produced in a Mediterranean city (Barcelona). *J. Clean. Prod.* 195, 385–395. doi: 10.1016/j.jclepro.2018.05.183
- Erokhin, V., and Gao, T. (2020). Impacts of COVID-19 on trade and economic aspects of food security: evidence from 45 developing countries. *Int. J. Environ. Res. Public Health* 17:5775. doi: 10.3390/ijerph17165775
- Ezzeddin, N., Kalantari, N., Abdollahi, M., Amiri, P., Amini, B., and Zayeri, F. (2024). Outcomes of a homestead food production program on nutritional knowledge, dietary diversity, food security and empowerment of rural women in Tehran province. *Iran. BMC Public Health* 24:118. doi: 10.1186/s12889-024-17658-z
- Fan, Y. V., Lee, C. T., Klemes, J. J., Chua, L. S., Sarmidi, M. R., and Leow, C. W. (2018). Evaluation of effective microorganisms on home scale organic waste composting. *J. Environ. Manag.* 216, 41–48. doi: 10.1016/j.jenvman.2017.04.019
- Furlan, V., Pochettino, M. L., and Hilgert, N. I. (2017). Management of fruit species in urban home gardens of Argentina Atlantic forest as an influence for landscape domestication. *Front. Plant Sci.* 8:1690. doi: 10.3389/fpls.2017.01690
- Gao, L., Shi, Y., Li, W., Liu, J., and Cai, Y. (2015). Occurrence and distribution of antibiotics in urban soil in Beijing and Shanghai, China. *Environ. Sci. Pollut. Res.* 22, 11360–11371. doi: 10.1007/s11356-015-4230-3
- Gao, X., Yang, F., Yan, Z., Zhao, J., Li, S., Nghiem, L., et al. (2022). Humification and maturation of kitchen waste during indoor composting by individual households. *Sci. Total Environ.* 814:152509. doi: 10.1016/j.scitotenv.2021.152509
- Ghosh, S. (2014). Measuring sustainability performance of local food production in home gardens. *Local Environ.* 19, 33–55. doi: 10.1080/13549839.2012.716412
- Gilbert, G. S., Diaz, A., and Bregoff, H. A. (2023). Seed disinfestation practices to control seed-borne fungi and bacteria in home production of sprouts. *Food Secur.* 12:747. doi: 10.3390/foods12040747
- Goddek, S., and Keesman, K. J. (2020). Improving nutrient and water use efficiencies in multi-loop aquaponics systems. *Aquac. Int.* 28, 2481–2490. doi: 10.1007/s10499-020-00600-6
- Godrich, S. L., Lo, J., Kent, K., Macau, F., and Devine, A. (2022). A mixed-methods study to determine the impact of COVID-19 on food security, food access and supply in regional Australia for consumers and food supply stakeholders. *Nutr. J.* 21:17. doi: 10.1186/s12937-022-00770-4
- Grivna, M., Eid, H. O., and Abu-Zidan, F. M. (2015). Injuries from falling objects in the United Arab Emirates. *Int. J. Inj. Control Saf. Promot.* 22, 68–74. doi: 10.1080/17457300.2013.863784
- Guan, L., Wilson, Z. A., Zhao, M., Qiao, Y., Wu, E., Wang, Q., et al. (2023). New germplasm for breeding: pink-flowered and white-fruited strawberry. *HortScience* 58, 1005–1009. doi: 10.21273/HORTSCI17047-22
- Guo, L., Yang, R., Zhou, Y., and Gu, Z. (2016). Heat and hypoxia stresses enhance the accumulation of aliphatic glucosinolates and sulforaphane in broccoli sprouts. *Eur. Food Res. Technol.* 242, 107–116. doi: 10.1007/s00217-015-2522-y
- Hardigan, M. A., Lorient, A., Pincot, D. D. A., Feldmann, M. J., Famula, R. A., Acharya, C. B., et al. (2021). Unraveling the complex hybrid ancestry and domestication

history of cultivated strawberry. *Mol. Biol. Evol.* 38, 2285–2305. doi: 10.1093/molbev/msab024

Hong, Y., and Zimmerer, K. S. (2022). Useful plants from the wild to home gardens: An analysis of home garden ethnobotany in contexts of habitat conversion and land use change in jeju, South Korea. *J. Ethnobiol.* 42, 1–21. doi: 10.2993/0278-0771-42.3.6

Hou, J., Lam, K. L., Chiu, Y. T., Kwong, K. Y., Lau, H. L., Marafa, L. M., et al. (2024). Urban green waste bulking agent is the major source of antimicrobial resistance genes persisted in home compost, not animal manure. *Environ. Res.* 242:117713. doi: 10.1016/j.envres.2023.117713

Humaida, N., Saputra, M. H., Sutomo, , and Hadiyan, Y. (2023). Urban gardening for mitigating heat island effect. *IOP Conf. Series* 1133:12048. doi: 10.1088/1755-1315/1133/1/012048

Ichinose, Y., Nishigaki, T., Shibata, M., Kilasara, M., Shinjo, H., and Funakawa, S. (2023). Carbon and nutrient budgets of the Chagga home garden system in the Kilimanjaro highlands, Tanzania. *Soil Use Manag.* 39, 1155–1171. doi: 10.1111/sum.12923

Issahaku, G., Kornher, L., Saiful Islam, A. H. M., and Abdul-Rahaman, A. (2023). Heterogeneous impacts of home-gardening on household food and nutrition security in Rwanda. *Food Secur.* 15, 731–750. doi: 10.1007/s12571-023-01344-w

Izquierdo-Díaz, M., Hansen, V., Barrio-Parra, F., De Miguel, E., You, Y., and Magidl, J. (2023). Assessment of lettuces grown in urban areas for human consumption and as bioindicators of atmospheric pollution. *Ecotoxicol. Environ. Saf.* 256:114883. doi: 10.1016/j.ecoenv.2023.114883

Jordan, J. A. (2007). The heirloom tomato as cultural object: investigating taste and space. *Sociol. Rural.* 47, 20–41. doi: 10.1111/j.1467-9523.2007.00424.x

Joseph, H., Nink, E., McCarthy, A., Messer, E., and Cash, S. B. (2017). The heirloom tomato is in. Does it matter how it tastes? *Food, Cult. Soc.* 20, 257–280. doi: 10.1080/15528014.2017.1305828

Jurat-Fuentes, J. L., Heckel, D. G., and Ferré, J. (2021). Mechanisms of resistance to insecticidal proteins from *Bacillus thuringiensis*. *Annu. Rev. Entomol.* 66, 121–140. doi: 10.1146/annurev-ento-052620-073348

Ke, X., Yoshida, H., Hikosaka, S., and Goto, E. (2022). Optimization of photosynthetic photon flux density and light quality for increasing radiation-use efficiency in dwarf tomato under LED light at the vegetative growth stage. *Plant. Theory* 11:121. doi: 10.3390/plants11010121

Khan, M. W., Hussain, Z., and Farooq, M. (2022). Maintenance of tissue water status, osmoregulation, and antioxidant defence system improves heat tolerance in okra genotypes with contrast heat tolerance. *J. Soil Sci. Plant Nutr.* 22, 4273–4281. doi: 10.1007/s42729-022-01026-0

Khanzadeh, S., Deschênes, M., and Dubé, C. (2010). Roseberry strawberry. *HortScience* 45, 1545–1546. doi: 10.21273/HORTSCI.45.10.1545

Khosa, Q., Zaman, Q. U., An, T., Ashraf, K., Abbasi, A., Nazir, S., et al. (2023). Silicon-mediated improvement of biomass yield and physio-biochemical attributes in heat-stressed spinach (*Spinacia oleracea*). *Crop Pasture Sci.* 74, 230–243. doi: 10.1071/CP22192

Kim, J. G., Jeong, W., Park, S., and Yang, M. (2022). Development of a fuzzy logic-controlled system for home cultivation of sweet basil. *Front. Plant Sci.* 13:999106. doi: 10.3389/fpls.2022.999106

Kohli, A., Guénon, R., Jean-Soro, L., and Vidal-Beaudet, L. (2022). Home and community composts in Nantes city (France): quality and safety regarding trace metals and metalloids. *Environ. Monit. Assess.* 194:649. doi: 10.1007/s10661-022-10251-0

Korpeläinen, H. (2023). The role of home gardens in promoting biodiversity and food security. *Plant. Theory* 12:2473. doi: 10.3390/plants12132473

Kumar, R., Verma, V., Thakur, M., Singh, G., and Bhargava, B. (2023). A systematic review on mitigation of common indoor air pollutants using plant-based methods: a phytoremediation approach. *Air Qual. Atmos. Health* 16, 1501–1527. doi: 10.1007/s11869-023-01326-z

Kunszabó, A., Szakos, D., Dorkó, A., Farkas, C., and Kasza, G. (2022). Household food waste composting habits and behaviours in Hungary: a segmentation study. *Sustain. Chem. Pharm.* 30:100839. doi: 10.1016/j.scp.2022.100839

Kyaw, T. Y., and Ng, A. K. (2017). Smart aquaponics system for urban farming. *Energy Procedia* 143, 342–347. doi: 10.1016/j.egypro.2017.12.694

Laborde, D., Martin, W., Swinnen, J., and Vos, R. (2020). COVID-19 risks to global food security. *Science* 369, 500–502. doi: 10.1126/science.abc4765

Lal, R. (2020). Home gardening and urban agriculture for advancing food and nutritional security in response to the COVID-19 pandemic. *Food Secur.* 12, 871–876. doi: 10.1007/s12571-020-01058-3

Lange, C. N., Freire, B. M., Monteiro, L. R., de Jesus, T. A., Dos Reis, R. A., Nakazato, G., et al. (2024). Multiple potentially toxic elements in urban gardens from a Brazilian industrialized city. *Environ. Geochem. Health* 46:36. doi: 10.1007/s10653-023-01808-0

Larder, N., Lyons, K., and Woolcock, G. (2014). Enacting food sovereignty: values and meanings in the act of domestic food production in urban Australia. *Local Environ.* 19, 56–76. doi: 10.1080/13549839.2012.716409

Le, L., Gong, X., An, Q., Xiang, D., Zou, L., Peng, L., et al. (2021). Quinoa sprouts as potential vegetable source: nutrient composition and functional contents of different quinoa sprout varieties. *Food Chem.* 357:129752. doi: 10.1016/j.foodchem.2021.129752

León-Cañedo, J. A., Alarcón-Silvas, S. G., Fierro-Sañudo, J. F., Rodríguez-Montes De Oca, G. A., Fregoso-López, M. G., and Pérez-Osuna, F. (2023). Mercury in basil (*Ocimum basilicum*) grown simultaneously with shrimp (*Litopenaeus vannamei*) by aquaponics. *J. Food Compos. Anal.* 115:104929. doi: 10.1016/j.jfca.2022.104929

Li, C., Lee, C. T., Gao, Y., Hashim, H., Zhang, X., Wu, W., et al. (2018). Prospect of aquaponics for the sustainable development of food production in urban. *Chem. Eng. Trans.* 63, 475–480. doi: 10.3303/CET1863080

Li, Q., Yu, Z., Li, M., Zhang, G., Lu, T., Li, Y., et al. (2023). Urban vegetable production in Beijing, China: current progress, sustainability, and challenges. *Front. Sustain. Food Syst.* 7:1191561. doi: 10.3389/fsufs.2023.1191561

Lin, Y., Zhou, C., Li, D., Wu, Y., Dong, Q., Jia, Y., et al. (2023). Integrated non-targeted and targeted metabolomics analysis reveals the mechanism of inhibiting lignification and optimizing the quality of pea sprouts by combined application of nano-selenium and lentinans. *J. Sci. Food Agric.* 103, 5096–5107. doi: 10.1002/jsfa.12579

Liu, X., Chen, X., Wang, H., Yang, Q., Ur Rehman, K., Li, W., et al. (2017). Dynamic changes of nutrient composition throughout the entire life cycle of black soldier fly. *PLoS One* 12:e182601. doi: 10.1371/journal.pone.0182601

Liu, J., Wang, J., Wang, M., Zhao, J., Zheng, Y., Zhang, T., et al. (2021). Genome-wide analysis of the R2R3-MYB gene family in *fragaria* × *ananassa* and its function identification during anthocyanins biosynthesis in pink-flowered strawberry. *Front. Plant Sci.* 12:702160. doi: 10.3389/fpls.2021.702160

Liu, Y., Xie, G., Yang, Q., and Ren, M. (2021). Biotechnological development of plants for space agriculture. *Nat. Commun.* 12:5998. doi: 10.1038/s41467-021-26238-3

Liu, C., Yao, H., Chapman, S. J., Su, J., and Wang, C. (2020). Changes in gut bacterial communities and the incidence of antibiotic resistance genes during degradation of antibiotics by black soldier fly larvae. *Environ. Int.* 142:105834. doi: 10.1016/j.envint.2020.105834

Liu, M., Zhang, F., Xiao, J., Liu, B., Cespedes, C. L., and Meng, X. (2024). The M/G ratio of alginate oligosaccharides: the key to enhance the coloration of strawberries. *Carbohydr. Polym.* 323:121422. doi: 10.1016/j.carbpol.2023.121422

Ma, K., Yuan, Y., and Fang, C. (2023). Mainstreaming production and nutrient resilience of vegetable crops in megacities: pre-breeding for terrace cultivation. *Front. Plant Sci.* 14:1237099. doi: 10.3389/fpls.2023.1237099

Mabberley, D. J. (2002). *Potentilla* and *Fragaria* (Rosaceae) reunited. *Telopea* 9, 793–801. doi: 10.7751/telopea20024018

Machida, D. (2019). Relationship between community or home gardening and health of the elderly: a web-based cross-sectional survey in Japan. *Int. J. Environ. Res. Public Health* 16:1389. doi: 10.3390/ijerph16081389

Majid, M., Khan, J. N., Ahmad Shah, Q. M., Masoodi, K. Z., Afroza, B., and Parvaze, S. (2021). Evaluation of hydroponic systems for the cultivation of lettuce (*Lactuca sativa* L., Var. Longifolia) and comparison with protected soil-based cultivation. *Agric. Water Manag.* 245:106572. doi: 10.1016/j.agwat.2020.106572

Makhdom, S., Shekarabi, S. P. H., and Shamsaie Mehrgan, M. (2017). Biological nutrient recovery from culturing of pearl gourami (*Trichogaster leeri*) by cherry tomato (*Solanum lycopersicum*) in aquaponic system. *Environ. Sci. Pollut. Res.* 24, 20634–20640. doi: 10.1007/s11356-017-9702-1

Manucharova, N. A., Bolshakova, M. A., Babich, T. L., Tourova, T. P., Semenova, E. M., Yanovich, A. S., et al. (2021). Microbial degraders of petroleum and polycyclic aromatic hydrocarbons from sod-Podzolic soil. *Microbiology* 90, 743–753. doi: 10.1134/S0026261721060096

Margaritis, M., Dimos, V., Malamis, D., and Loizidou, M. (2023). An experimental investigation of the composting process in an innovative home composting system: the influence of additives. *Cleaner Mater.* 8:100185. doi: 10.1016/j.clema.2023.100185

Marques, P., Silva, A. S., Quaresma, Y., Manna, L. R., de Magalhães Neto, N., and Mazzoni, R. (2021). Home gardens can be more important than other urban green infrastructure for mental well-being during COVID-19 pandemics. *Urban For. Urban Green.* 64:127268. doi: 10.1016/j.ufug.2021.127268

Martin-Pizarro, C., Vallarino, J. G., Osorio, S., Meco, V., Urrutia, M., Pillet, J., et al. (2021). The NAC transcription factor FaRIF controls fruit ripening in strawberry. *Plant Cell* 33, 1574–1593. doi: 10.1093/plcell/koab070

Melo, R. A. C., Jorge, M. H., Botrel, N., and Boiteux, L. S. (2018). Effect of a novel hydrogel amendment and seedling plugs volume on the quality of ornamentalminiature tomato. *Adv. Hortic. Sci.* 32, 535–540. doi: 10.13128/ahs-22474

Mullins, L., Charlebois, S., Finch, E., and Music, J. (2021). Home food gardening in Canada in response to the COVID-19 pandemic. *Sustain. For.* 13:3056. doi: 10.3390/su13063056

Music, J., Mullins, L., Charlebois, S., Large, C., and Mayhew, K. (2022). Seeds and the city: a review of municipal home food gardening programs in Canada in response to the COVID-19 pandemic. *Human. Soc. Sci. Commun.* 9:273. doi: 10.1057/s41599-022-01301-6

Nematollahi, M. J., Keshavarzi, B., Mohit, F., Moore, F., and Busquets, R. (2022). Microplastic occurrence in urban and industrial soils of Ahvaz metropolis: a city with a

- sustained record of air pollution. *Sci. Total Environ.* 819:152051. doi: 10.1016/j.scitotenv.2021.152051
- Nguyen, T. T. X., Tomberlin, J. K., and Vanlaerhoven, S. (2015). Ability of black soldier fly (Diptera: Stratiomyidae) larvae to recycle food waste. *Environ. Entomol.* 44, 406–410. doi: 10.1093/ee/nvv002
- Noh, K., and Jeong, B. R. (2021). Optimizing temperature and photoperiod in a home cultivation system to program normal, delayed, and hastened growth and development modes for leafy oak-leaf and romaine lettuces. *Sustain. For.* 13:10879. doi: 10.3390/su131910879
- Noh, K., and Jeong, B. R. (2022). Silicon supplementation alleviates adverse effects of ammonium on ssamchoo grown in home cultivation system. *Plan. Theory* 11:2882. doi: 10.3390/plants11212882
- Nolasco, E., Krassovskaya, I., Hong, K., Hansen, K., Alvarez, S., Obata, T., et al. (2023). Sprouting alters metabolite and peptide contents in the gastrointestinal digest of soybean and enhances in-vitro anti-inflammatory activity. *J. Funct. Foods* 109:105780. doi: 10.1016/j.jff.2023.105780
- Oberholtzer, L., Dimitri, C., and Pressman, A. (2014). Urban agriculture in the United States: characteristics, challenges, and technical assistance needs. *J. Ext.* 52:28. doi: 10.34068/joe.52.06.28
- Olbricht, K., Pohlheim, F., Eppendorfer, A., Vogt, F., and Rietze, E. (2014). Strawberries as balcony fruit. *Acta Hortic.* 1049, 215–218. doi: 10.17660/ActaHortic.2014.1049.22
- Osmani, J., Davidson, M. T., Tevlin, S., and Pérez, H. E. (2023). Producing high-quality seeds of an heirloom cabbage in different crop management systems. *HortScience* 58, 811–818. doi: 10.21273/HORTSCI17173-23
- Patel, S. K., Sharma, A., Singh, R., Tiwari, A. K., and Singh, G. S. (2022). Diversity and distribution of traditional home gardens along different disturbances in a dry tropical region, India. *Front. Forests Global Change* 5:822320. doi: 10.3389/ffgc.2022.822320
- Perez-Lugones, D., Campbell, C. G., and Gómez, C. (2023). Using citizen science to evaluate home gardeners' experiences with compact tomato plants. *HortTechnology* 33, 578–586. doi: 10.21273/HORTTECH05312-23
- Perveen, R., Suleria, H. A. R., Anjum, F. M., Butt, M. S., Pasha, I., and Ahmad, S. (2015). Tomato (*Solanum lycopersicum*) carotenoids and lycopenes chemistry; metabolism, absorption, nutrition, and allied health claims—a comprehensive review. *Crit. Rev. Food Sci. Nutr.* 55, 919–929. doi: 10.1080/10408398.2012.657809
- Pineda-Pineda, J., Valdez-Zamora, A., Miranda-Velázquez, I., Rodríguez-Pérez, J. E., Ramírez-Arias, J. A., and Lozano-Toledano, A. (2018). Yield of two cultivars of lettuce (*Lactuca sativa* L.) in hydroponic and aquaponic systems. *Acta Hortic.* 1227, 347–354. doi: 10.17660/ActaHortic.2018.1227.43
- Qiu, J., Luo, C., Ren, L., Li, W., Dai, T., Wang, G., et al. (2023). Black soldier fly larvae replace traditional iced trash fish diet to enhance the delicious flavor of Chinese mitten crab (*Eriocheir sinensis*). *Front. Mar. Sci.* 9:1089421. doi: 10.3389/fmars.2022.1089421
- Rajan, P., Lada, R. R., and MacDonald, M. T. (2019). Advancement in indoor vertical farming for microgreen production. *Am. J. Plant Sci.* 10, 1397–1408. doi: 10.4236/ajps.2019.108100
- Reed, E., Ferreira, C. M., Bell, R., Brown, E. W., Zheng, J., and Schaffner, D. W. (2018). Plant-microbe and abiotic factors influencing salmonella survival and growth on alfalfa sprouts and swiss chard microgreens. *Appl. Environ. Microbiol.* 84, e2814–e2817. doi: 10.1128/AEM.02814-17
- Richardson, M. L., and Arlotta, C. G. (2022). Producing cherry tomatoes in urban agriculture. *Horticulturae* 8:274. doi: 10.3390/horticulturae8040274
- Romero, J., Albertos, I., Díez-Méndez, A., and Poveda, J. (2022). Control of postharvest diseases in berries through edible coatings and bacterial probiotics. *Sci. Hortic.* 304:111326. doi: 10.1016/j.scienta.2022.111326
- Santos, M., Moreira, H., Cabral, J. A., Gabriel, R., Teixeira, A., Bastos, R., et al. (2022). Contribution of home gardens to sustainable development: perspectives from a supported opinion essay. *Int. J. Environ. Res. Public Health* 19:13715. doi: 10.3390/ijerph192013715
- Saroinsong, F. B., Ismail, Y., Gravitiani, E., and Sumantra, K. (2021). Utilization of home gardens as a community empowerment-based edible landscape to combat stunting. *IOP Conf. Series* 940:012093. doi: 10.1088/1755-1315/940/1/012093
- Scott, I. M., Jensen, H., Nicol, R., Lesage, L., Bradbury, R., Sánchez-Vindas, P., et al. (2004). Efficacy of piper (Piperaceae) extracts for control of common home and garden insect pests. *J. Econ. Entomol.* 97, 1390–1403. doi: 10.1093/jee/97.4.1390
- Shin, K. K. Y., Ping, T. P., Ling, M. G. B., Chee Jiun, C., and Bolhassan, N. A. B. (2024). SMART GROW—low-cost automated hydroponic system for urban farming. *HardwareX* 17:e498e00498. doi: 10.1016/j.ohx.2023.e00498
- Shivaperumal, N., Chang, B. J., Riley, T. V., Elkins, C. A., and Elkins, C. A. (2020). High prevalence of clostridium difficile in home gardens in western Australia. *Appl. Environ. Microbiol.* 87:1. doi: 10.1128/AEM.01572-20
- Shrestha, P., Small, G. E., and Kay, A. (2020). Quantifying nutrient recovery efficiency and loss from compost-based urban agriculture. *PLoS One* 15:e230996. doi: 10.1371/journal.pone.0230996
- Sia, A., Tan, P. Y., and Er, K. B. H. (2023). The contributions of urban horticulture to cities' liveability and resilience: insights from Singapore. *Plants People Planet* 5, 828–841. doi: 10.1002/ppp3.10377
- Sia, A., Tan, P. Y., Wong, J. C. M., Araib, S., Ang, W. F., and Er, K. B. H. (2022). The impact of gardening on mental resilience in times of stress: a case study during the COVID-19 pandemic in Singapore. *Urban For. Urban Green.* 68:127448. doi: 10.1016/j.ufug.2021.127448
- Small, G., Shrestha, P., Metson, G. S., Polsky, K., Jimenez, I., and Kay, A. (2019). Excess phosphorus from compost applications in urban gardens creates potential pollution hotspots. *Environ. Res. Commun.* 1:91007. doi: 10.1088/2515-7620/ab3b8c
- Solis-Toapanta, E., Fisher, P. R., and Gómez, C. (2020). Effects of nutrient solution management and environment on tomato in small-scale hydroponics. *HortTechnology* 30, 697–705. doi: 10.21273/HORTTECH04685-20
- Srinivasan, R., and Huang, C. (2009). The effect of simulated borer infested shoot pruning on yield parameters of eggplant. *J. Asia Pac. Entomol.* 12, 41–43. doi: 10.1016/j.aspen.2008.10.001
- Stevens, D. J., Murray, D., Diepeveen, D., and Toohey, D. (2022). AdaptaLight: An inexpensive PAR sensor system for daylight harvesting in a micro indoor smart hydroponic system. *Horticulturae* 8:105. doi: 10.3390/horticulturae8020105
- Storino, F., Arizmendiarieta, J. S., Irigoyen, I., Muro, J., and Aparicio-Tejo, P. M. (2016). Meat waste as feedstock for home composting: effects on the process and quality of compost. *Waste Manag.* 56, 53–62. doi: 10.1016/j.wasman.2016.07.004
- Suarez, E., Agrawal, P., Izzo, L. G., and Gómez, C. (2023). Intumescence response by tomato plants grown in a greenhouse or indoors using two types of soilless culture systems. *HortScience* 58, 1550–1559. doi: 10.21273/HORTSCI17415-23
- Suárez-Cáceres, G. P., Lobillo-Eguíbar, J., Fernández-Cabanás, V. M., Quevedo-Ruiz, F. J., and Pérez-Urrestarazu, L. (2021). Polyculture production of vegetables and red hybrid tilapia for self-consumption by means of micro-scale aquaponic systems. *Aquac. Eng.* 95:102181. doi: 10.1016/j.aquaeng.2021.102181
- Suathong, W., Ongkunaruk, P., and Trevanich, S. (2024). The shelf life and quality of green pea (*Pisum sativum*) sprouts during storage at different refrigerated temperatures and durations of indirect-sunlight exposure. *Postharvest Biol. Technol.* 207:112590. doi: 10.1016/j.postharvbio.2023.112590
- Supapvanich, S., Anan, W., and Chimsornthorn, V. (2019). Efficiency of combinative salicylic acid and chitosan preharvest-treatment on antioxidant and phytochemicals of ready to eat daikon sprouts during storage. *Food Chem.* 284, 8–15. doi: 10.1016/j.foodchem.2019.01.100
- Suwardi, A. B., Navia, Z. I., Mubarak, A., and Mardudi, M. (2023). Diversity of home garden plants and their contribution to promoting sustainable livelihoods for local communities living near Serbajadi protected forest in Aceh Timur region, Indonesia. *Biol. Agric. Hortic.* 39, 170–182. doi: 10.1080/01448765.2023.2182233
- Sykes, V. R., Bumgarner, N. R., Keadle, S. B., Wilson, A., and Palacios, F. (2021). Citizen science in vegetable garden cultivar evaluation in Tennessee. *Horticulturae* 7:422. doi: 10.3390/horticulturae7110422
- Tanzilli, D., D'Alessandro, A., Tamelli, S., Durante, C., Cocchi, M., and Strani, L. (2023). A feasibility study towards the on-line quality assessment of pesto sauce production by NIR and chemometrics. *Food Secur.* 12:1679. doi: 10.3390/foods12081679
- Tatano, F., Pagliaro, G., Di Giovanni, P., Floriani, E., and Mangani, F. (2015). Biowaste home composting: experimental process monitoring and quality control. *Waste Manag.* 38, 72–85. doi: 10.1016/j.wasman.2014.12.011
- Taylor, J. R., Lovell, S. T., Wortman, S. E., and Chan, M. (2017). Ecosystem services and tradeoffs in the home food gardens of African American, Chinese-origin and Mexican-origin households in Chicago, IL. *Renew. Agric. Food Syst.* 32, 69–86. doi: 10.1017/S174217051600003X
- Teng, Z., Luo, Y., Pearlstein, D. J., Wheeler, R. M., Johnson, C. M., Wang, Q., et al. (2023). Microgreens for home, commercial, and space farming: a comprehensive update of the most recent developments. *Annu. Rev. Food Sci. Technol.* 14, 539–562. doi: 10.1146/annurev-food-060721-024636
- Thamilini, J., Wekumbura, C., Mohotti, A. J., Kumara, A. P., Kudagammana, S. T., Silva, K. D. R. R., et al. (2019). Organized homegardens contribute to micronutrient intakes and dietary diversity of rural households in Sri Lanka. *Frontiers in Sustainable Food Systems* 3:94. doi: 10.3389/fsufs.2019.00094
- Theodorou, A., Panno, A., Carrus, G., Carbone, G. A., Massullo, C., and Imperatori, C. (2021). Stay home, stay safe, stay green: the role of gardening activities on mental health during the Covid-19 home confinement. *Urban For. Urban Green.* 61:127091. doi: 10.1016/j.ufug.2021.127091
- Tieman, D., Zhu, G., Resende, M. F. R., Lin, T., Nguyen, C., Bies, D., et al. (2017). A chemical genetic roadmap to improved tomato flavor. *Science* 355, 391–394. doi: 10.1126/science.aal1556
- Tien, P. W., Wei, S., Liu, T., Calautit, J., Darkwa, J., and Wood, C. (2021). A deep learning approach towards the detection and recognition of opening of windows for effective management of building ventilation heat losses and reducing space heating demand. *Renew. Energy* 177, 603–625. doi: 10.1016/j.renene.2021.05.155
- Tulipani, S., Alvarez-Suarez, J. M., Busco, F., Bompadre, S., Quiles, J. L., Mezzetti, B., et al. (2011). Strawberry consumption improves plasma antioxidant status and erythrocyte resistance to oxidative haemolysis in humans. *Food Chem.* 128, 180–186. doi: 10.1016/j.foodchem.2011.03.025

- Turnšek, M., Gangenes Skar, S., Piirman, M., Thorarinsdottir, R. I., Bavec, M., and Junge, R. (2022). Home gardening and food security concerns during the COVID-19 pandemic. *Horticulturae* 8:778. doi: 10.3390/horticulturae8090778
- Vázquez, M. A., and Soto, M. (2017). The efficiency of home composting programmes and compost quality. *Waste Manag.* 64, 39–50. doi: 10.1016/j.wasman.2017.03.022
- Visvanathan, G., Patil, K., Suryawanshi, Y., and Chumchu, P. (2023). Sensor based dataset to assess the impact of urban heat island effect mitigation and indoor thermal comfort via terrace gardens. *Data Brief* 49:109431. doi: 10.1016/j.dib.2023.109431
- Wang, S., Shi, M., Zhang, Y., Pan, Z., Xie, X., Zhang, L., et al. (2022). The R2R3-MYB transcription factor FaMYB63 participates in regulation of eugenol production in strawberry. *Plant Physiol.* 188, 2146–2165. doi: 10.1093/plphys/kiac014
- Wang, C., Zhang, J., Li, J., Xie, J., and Chai, Q. (2024). Exogenous methyl jasmonate regulates endogenous hormone synthesis of soilless cultivated Chinese chive to promote growth physiology and photosynthesis. *Sci. Hortic.* 327:112861. doi: 10.1016/j.scienta.2024.112861
- Wang, X., Zhang, M., Wang, X., Yang, D., and Zhang, X. (2023). Synergistic regulation of the growth and fruit quality of cherry tomato by remaining fruit spikes and number of interspike leaves after pruning. *Sci. Hortic.* 322:112458. doi: 10.1016/j.scienta.2023.112458
- Wiersema, S. G., and Booth, R. H. (1987). A potential family food production system for warm climates based on potato production from true seed in home gardens and simple processing. *Agric. Syst.* 23, 95–105. doi: 10.1016/0308-521X(87)90088-6
- Winter, K., Aranda, J., and Holtum, J. A. M. (2005). Carbon isotope composition and water-use efficiency in plants with crassulacean acid metabolism. *Funct. Plant Biol.* 32, 381–388. doi: 10.1071/FP04123
- Wongkiew, S., Hu, Z., Chandran, K., Lee, J. W., and Khanal, S. K. (2017). Nitrogen transformations in aquaponic systems: a review. *Aquac. Eng.* 76, 9–19. doi: 10.1016/j.aquaeng.2017.01.004
- Wu, C., Chou, L., Huang, H., and Tu, H. (2022). Perceived COVID-19-related stress drives home gardening intentions and improves human health in Taiwan. *Urban For. Urban Green.* 78:127770. doi: 10.1016/j.ufug.2022.127770
- Wyon, D. P. (2004). The effects of indoor air quality on performance and productivity. *Indoor Air* 14, 92–101. doi: 10.1111/j.1600-0668.2004.00278.x
- Xiao, Z., Pan, Y., Wang, C., Li, X., Lu, Y., Tian, Z., et al. (2022). Multi-functional development and utilization of rapeseed: comprehensive analysis of the nutritional value of rapeseed sprouts. *Food Secur.* 11:778. doi: 10.3390/foods11060778
- Xue, L., Dai, H., and Lei, J. (2015). Creating high polyploidy pink-flowered strawberries with improved cold tolerance. *Euphytica* 206, 417–426. doi: 10.1007/s10681-015-1499-8
- Xue, L., Wang, Z., Zhang, W., Li, Y., Wang, J., and Lei, J. (2016). Flower pigment inheritance and anthocyanin characterization of hybrids from pink-flowered and white-flowered strawberry. *Sci. Hortic.* 200, 143–150. doi: 10.1016/j.scienta.2016.01.020
- Xue, L., Wang, J., Zhao, J., Zheng, Y., Wang, H., Wu, X., et al. (2019). Study on cyanidin metabolism in petals of pink-flowered strawberry based on transcriptome sequencing and metabolite analysis. *BMC Plant Biol.* 19:423. doi: 10.1186/s12870-019-2048-8
- Yoon, Y., Kuppusamy, S., Cho, K. M., Kim, P. J., Kwack, Y., and Lee, Y. (2017). Influence of cold stress on contents of soluble sugars, vitamin C and free amino acids including gamma-aminobutyric acid (GABA) in spinach (*Spinacia oleracea*). *Food Chem.* 215, 185–192. doi: 10.1016/j.foodchem.2016.07.167
- Yue, J., Liu, Z., Zhao, C., Zhao, J., Zheng, Y., Zhang, H., et al. (2022). Comparative transcriptome analysis uncovers the regulatory roles of MicroRNAs involved in petal color change of pink-flowered strawberry. *Front. Plant Sci.* 13:854508. doi: 10.3389/fpls.2022.854508
- Zasada, I., Schmutz, U., Wascher, D., Kneafsey, M., Corsi, S., Mazzocchi, C., et al. (2019). Food beyond the city – Analysing foodsheds and self-sufficiency for different food system scenarios in European metropolitan regions. *City Cult. Soc.* 16, 25–35. doi: 10.1016/j.ccs.2017.06.002
- Zhang, S., Guo, X., Li, J., Zhang, Y., Yang, Y., Zheng, W., et al. (2022). Effects of light-emitting diode spectral combinations on growth and quality of pea sprouts under long photoperiod. *Front. Plant Sci.* 13:978462. doi: 10.3389/fpls.2022.978462
- Zhang, Y., Zhang, W., Wu, W., Farag, M. A., Wang, L., Xiao, S., et al. (2023). Critical assessment of the delivery methods of chemical and natural postharvest preservatives for fruits and vegetables: a review. *Crit. Rev. Food Sci. Nutr.* 1–23, 1–23. doi: 10.1080/10408398.2023.2289071
- Zhao, T., Nie, J., Yan, X., and Xue, W. (2024). Identifying the critical LED light condition for optimum yield and flavonoid of pea sprouts. *Sci. Hortic.* 327:112801. doi: 10.1016/j.scienta.2023.112801
- Zhao, X., Zhang, K., Zhang, H., Bi, M., He, Y., Cui, Y., et al. (2023). Tomato short internodes and pedicels encode an LRR receptor-like serine/threonine-protein kinase ERECTA regulating stem elongation through modulating gibberellin metabolism. *Front. Plant Sci.* 14:1283489. doi: 10.3389/fpls.2023.1283489
- Zheng, Z., Zhang, Y., Gao, Y., Shen, Y., and Huang, Y. (2023). GRAS family transcription factor FaSCL8 regulates FaVPT1 expression mediating phosphate accumulation and strawberry fruit ripening. *Fruit Res.* 3:15. doi: 10.48130/FruRes-2023-0015
- Zhu, Y., Gu, H., Li, H., Lam, S. S., Verma, M., Ng, H. S., et al. (2023). Phytoremediation of contaminants in urban soils: a review. *Environ. Chem. Lett.* 22, 355–371. doi: 10.1007/s10311-023-01663-6



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Factors affecting the adoption of high technology in vegetable production in Hanoi, Vietnam

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High-tech vegetable production is becoming a priority in agricultural development in Vietnam in the context of digital economic development. This study aims at identifying factors involving the adoption of high technology in vegetable production by local farmers in Hanoi. We used the theory of planned behavior and other farmers' personal, social and economic factors to develop empirical model and hypotheses. Primary data was collected from a survey of 450 vegetable producers in Hanoi using cluster sampling method combined with random selection. Then, binary logit model was used to analyze the impact of influencing factors. Results showed that there were 7 factors having significant influences the decision to apply technology in vegetable production of farmers including attitude on high tech production, access to information, size of farm, member of extension organization, education level, access to credit and perceived behavior control, in which attitude variable was the most influential factor. Main management implications raised included enhancing access to technological information, providing demonstration visits, giving more extension services, improving social inclusion and implementing hi-tech training for farmers in vegetable production.

KEYWORDS

binary logit regression, high-technology agriculture, social inclusion, vegetable production, theory of planned behavior

1 Introduction

In the context of the industrial revolution 4.0, high-tech agriculture plays a very important role in the process of restructuring agricultural production and is a solution to solve the problem of food security and improve quality. Agricultural products and environmentally friendly (Cavatassi et al., 2011; Aung et al., 2021; Truong et al., 2022). Currently, the application of high technology in agricultural production has been replicated in developed and developing countries to improve productivity, meet the market's demand for agricultural product quality and ensure food security (Cavatassi et al., 2011; Dalton et al., 2011; Kassie et al., 2015; Basuki et al., 2019). In the field of vegetable production, to achieve the above goals, high tech vegetable (HTV) practices have been introduced and applied in many forms from managing soil structure, saving irrigation water, diversifying crops and use organic fertilizers. HTV brings many benefits to farmers and depending on specific conditions, the benefits may be different (Bokusheva et al., 2012; Fisher et al., 2015; Fischer, 2016; Khonje et al., 2018). The general benefits of proven technology models include being environmentally friendly, protecting ecosystems, using resources efficiently and having high economic value. Despite the above superior attributes and clear potential benefits, the use of high technology in vegetable growing

is still low in developing countries that rely heavily on agriculture (Katengeza et al., 2018; Lam et al., 2018; Truong et al., 2022).

As to Liu et al. (2018), HTV practices adoption is a dynamic process that depends on factors such as farming households' farms' features, environmental challenges, and government supporting policies. For example, Moser and Barrett (2016) argued that HTV producing depended on farmers' personal, economic, social and cultural characteristics. Pardey et al. (2016a,b) also implied that factors such as financial investment and knowledge of HTV might explain their application. However, the literature concluded that there were no universal factors can explain HTV adoption and that factor differ based on the contexts (Teklewold et al., 2013; Rapsomanikis, 2015; Sharma, 2015). In developed nations, for example, Kassie et al. (2015) indicated that factors like capital, social networking, and access to information are positively related to HTV adoption. Larsen (2018) also found that HTV practices adoption is positively related to education level, gender, land tenure and farm size.

With favorable conditions and diverse climates, Vietnam has long been known for its well-developed agriculture, in which growing vegetables is essential because green vegetables are an important source of the Vietnam people's food (Le and Nguyen, 2019; Mai and Truong, 2022). Facing with increasingly complex challenges, such as climate change, international competition, and growing demands for food safety, Vietnam has been accelerating agricultural modernization and improving methods in vegetable production (Le and Truong, 2019). Although HTV growing has contributed to agricultural development and improved farmer welfare, policies promoting high-tech agriculture in general and HTV growing in particular in Vietnam still have shortages. The fundamental knowledge for growing vegetables is still based on traditional processes and there is a great need to improve reliable scientific information to promote the application of modern and sustainable vegetable growing technologies (Dat and Truong, 2020; Truong et al., 2022).

This growing need is based on the fact that high-tech vegetables have economic, health, ecological and cultural value (Le and Truong, 2019). Firstly, high-tech vegetable growing with superior attributes over traditional vegetable growing can contribute to poverty reduction, malnutrition and ensuring food security. In the context of people in Vietnamese urban areas increasingly favoring foods of origin and safety, high-tech vegetables will help customers better identify production processes, safety features and domestically brands (Dat and Truong, 2020). High-tech vegetables also contribute to eliminating nutritional deficiencies in the meals of children and women. They also have higher market prices with an inexpensive investment process if knowledge and support are available, thereby helping farmers improve their livelihood income and long-term economic incentives for community (Truong et al., 2022). Secondly, switching to high-tech vegetable growing will also help improve social aspects of agricultural production, which is the participation of women and the poor in management processes and application of new technology, hence contributing to increasing knowledge for the community. In addition, the dissemination of new techniques and supporting information will also make the network of local civic organizations grow stronger, which increases social inclusion in agricultural and community development (Le and Nguyen, 2019). Thirdly, high-tech vegetables are often better adapted to harsh climatic conditions and are short duration crops. With usually shorter growing cycles than staple crops, high-tech vegetables can be less affected by

environmental threats such as temperature fluctuations and drought. Basically, they require less space than traditional crops and can maximize natural resources when water and nutrients are scarce. This makes them suitable for Vietnam as the area continues to experience shorter and unreliable rainfall patterns under rapidly changing and unpredictable climatic conditions (Le and Truong, 2019; Dat and Truong, 2020; Truong et al., 2022).

In the literature, up to now, the majority of studies on technology application in agricultural production focus on a certain group of solutions or an acceptance model in the form of 'Yes' or 'No' with influencing factors are separate from each other. There are studies that focus on psychological factors such as studies by Moser and Barrett (2016), Lam et al. (2018), and Mulema et al. (2022). Besides, there are studies focusing on physical factors and socio-economic characteristics of farming households. Some other studies give priority to factors belonging to support policies and the external social environment (Kassie et al., 2015; Katengeza et al., 2018; Aung et al., 2021). There have not been many studies that combine these groups of factors to have a more complete picture of the drivers of technology adoption in agricultural production by farmers in developing countries (Lam et al., 2018; Dat and Truong, 2020; Bassyouni et al., 2022).

This article fills in the above gap with the purpose of analyzing factors affecting technology acceptance in vegetable production by smallholder farmers in a country with an emerging economy, Vietnam. While most recent literature only analyzed the impact of factors separately (e.g., experience, education, training or access to credit), this study analyzed them simultaneously, in particular, the interaction between psychological factors, farmer characteristics and environmental factors in driving the application of technology in vegetable production. Therefore, this is one of the first studies to mix groups of factors to find the interaction between them and their influence on the technology acceptance behavior of farmers. We believe that such an approach is essential to design policies and solutions to promote technology applications in agricultural production in general and vegetable production in particular in developing countries.

Our article is organized as follows: section 2 introduces the analysis framework and model development; section 3 describes data collection and analysis process; section 4 presents the study results and discussions; section 5 includes conclusions and management implications.

2 Analytical framework and model development

According to Mukasa (2018), it is possible to plan solutions to promote agricultural application of high technology among farmers if the factors determining their behavior to apply high technology in production are identified. So far, researchers have used a number of adoption models to explain intentions actual behaviors, in which Theory of Planned Behavior (TPB) is one of the most commonly used theories. The TPB model assumes that a behavior can be predicted or explained by intentions to perform that behavior. Ajzen (1991) believed that intention is a function of three influencing factors including, attitudes toward behavior; subjective norms and perceived behavioral control. Dima (2013) implied that TPB theory is suitable for empirical research in identifying important factors from which

policies and solutions can be proposed - it is one of the best models to implement policies and solutions after research. TPB has been applied in many empirical studies on technology acceptance behavior of individuals, households and businesses and is suitable for the context of many countries around the world (Gadenne et al., 2011; Dima, 2013; Elmustapha et al., 2018).

In addition, the decision to adopt new technology is often based on comparing the volatile benefits of new initiatives with the costs of adoption (Kristjanson et al., 2015; Ankuyi and Tham, 2022). Lambrecht et al. (2014) added social network factors to the factors affecting the application of technology. Although there are many ways to categorize factors to determine the application of technology, the classification depends on the current technology being studied, the location, and the researcher's interest in choosing the suitable study (Larsen, 2018). In this study, we combine factors from the TPB and other personal, social and economic factors of households identified in previous studies to analyze determinants of high-tech vegetable production in Hanoi. The proposed analytical framework is shown in Figure 1.

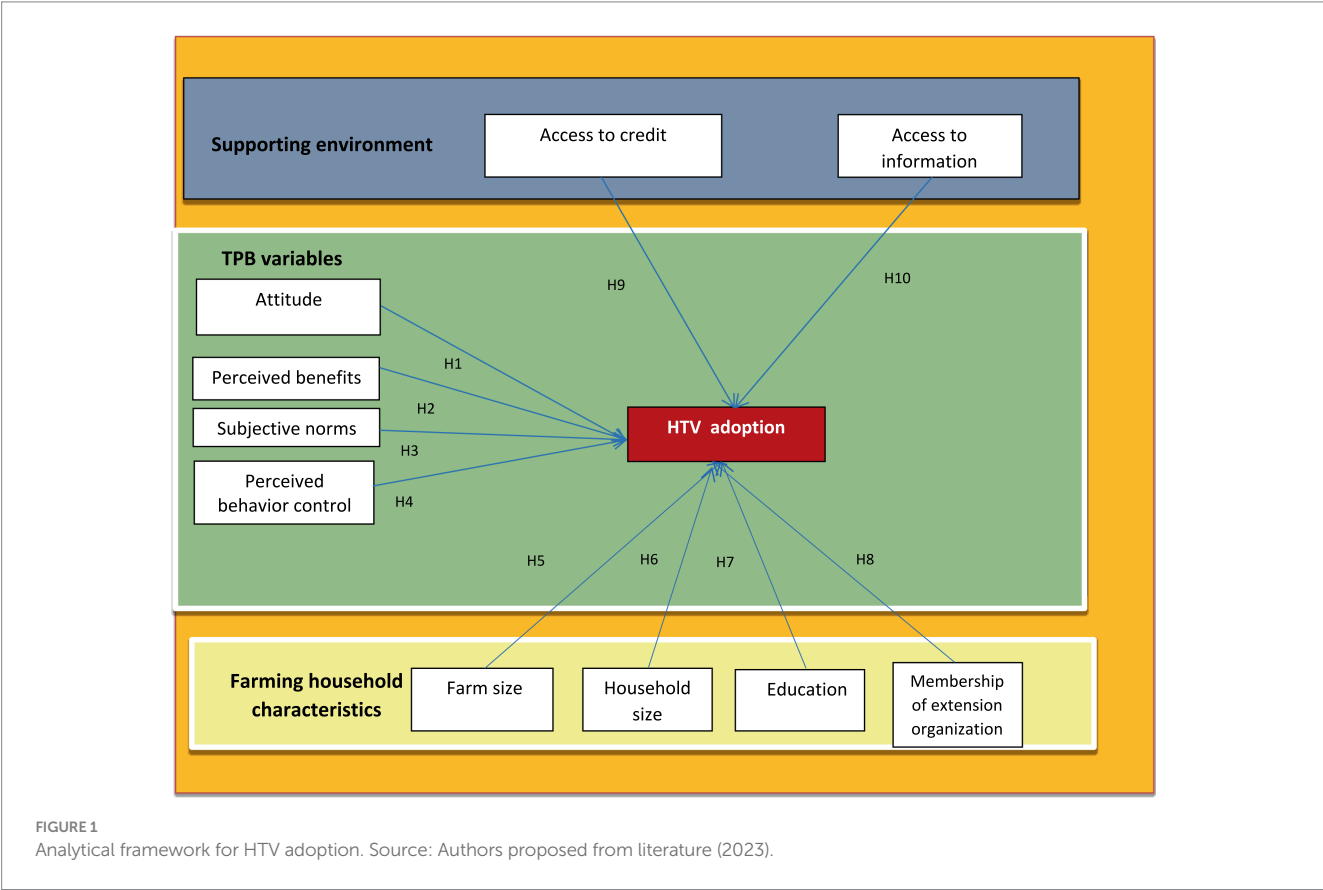
2.1 Data collection and analysis

Attitude on high tech production: TPB proves that individual attitude is a crucial factor that directly affects intentional behavior, and this hypothesis has been verified through various research papers in technological application behaviors (Ajzen, 1991; Khonje et al., 2015). Basically, an individual positive or negative attitude toward a behavior

is related to his evaluation of the outcome of that behavior (Baumgartetz et al., 2012; Kristjanson et al., 2015). Elmustapha et al. (2018) found that farmer' attitudes toward high tech production relating to their evaluation about the form, price, process and benefits of the application. In addition, Dima (2013) indicated that attitudes not only include subjective perceptions and personal feelings about the advantages or disadvantages of a solution but also involve the compatibility between the values that the solution may bring with that individual's expectations. When people have a positive attitude toward technology, their likelihood of accepting the use of technology may also increase (Gadenne et al., 2011; Kassie et al., 2015; Negatu and Parikh, 2019).

Hypothesis H1: Attitude on high tech production has positive impact on the adoption of HTV production.

Perceived benefits: Perceived benefits are related to the willingness to adopt something new compared to traditional practice (Kristjanson et al., 2015; Elmustapha et al., 2018). User behavior is shaped by the perception of higher benefits achieving through the use of a specific solution (Gadenne et al., 2011). Mottaleb et al. (2016) argued in their theoretical framework that perceived benefits can be defined as the extent to which users believe that using products/services will yield significant effectiveness for them. In the case of applying technology to agricultural production, Mukasa (2018) believed that the characteristics of the technology play an essential role in determining its application. When farmers consider technology adoption, they decide whether the technology has positive, efficient, and profitable



(Muthumanickam et al., 2022). Additionally, farmers expect high farm income to increase their capital, enabling them to increase such as improved cultivars, seeds, and fertilizer quality. The relationship between perceived benefits and technology adoption plays a vital role in household decisions about technology adoption in agriculture production (Negatu and Parikh, 2019).

Hypothesis H2: Perceived benefit has positive impact on the adoption of HTV production.

Subjective norm: Ajzen (1991) defined subjective norms, also known as social influence, as the perceptions of influencers who think that an individual should or should not perform a behavior. Subjective norms can be described as an individual's perception of social pressures to perform or not perform a behavior (Dima, 2013). According to TPB, subjective norms can be formed through sensing normative beliefs from people or social factors that influence consumers (such as family, friends, colleagues, media...). The degree of impact of subjective normative belief factors on consumers' buying tendency depends on: (1) the level of support/opposition for the consumer's purchase and (2) the consumer's motivation (Gadenne et al., 2011; Liu et al., 2018). In case of farming, farmers may follow the wishes of influencers. The degree of influence of related people on application behavioral trends and the motivation to follow related people are two basic factors to evaluate subjective norms. The stronger the level of intimacy of the people involved with the individual, the greater the influence on their high tech application. Researches by Meijer et al. (2015) and Moser and Barrett (2016) found that social factors such as influence from family and society are important sources affecting people's interest in applying new technology. Some other studies built and tested a model based on TPB with the effects of social agents (family, society, government, media, and communication) in addition to attitudes also show significant relation with actual behaviors (Matuschke and Qaim, 2001; Njuki et al., 2018; Negatu and Parikh, 2019).

Hypothesis H3: Subjective norm has positive impact on the adoption of HTV production.

Perceived behavioral control: Each individual's perceived behavioral control is related to their self-assessment of the difficulty or ease of performing a behavior (Pardey et al., 2016a,b; Elmustapha et al., 2018). According to Ajzen (1991), this perceived control factor comes from the confidence of the individual who intends to perform the behavior and the easy and favorable conditions for performing the behavior. The more resources and opportunities they have, the less resistance they think there will be, and the greater the perceived control over behavior will be. Ntshangase et al. (2018) believed that perceived behavioral control is measured through the person intending to perform the behavior's awareness of having sufficient information and other necessary conditions for his or her decision.

Hypothesis H4: Perceived behavioral control has positive impact on the adoption of HTV production.

Farm size: The size of the farm has a positive or negative influence on the decision to apply technology in farming in many empirical studies (Lowder et al., 2016; Ojiako et al., 2017; Noack and Larsen, 2019). A study in Malawi demonstrated a positive relationship

between farm size and farmers' decision to apply technology (Orr et al., 2015). Prager and Posthumus (2020) also found a similar relationship in Europe in the case of coffee farmers. However, some studies show a negative relationship between farm size and the application of new technologies in agriculture (Noack and Larsen, 2019). Small-scale farms are often encouraged to adopt technology, especially in cases where innovation requires limited inputs such as labor or land. In addition, Ojiako et al. (2017) in Nigeria indicated that farmers with small land had higher motivation to apply land-saving technology to increase productivity.

Hypothesis H5: Farm size has positive impact on the adoption of HTV production.

Household size: There is a relationship between household size and technology application in agricultural production (Sharma, 2015; Shiferaw et al., 2015). Research by Sitko et al. (2014) discovered that there is a positive relationship between these two variables in Zambia. Households with many members will have an easier time meeting the number of workers, leading to reduced pressure on labor costs in the early stages of technology application. Therefore, they tend to apply higher technology than families with fewer members. However, Sodjinou et al. (2016) found a negative relationship exists between household size and the adoption of new technology in rice farming in Benin. The author explains that when households have more members, they need more spending for other household purposes and less funds to adopt new technology, so they tend to reduce interest in long-term investments for technology adoption. There are also some studies that do not find a significant relationship between household size and technology adoption in agriculture (Rapsomanikis, 2015; Teshome et al., 2016).

Hypothesis H6: Household size has positive impact on the adoption of HTV production.

Education: Education level is positively related to technology application in agriculture in many previous studies (Teklewold et al., 2013; Ogada et al., 2014; Shiferaw et al., 2018). The higher the level of education of farmers, the easier it will be for them to access and use information related to the application of new technology. Studies on applying new technologies in aquaculture and organic fertilizers have concluded that educational attainment significantly affects households' technology adoption (Ndiritu et al., 2014; Aung et al., 2021). Highly educated farm owners often accumulate more knowledge and experience over time, providing a better evaluation of the potential of applying technology.

Hypothesis H7: Education level has positive impact on the adoption of HTV production.

Membership of agricultural extension organizations: Agricultural extension activities have an important impact on farmers' technology adoption behavior (Mulema et al., 2022). In developing countries, local agricultural extension associations are the main focal points for disseminating information about new technologies in agricultural production and the benefits of these technologies. When farmers join agricultural extension associations, they have a higher chance of receiving technology information and technical assistance.

Agricultural extension organizations also connect farmers with technology distributors for direct consultation and installation, thereby increasing the ability of farmers to apply technology in production. Many previous studies have demonstrated this positive relationship in developing countries (Marenja and Barrett, 2011; Grabowski et al., 2016; Lam et al., 2018).

Hypothesis H8: Membership of agricultural extension organizations has positive impact on the adoption of HTV production.

Access to credit: Access to credit influenced a farmer's decision to adopt improved technology positively in many experimental studies (Fischer, 2016; Floro et al., 2018; Dissanayake et al., 2022). Farmers having access to credit are more likely to adopt new technology normally, partly because new technologies will come with investments and increased costs such as labor and fuel. Receiving financial support will help farmers reduce the burden of initial investment as well as in the process of operating technology. This leads to a higher likelihood of adopting their technology. Ogundari and Bolarinwa (2018) showed that credit access had a positive relationship with technology adoption by farmers but to different degrees and this is the most important factor determining technology adoption by farmers. New technology is often associated with an initial investment and will bring long-term profits to farmers. This economic problem will determine the acceptance of technology by farmers. And better access to credit will help make economic aspects more feasible (Baumgartetz et al., 2012; Simitowe et al., 2019).

Hypothesis H9: Access to credit has positive impact on the adoption of HTV production.

Access to information about new technology: Farmers will carefully study existing technology and the effectiveness of new technologies before deciding whether to adopt them (Kabunga et al., 2012; Burton, 2014; Dissanayake et al., 2022). They do not simply apply but also proceed from the initial step of awareness, then learn about the technology before finally deciding its application in their agricultural production (Di Falco et al., 2018). There is a positive relationship between access to information and technology adoption by farmers in studies by Di Falco and Bulte (2013) and Brown et al. (2019). Access to information can be done in traditional ways such as meeting farmers directly to disseminate techniques at agricultural fairs, agricultural extension associations, farmer associations or projects to strengthen the capacity of farmers. However, accessing information can also be done indirectly through television, promotional programs and especially social networks in today's modern society.

Hypothesis H10: Access to information about new technology has positive impact on the adoption of HTV production.

3 Data collection and analysis

The model in this study was estimated using data obtained from primary and secondary data of vegetable producers in Hanoi. First, we mapped the main vegetable production districts of Hanoi and then collected secondary data on vegetable farmers

through the District Statistics Office and Agriculture Departments. Information collected includes the number of vegetable growing households, list of households, vegetable growing models, vegetable growing area and the current status of local vegetable production activities. To collect primary data, the study used the following formula to estimate the sample size (Hair et al., 2013):

$$n = \frac{N}{1 + N * e^2}$$

In which n is the sample size, N is the total number of producers in population, e is accepted errors.

With a total number of households growing vegetables of 10,723 and 5% errors, the calculated sample to ensure reliability was 435. In fact, a stratified random sample of 450 producers was surveyed. The survey is conducted by the authors focusing on districts of producing vegetables such as Dan Phuong, Dong Anh, Ung Hoa, Phuc Tho and Thanh Tri districts. The total surveyed area was more than 5,000 hectares. The area of vegetables applying high technology was nearly 1,260 hectares, reaching nearly 26% of total high technology vegetable area in Hanoi. To select households for interview and research, first research the distribution of 90 households in each of the above districts, and then randomly draw 3 wards with vegetable production in each district. In each ward, we randomly selected 30 households according to the list provided by the local government. The research team approached households in the evening when the head of the household was usually present. At each household, we introduced the objectives of the study and asked for households' consent to participate. If they agreed, they would check the "agree" box and sign the survey form. Absent households were replaced by a list of 10 backup households also randomly drawn from the list of households. The official investigation was conducted in July and August 2023 in Hanoi.

Based on the empirical model proposed in Section 2, the binary logit model was used to analyze the factors affecting the adoption of high technology in vegetable production in Hanoi. The dependent variable Y had two values, 0 and 1, in which 0 represented the no application of high technology application, and 1 represented the adoption of high technology in vegetable production. The probability function was expressed as:

$$P_i = \log_e \left[\frac{P_i}{1 - P_i} \right] = \beta_0 + \sum_{i=1}^n \beta_n X_n$$

P_i : probability of high technology adoption of farming households.

X_i : impact factors.

β_i : coefficient of marginal impact.

Experimentally, the regression equation was expressed as follows:

$$\text{Pr } ADOPT_i = \alpha + \beta_1 * ATT + \beta_2 * PB + \beta_3 * SN + \beta_4 * PBC + \beta_5 * FSIZE + \beta_6 * HHSIZE + \beta_7 * EDU + \beta_8 * MEO + \beta_5 * ACRE + \beta_6 * ACIF + e_i$$

The description and measurement of variables is present in Table 1.

TABLE 1 Description of variables in the research model.

Variables symbol	Meaning	Scale	Literature sources
PrADOPT	The decision to apply high technology of farmers in vegetable production	1: adoption of HTV in production 0: No adoption	Matuschke and Qaim (2001), Gadenne et al. (2011), Kassie et al. (2015), Negatu and Parikh (2019)
ATT	Attitude on HTV production	1 to 5 points	Kristjanson et al. (2015), Baumgartetz et al. (2012), Elmustapha et al. (2018)
PB	Perceived benefits of HTV production	1 to 5 points	Gadenne et al. (2011), Kassie et al. (2015), Mottaleb et al. (2016), Negatu and Parikh (2019)
SN	Subjective norm	1 to 5 points	Matuschke and Qaim (2001), Dima (2013), Meijer et al. (2015), Moser and Barrett (2016)
PBC	Perceived behavior control	1 to 5 points	Pardey et al. (2016a,b), Elmustapha et al. (2018), Negatu and Parikh (2019)
FSIZE	Farm size	Square meter	Lowder et al. (2016), Ojiako et al. (2017), Noack and Larsen (2019)
HHSIZE	Household size	person	Sharma (2015), Shiferaw et al. (2015), Shiferaw et al. (2015)
EDU		Years of schooling	Teklewold et al. (2013), Ogada et al. (2014), Shiferaw et al. (2018)
MEO	Membership of extension organizations	1: membership 0: no membership	Marenja and Barrett (2011), Grabowski et al. (2016), Lam et al. (2018), Mulema et al. (2022)
ACRE	Access to credit	1: access to credit source in agricultural production 0: no access to credit source	Floro et al. (2018), Fischer (2016), Dissanayake et al. (2022), Simtowe et al. (2019), Baumgartetz et al. (2012)
ACIF	Access to HTV information	1: have accessed to HTV information 0: no access to HTV information	Kabunga et al. (2012), Burton (2014), Dissanayake et al. (2022), Brown et al. (2019)

Source: Research design (2023).

4 Results and discussions

4.1 High technology vegetable production in study area

Since 2009, Hanoi's high-tech agricultural application program has been promoted. After more than 14 years of implementation, it has had a positive impact on the growth of Hanoi's agricultural industry, reaching an average growth rate of 8.5%/year (Department of Agricultural and Rural Development, 2022). High-tech agricultural production achieved an average income more than 2 times higher than the average production value of the entire city, typically: high-quality vegetables reach about 450–500 million VND/ha/year, many models reach 2 billion VND/hectare/year. Currently, the area of high-tech vegetables alone reached 13,655 hectares, accounting for nearly 22.1% of the total cultivated vegetable area. To achieve the above achievements, Hanoi has invested in research, built models, and applied new technical solutions and technologies. Common technologies applied included biotechnology in breeding (*in vitro* plant tissue culture, vegetable grafting technology), net house technology, drip irrigation technology with pressurization and fertilizer supply system, post-harvest technologies, heat drying technology, film forming technology using automatic or semi-automatic machines in harvesting products. In addition, application of water-saving irrigation technology is also a relatively common model of use in vegetable growing areas with

irrigation forms such as drip, local sprinkler and local underground irrigation. The advantage of this system is that it saves 30–60% of water compared to traditional methods, reduces labor, improves crop productivity and quality, and can especially provide fertilizer through a small irrigation system.

4.2 Socio-economic characteristics of the survey sample

Survey results in Table 2 showed that within 450 producers out of a total of 436 respondents, 53.9% were male, and 46.1% were female; the ratio of men and women participating in the interview was quite balanced. The average age of respondents was 42.1, of which the age group from 41 to 50 accounts for the highest proportion (51.2%), this is also the common age group of household heads and the main labor force of farming households in Hanoi. On average, each household participating in the interview had 4.4 people. Over 59% of respondents had graduated from secondary school and the average number of years of schooling was 9.8 years. In the research sample, 34.1% of households applied technology in vegetable production and 65.9% applied traditional methods. The average vegetable growing area per household ranged from 2 to 20 *sao* (1 *sao* = 1,000 m²). Up to 62.5% of households had average income, high income households accounted for only 5.7% and low income households accounted for 17.6%.

TABLE 2 Socio-economic characteristics of the sample.

Indicator	Number	%	Average
Gender			
Male	243	53.9	
Female	207	46.1	
Age			
20–30	33	7.5	42.1 years
31–45	155	34.4	
46–50	231	51.3	
Over 60	31	6.8	
Average people in household			4.4 persons
Education			
Primary	23	5.1	9.8 years
Secondary	202	44.9	
High school	168	37.3	
University	57	12.7	
Types of vegetable productions			
Traditional production	154	34.1	
HTV production	296	65.9	
Agricultural land area (sào = 1,000 m2)			
< 5	163	36.2	7.3 sao
5–10	148	32.9	
11–15	82	18.2	
> 15	57	12.7	
Household income/month			
Low	79	17.6	35.7 million VND
Average	281	62.5	
Fairly high	64	14.2	
High	26	5.7	

Source: Research results (2023).

4.3 Factors affecting the decision to apply high technology in vegetable production in Hanoi

Table 3 showed the results of analyzing the relationship between independent variables and the probability adoption of vegetable production in study area. We used binary logit regression with maximum likelihood estimation. Firstly, the results of model goodness of fit had significance value of $0.000 < 0.05$. Thus, the regression model was consistent. The -2 Log likelihood ($-2LL$) measured how well the model fitted the data. In this case, the $-2LL$ for the empty model (no independent variables) was 134.32. This significant reduction in $-2LL$ indicated that the independent variables included in the model improved their fit compared to the empty model. Furthermore, the Cox & Snell R^2 and Nagelkerke R^2 values were greater than 0.5, suggesting that the regression model had a good fit and explained a substantial portion of the variability of the dependent variable.

Logit regression results indicated that there were 8 factors having a significant influence on the application of technology in vegetable production in Hanoi including ATT, PBC, FSIZE, EDU, MEO, ACRE

and ACIF, in which ACIF had the strongest impact on farmers' decisions to apply technology (Table 3).

The logit regression equation is written as follows:

$$\text{Pr } ADOPT_i = 1.324 + 0.132 * ATT + 0.056 * PBC + 0.082 * FSIZE + 0.077 * EDU + 0.104 * MEO + 0.076 * ACRE + 0.115 * ACIF + e_i$$

From the results, farmer households' attitude toward technology was the factor that had the strongest influence on their decision to apply high technology in vegetable production. This result is consistent with the TPB model, which says that the attitude factor is crucial in individual intention-making. This result was also discovered in previous studies on technological application behavior of farmers (Gadenne et al., 2011; Kassie et al., 2015; Negatu and Parikh, 2019). The results show that when attitude increases by 1 point, technology acceptance increases by 13.2%. According to Kristjanson et al. (2015), attitude was farmers' perception of the application of technology. The more they understand the superiority of technology, the attitude will improve. Study by Elmustapha et al. (2018) in Malawi also found that demonstration field visits help improve farmers' attitudes toward

TABLE 3 Logit regression results.

	B	S.E.	Wald	Sig.	Exp(B)
Constant	1.324	0.463	2.189	0.037**	2.682
ATT	0.132	0.043	0.306	0.003***	1.256
PB	0.012	0.034	1.457	0.244	0.996
SN	0.091	1.042	2.147	0.078	1.025
PBC	0.056	0.357	2.173	0.043**	1.326
FSIZE	0.082	0.462	1.285	0.019**	2.043
HHSIZE	0.241	0.576	0.201	0.134	1.532
EDU	0.077	0.071	1.483	0.022**	0.642
MEO	0.104	0.873	1.212	0.037**	1.867
ACRE	0.076	0.945	2.391	0.032**	1.202
ACIF	0.115	0.303	0.176	0.026**	0.473

*** and **correspond for the significant level of 1 and 5%. Source: Research results (2023).

technology adoption. [Dima \(2013\)](#) found similar results in their study on the determinants of technology adoption by vegetable farmers in Malaysia. Technology demonstrations give farmers the opportunity to evaluate new technology before deciding whether to adopt it. Additionally, field demonstrations promote positive adaptive behavior among farmers as they have the opportunity to interact closely with technology enablers, thereby dispelling any doubts they may have about a particular technology. This result was also consistent with researches by [Kristjanson et al. \(2015\)](#) and [Baumgartetz et al. \(2012\)](#).

Access to information is the second most influential factor in farmers' decisions to apply technology in production. Applying new technology is a complex process and the more information farmers have, the more confident they are in their decision-making process. In previous studies by [Kabunga et al. \(2012\)](#), [Burton \(2014\)](#), access to information was also proven to be one of the most important factors in the decision-making process to apply technology for farming households. There are many channels that can provide information about technology applications in production to people. [Dissanayake et al. \(2022\)](#) showed that traditional forms of providing information such as agricultural associations, training and disseminating agricultural knowledge directly have a stronger impact than indirect channels such as community media. However, [Brown et al. \(2019\)](#) in the study in Asia pointed out those social networks were the most important channel for disseminating knowledge and information for farmers. Whether provided directly or indirectly, access to information is always an important factor in promoting technology adoption behaviors whether in developed or developing countries ([Di Falco and Bulte, 2013](#); [Lam et al., 2018](#)).

Participation in local agricultural extension organizations was the third most influential factor in the application of technology in vegetable growing by farmers. The positive sign of the coefficient was as expected that when farmers join agricultural extension organizations, the level of technology adoption would increase. This result is consistent with other findings from studies by [Marenja and Barrett \(2011\)](#), [Grabowski et al. \(2016\)](#), and [Lam et al. \(2018\)](#). Extension agencies were expected to increase awareness among farmers about techniques in agriculture production. Furthermore, adequate accompaniment of farmers by extension officers and other technical experts is crucial for technology adoption because their presence increases farmers' confidence in the applied technologies.

Farm size was proposed to have a positive influence on farmers' technology adoption decisions. As expected, this variable was statistically significant at the 5% significance level. This means that the larger farm, the more likely farmers were to adopt new technology. Although the vegetable growing area in the study area was fairly small, it was common for farmers to have multiple vegetable growing areas in different locations for different crops. This might spread production risks. Other studies also supported this hypothesis such as [Lowder et al. \(2016\)](#), [Ojiako et al. \(2017\)](#) and [Noack and Larsen \(2019\)](#). However, [Noack and Larsen \(2019\)](#) found a negative significant relationship between farm size and farmers' technology adoption.

Access to credit had also a positive effect on farmers' decision to apply advanced technology in our analysis. This result was consistent with initial expectation that access to credit had a direct impact on technology adoption. Farmers with access to credit were more likely to adopt new technologies ([Fischer, 2016](#); [Floro et al., 2018](#); [Dissanayake et al., 2022](#)). This makes sense because some technologies involve additional production costs, higher demands on labor and resources. Therefore, farmers' ability to cover these additional costs by taking out loans was an important factor in their decision to adopt the production technology.

The educational attainment of farmers was also recognized as a positive influence on the decision to embrace new technologies. A higher level of education equips farmers with the capability to access and utilize information on the adoption of new technology effectively. This phenomenon can be attributed to the fact that a robust educational background tends to foster broader and more analytical thinking, enabling individuals to assess the advantages presented by innovative technology more comprehensively. The observed relationship between education level and the decision to apply advanced vegetable technology further substantiates this notion. Specifically, it becomes evident that farmers with higher levels of education are inclined to adopt a more expansive and accurate perspective, which enables them to make informed decisions regarding technology adoption. This aligns coherently with a similar study on factors influencing agricultural technology adoption in Asia and Africa such as [Ndiritu et al. \(2014\)](#), [Ogada et al. \(2014\)](#), and [Aung et al. \(2021\)](#).

Finally, perceived behavioral control was the factor with the weakest significant influence on the adoption of technology by farmers. For every 1 point increased in this variable, the likelihood of people accepting the technology increased by 5.6%. Perceived

behavioral control is an individual's perception of how easy or difficult it is to perform a behavior; it represents the degree of control over performing the behavior, not the outcome of the behavior (Ajzen, 1991). This outcome aligned harmoniously with a study on the impact of farmers' use of information technology by Pardey et al. (2016a,b), Elmustapha et al. (2018), and Negatu and Parikh (2019). It implied a universal trend where farmers are more likely to recognize the advantages of applying technology; they tend to accept higher technology in agricultural production.

5 Conclusion and implications

This study addressed the gap in the lack of scientific information about factors affecting farmers' decisions to apply high technology in vegetable production in Hanoi. The study also mixed the psychological factors of the TPB model with the characteristics of the farming household and the supporting factors of the external environment in the model. Since then, logit analysis has found 7 main factors that affect the acceptance of technology in agricultural production by farming households. Understanding the factors affecting technology adoption will play an essential role in promoting the development of high-tech agriculture in Hanoi and Vietnam. From the results and discussions, the following management implications are proposed:

Firstly, it is necessary to improve the attitude of farming households toward applying technology in production. This is the most decisive factor in this study on farmer behavior. To change attitudes, it is important to raise farmers' awareness about technology adoption. This can be done through a number of specific solutions including (i) taking farmers to visit demonstration sites on applying technology in vegetable growing so that they can see the benefits of applying technology, (ii) disseminate benefits and technological solutions through media and social networks to farmers, (iii) promote the integration of high-tech agricultural production in agricultural extension activities in the community.

Secondly, regulatory agencies also need to strengthen access to technology information and extension services, to increase their awareness and technology application capacity. Information on agricultural technology and related extension services is vital in promoting awareness and application of high technology in agricultural production. Farmers might evaluate existing and new technologies, and then make consideration for application. They do not have to apply immediately, but can learn information carefully before making a final decision. In addition, through extension service, farmers can access information about effective technologies and the benefits of using new technologies through distribution agents. These agents help connect technology suppliers with users, reducing the cost of transmitting information about new technology to many farmers, thereby reducing the gap between them and the technology. Moreover, through the information dissemination network, farmers will be updated with knowledge and skills about specific technological solutions, suitable to the production situation of farming households. Farmers can also share information and learn from each other in specific agricultural innovation situations while engaging in practical production models. From there, they might evaluate the effectiveness of applying new technology in production and, from there, make progress together. Localities need to focus on propaganda to raise public awareness of the importance of technological development in

agriculture. At the same time, it is necessary to build a mentality for people who are always ready to mobilize and be creative to find new technological solutions to overcome the difficulties of agriculture with a limited starting point.

Thirdly, strengthen farmers' capacity in technology in production through training. Training human resources with the proper knowledge, skills, qualities, and attitude is crucial in applying high-tech agriculture. This human resource is the decision factor for the modernization of agriculture, closely linked with new rural construction and creating breakthroughs in agricultural production. This also contributes to promoting rural economic development in the context of international economic integration. To successfully apply new technology to production, it is necessary to increase farmers' awareness about technology applications and choose methods suitable to family economic conditions and situations. In the future, the suburbs of Hanoi need to strengthen the policy of training human resources through various forms. This includes attracting quality human resources and raising awareness among households, businesses, cooperatives, and cooperative groups about changing and applying new technologies in production. The promotion of human resources related to high-technology should agriculture also focus on improving the qualifications of technical and administrative staff. Vocational training methods need to be renewed, focusing on improving practical capacity, core skills, techniques, and soft skills to adapt and promote in the modern technology in agricultural production.

Last but not least, the state needs to continue to strengthen financial solutions to support farmers to apply technology in production. Options could include increasing farmers' access to micro credit, providing interest rate subsidies when applying production technology, or supporting part of the initial investment capital when establishing new technologies by farming households.

Data availability statement

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

Author contributions

BN: Conceptualization, Formal analysis, Methodology, Writing – original draft, Writing – review & editing. DT: Conceptualization, Data curation, Formal analysis, Writing – original draft.

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References

- Ajzen, I. (1991). The theory of planned behavior. *Organ. Behav. Hum. Decis. Process.* 50, 179–211. doi: 10.1016/0749-5978(91)90020-T
- Ankuyi, F., and Tham, A. (2022). Drivers of knowledge, attitude, practice, aspiration, and perceptions of sustainable agriculture standard: evidence from certified cocoa farmers in Ghana. *Russian J. Agric. Socio-Econ. Sci.* 131, 125–140.
- Aung, Y., Khor, L., and Tran, N. (2021). The impact of sustainable aquaculture technologies on the welfare of small-scale fish farming households in Myanmar. *Aquac. Econ. Manag.* 27, 1–30.
- Bassyouni, G., El-Habal, A., and Abdulrazzaq, A. (2022). Impact of farmers' use of information technology to improve agricultural marketing extension services in Wasit governorate, Iraq. *Advan. Soc. Sci. Res. J.* 9, 298–314.
- Basuki, R., Adiyoga, W., and Gunadi, N. (2019). Impact of improved vegetable farming technology on farmers' livelihoods in Indonesia. *Acta Hort.* 809, 101–112.
- Baumgartetz, A., Stalker, L., and Floress, K. (2012). Why farmers adopt best management practice in the United States: a meta-analysis of the adoption literature. *J. Environ. Manag.* 96, 17–25. doi: 10.1016/j.jenvman.2011.10.006
- Bokusheva, R., Finger, R., Fischler, M., Berlin, R., Marín, Y., Pérez, F., et al. (2012). Factors determining the adoption and impact of a postharvest storage technology. *Food Secur.* 4, 279–293. doi: 10.1007/s12571-012-0184-1
- Brown, P., Daigneault, A., and Dawson, J. (2019). Age, values, farming objectives, past management decisions, and future intentions in New Zealand agriculture. *J. Environ. Manag.* 231, 110–120. doi: 10.1016/j.jenvman.2018.10.018
- Burton, R. (2014). The influence of farmer demographic characteristics on environmental behaviour: a review. *J. Environ. Manag.* 135, 19–26. doi: 10.1016/j.jenvman.2013.12.005
- Cavatassi, R., Lipper, L., and Narloch, U. (2011). Modern variety adoption and risk management in drought prone areas: insights from the sorghum farmers of eastern Ethiopia. *Agric. Econ.* 42, 279–292. doi: 10.1111/j.1574-0862.2010.00514.x
- Dalton, T. J., Lilja, N. K., Johnson, N., and Howeler, R. (2011). Farmer participatory research and soil conservation in southeast Asian cassava systems. *World Dev.* 39, 2176–2186. doi: 10.1016/j.worlddev.2011.05.011
- Dat, T. T., and Truong, D. D. (2020). Resource management, environment and climate change towards development sustainability in Vietnam from an economic perspective. *J. Econ. Dev.* 278, 2–11.
- Department of Agricultural and Rural Development (2022). *Annual report*. Agricultural Publisher: Hanoi.
- Di Falco, S., and Bulte, E. (2013). The impact of kinship networks on the adoption of risk-mitigating strategies in Ethiopia. *World Dev.* 43, 100–110. doi: 10.1016/j.worlddev.2012.10.011
- Di Falco, S., Feri, F., Pin, P., and Vollenweider, X. (2018). Ties that bind: network redistributive pressure and economic decisions in village economies. *J. Dev. Econ.* 131, 123–131. doi: 10.1016/j.jdevco.2017.12.001
- Dima, A. (2013). Green purchasing behavior: green products and Ajzen's theory of planned behavior. *Econ. Behav.* 34, 45–59.
- Dissanayake, C., Jayathilake, W., and Wickramasuriya, J. (2022). A review on factors affecting technology adoption in agricultural sector. *J. Agric. Sci. Sri Lanka.* 17, 280–296. doi: 10.4038/jas.v17i2.9743
- Elmustapha, H., Hoppe, T., and Bressers, H. (2018). Consumer renewable energy technology adoption decision-making: comparing models on perceived attributes and attitudinal constructs in the case of SWH in Lebanon. *J. Clean. Prod.* 172, 347–357. doi: 10.1016/j.jclepro.2017.10.131
- Fischer, K. (2016). Why new crop technology is not scale-neutral – a critique of the expectations for a crop-based African green revolution. *Res. Policy* 45, 1185–1194. doi: 10.1016/j.respol.2016.03.007
- Fisher, M., Abate, T., Alemayehu, Y., and Madulu, R. B. (2015). Drought tolerant maize for farmer adaptation to drought in sub-Saharan Africa: determinants of adoption in eastern and southern Africa. *Clim. Chang.* 133, 283–299. doi: 10.1007/s10584-015-1459-2
- Floro, V. O., Labarta, R. A., Becerra López-Lavalle, L. A., Martinez, J. M., and Ovalle, T. M. (2018). Household determinants of the adoption of improved cassava varieties using DNA fingerprinting to identify varieties in farmer fields: a case study in Colombia. *J. Agric. Econ.* 69, 518–536. doi: 10.1111/1477-9552.12247
- Gadenne, D., Sharma, B., Kerr, D., and Smith, T. (2011). The influence of consumers' environmental beliefs and attitudes on energy saving behaviours. *Energy Policy* 39, 7684–7694. doi: 10.1016/j.enpol.2011.09.002
- Grabowski, P. P., Kerr, J. M., Haggblade, S., and Kabwe, S. (2016). Determinants of adoption and disadoption of minimum tillage by cotton farmers in eastern Zambia. *Agriculture. Ecosyst. Environ.* 231, 54–67. doi: 10.1016/j.agee.2016.06.027
- Hair, J., Hult, G. T., and Ringle, C. (2013). A primer on partial least squares structural equation modeling (PLS-SEM). Sage publications.
- Kabunga, N. S., Dubois, T., and Qaim, M. (2012). Heterogeneous information exposure and technology adoption: the case of tissue culture bananas in Kenya. *Agric. Econ.* 43, 473–486. doi: 10.1111/j.1574-0862.2012.00597.x
- Kassie, M., Teklewold, H., Jaleta, M., Marennya, P., and Erenstein, O. (2015). Understanding the adoption of a portfolio of sustainable intensification practices in eastern and southern Africa. *Land Use Policy* 42, 400–411. doi: 10.1016/j.landusepol.2014.08.016
- Katengeza, S. P., Holden, S. T., and Lunduka, R. W. (2018). Adoption of drought tolerant maize varieties under rainfall stress in Malawi. *J. Agric. Econ.* 70, 1–17.
- Khonje, M., Manda, J., Alene, A. D., and Kassie, M. (2015). Analysis of adoption and impacts of improved maize varieties in eastern Zambia. *World Dev.* 66, 695–706. doi: 10.1016/j.worlddev.2014.09.008
- Khonje, M. G., Manda, J., Mkandawire, P., Tufa, A. H., and Alene, A. D. (2018). Adoption and welfare impacts of multiple agricultural technologies: evidence from eastern Zambia. *Agric. Econ.* 49, 599–609. doi: 10.1111/agec.12445
- Kristjanson, P., Okike, I., Tarawali, S., Singh, B. B., and Manyong, V. M. (2015). Farmers' perceptions of benefits and factors affecting the adoption of improved dualpurpose cowpea in the dry savannas of Nigeria. *Agric. Econ.* 32, 195–210. doi: 10.1111/j.0169-5150.2005.00338.x
- Lam, S., Pham, G., and Nguyen, V. H. (2018). Emerging health risks from agricultural intensification in Southeast Asia: a systematic review. *Int. J. Occup. Environ. Health* 23, 250–260. doi: 10.1080/10773525.2018.1450923
- Lambrech, I., Vanlauwe, B., Merckx, R., and Maertens, M. (2014). Understanding the process of agricultural technology adoption: mineral fertilizer in eastern DR Congo. *World Dev.* 59, 132–146. doi: 10.1016/j.worlddev.2014.01.024
- Larsen, A. F. (2018). When knowledgeable neighbors also share seedlings: diffusion of banana cultivation in Tanzania. *Agric. Econ.* 17, 1–15.
- Le, TN., and Nguyen, KH. (2019). Impact of removing industrial tariffs under the European–Vietnam free trade agreement: a computable general equilibrium approach. *J. Econ. Dev.* 21, 2–17.
- Le, K. N., and Truong, D. K. (2019). Trade credit use by shrimp farmers in Ca Mau province. *J. Econ. Dev.* 21, 270–284.
- Liu, T., Bruins, R. J. G., and Heberling, M. T. (2018). Factors influencing farmers' adoption of best management practices: a review and synthesis. *Sustain. For.* 10, 1–26. doi: 10.3390/su10020432
- Lowder, S. K., Skoet, J., and Raney, T. (2016). The number, size, and distribution of farms, smallholder farms, and family farms worldwide. *World Dev.* 87, 16–29. doi: 10.1016/j.worlddev.2015.10.041
- Mai, N. T., and Truong, D. D. (2022). Farming Households' Perception on Natural Disaster Impacts to Livelihoods and Adaptation Practices: A Case Study of Coastal Provinces in Central Vietnam. *International Journal of Sustainable Development and Planning* 17, 579–592.
- Marennya, P. P., and Barrett, C. B. (2011). Household-level determinants of adoption of improved natural resources management practices among smallholder farmers in western Kenya. *Food Policy* 32, 515–536. doi: 10.1016/j.foodpol.2006.10.002
- Matuschke, I., and Qaim, M. (2001). The impact of social networks on hybrid seed adoption in India. *Agric. Econ.* 40, 493–505. doi: 10.1111/j.1574-0862.2009.00393.x
- Meijer, S. S., Catacutan, D., Ajayi, O. C., Sileshi, G. W., and Nieuwenhuis, M. (2015). The role of knowledge, attitudes and perceptions in the uptake of agricultural and agroforestry innovations among smallholder farmers in sub-Saharan Africa. *Int. J. Agric. Sustain.* 13, 40–54. doi: 10.1080/14735903.2014.912493
- Moser, C. M., and Barrett, C. B. (2016). The complex dynamics of smallholder technology adoption: the case of SRI in Madagascar. *Agric. Econ.* 35, 373–388.
- Mottaleb, K. A., Krupnik, T. J., and Erenstein, O. (2016). Factors associated with smallscale agricultural machinery adoption in Bangladesh: census findings. *J. Rural. Stud.* 46, 155–168. doi: 10.1016/j.jrurstud.2016.06.012
- Mukasa, A. N. (2018). Technology adoption and risk exposure among smallholder farmers: panel data evidence from Tanzania and Uganda. *World Dev.* 105, 299–309. doi: 10.1016/j.worlddev.2017.12.006

- Mulema, A., Cramer, L., and Huyer, S. (2022). Stakeholder engagement in gender and climate change policy processes: lessons from the climate change, agriculture, and food security research program. *Front. Sustain. Food Syst.* 6:3389. doi: 10.3389/fsufs.2022.862654
- Muthumanickam, D., Chenniappan, P., and Ramalingam, K. (2022). Smart farming: internet of things (IoT)-based sustainable agriculture. *Agriculture* 12:1745. doi: 10.3390/agriculture12101745
- Ndiritu, S. W., Kassie, M., and Shiferaw, B. (2014). Are there systematic gender differences in the adoption of sustainable agricultural intensification practices? Evidence from Kenya. *Food Policy* 49, 117–127. doi: 10.1016/j.foodpol.2014.06.010
- Negatu, W., and Parikh, A. (2019). The impact of perception and other factors on the adoption of agricultural technology in the Moret and Jiru Woreda (district) of Ethiopia. *Agric. Econ.* 21, 205–216. doi: 10.1111/j.1574-0862.1999.tb00594.x
- Njuki, J. M., Mapila, M. T., Zingore, S., and Delve, R. (2018). The dynamics of social capital in influencing use of soil management options in the Chinyanja triangle of southern Africa. *Ecol. Soc.* 13, 22–39.
- Noack, F., and Larsen, A. (2019). The contrasting effects of farm size on farm incomes and food production. *Environ. Res. Lett.* 14, 10–24. doi: 10.1088/1748-9326/ab2dbf
- Ntshangase, N. L., Muroyiwa, B., and Sibanda, M. (2018). Farmers' perceptions and factors influencing the adoption of no-till conservation agriculture by smallscale farmers in Zashuke, KwaZulu-Natal province. *Sustainability (Switzerland)* 10, 1–16.
- Ogoda, M. J., Mwabu, G., and Muchai, D. (2014). Farm technology adoption in Kenya: a simultaneous estimation of inorganic fertilizer and improved maize variety adoption decisions. *Agric. Food Econ.* 2, 1–28. doi: 10.1186/s40100-014-0012-3
- Ogundari, K., and Bolarinwa, O. D. (2018). Impact of agricultural innovation adoption: a meta-analysis. *Aust. J. Agric. Resour. Econ.* 62, 217–236. doi: 10.1111/1467-8489.12247
- Ojiako, I. A., Manyong, V. M., and Ikpi, A. E. (2017). Determinants of rural farmers' improved soybean adoption decisions in northern Nigeria. *J. Food, Agricul. Environ.* 5, 215–223.
- Orr, A., Kambombo, B., Roth, C., Harris, D., and Doyle, V. (2015). Adoption of integrated food-energy systems: improved cookstoves and pigeonpea in southern Malawi. *Exp. Agric.* 51, 191–209. doi: 10.1017/S0014479714000222
- Pardey, P. G., Andrade, R. S., Hurley, T. M., Rao, X., and Liebenberg, F. G. (2016a). Returns to food and agricultural R & D investments in sub-Saharan Africa, 1975–2014. *Food Policy* 65, 1–8. doi: 10.1016/j.foodpol.2016.09.009
- Pardey, P. G., Chan-Kang, C., Dehmer, S. P., and Beddow, J. M. (2016b). Agricultural R&D is on the move. *Nature* 537, 301–303. doi: 10.1038/537301a
- Prager, K., and Posthumus, H. (2020). "Socio-economic factors influencing farmers' adoption of soil conservation practices in Europe" in *Human dimensions of soil and water conservation, number January chapter 12*. ed. T. L. Napier (New York: Nova Science Publishers Inc), 203–223.
- Rapsomanikis, G. (2015). *The economic lives of smallholder farmers (technical report)*. Rome: Food and Agriculture Organization of the United Nations.
- Sharma, R. (2015). Access to modern agricultural technologies and farmer household welfare: evidence from India. *Int. J. Asian Stud.* 6, 19–43. doi: 10.1177/0976399614563222
- Shiferaw, B., Kebede, T., Kassie, M., and Fisher, M. (2015). Market imperfections, access to information and technology adoption in Uganda: challenges of overcoming multiple constraints. *Agric. Econ.* 46, 475–488. doi: 10.1111/agec.12175
- Shiferaw, B. A., Kebede, T. A., and You, L. (2018). Technology adoption under seed access constraints and the economic impacts of improved pigeonpea varieties in Tanzania. *Agric. Econ.* 39, 309–323. doi: 10.1111/j.1574-0862.2008.00335.x
- Simtowe, F., Zeller, M., and Diagne, A. (2019). The impact of credit constraints on the adoption of hybrid maize in Malawi. *Rev. Agricul. Environ. Stud.* 90, 5–22.
- Sitko, N. J., Chamberlin, J., and Hichaambwa, M. (2014). Does smallholder land titling facilitate agricultural growth? An analysis of the determinants and effects of smallholder land titling in Zambia. *World Dev.* 64, 791–802. doi: 10.1016/j.worlddev.2014.07.014
- Sodjinou, E., Glin, L., Nicolay, G., Tovignan, S., and Hinvi, J. (2016). Socioeconomic determinants of organic cotton adoption in Benin, West Africa. *Agric. Food Econ.* 3, 1–22.
- Teklewold, H., Kassie, M., and Shiferaw, B. (2013). Adoption of multiple sustainable agricultural practices in rural Ethiopia. *J. Agric. Econ.* 64, 597–623. doi: 10.1111/1477-9552.12011
- Teshome, A., de Graaff, J., and Kassie, M. (2016). Household-level determinants of soil and water conservation adoption phases: evidence from North-Western Ethiopian highlands. *Environ. Manag.* 57, 620–636. doi: 10.1007/s00267-015-0635-5
- Truong, D., Dat, T., and Huan, L. (2022). Factors affecting climate-smart agriculture practice adaptation of farming households in coastal Central Vietnam: the case of Ninh Thuan province. *Front. Sustain. Food Syst.* 6:790089. doi: 10.3389/fsufs.2022.790089



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Adoption and desirable characteristics of Information and Communication Technologies for urban small-scale food producers in South Africa

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Small-scale food producers can benefit significantly from the adoption and effective utilization of Information and Communication Technologies (ICTs). For example, ICTs can help improve food production and access to markets, which is particularly valuable in many Sub-Saharan African countries that both urbanize rapidly but whose food systems still rely significantly on small-scale food producers. This study examines the adoption patterns and desirable characteristics of ICTs, as well as the factors influencing them, among small-scale food producers engaged in urban agriculture in South Africa. We administered 85 in-person surveys through referrals from local producers' network in disadvantaged areas of Cape Town ($n = 21$; Gugulethu, Philippi, Khayelitsha) and Johannesburg ($n = 64$; Central Business District, Soweto, Orange Farm). A substantial proportion of the respondents articulated the need for food-related mobile applications with functions that facilitate price comparisons, and the sharing of best practices and health advice. User-friendliness, low internet data use, and affordability were perceived as the most important characteristics for such food-related mobile applications. Redundancy analysis (RDA) reveals that the socioeconomic and demographic characteristics of respondents significantly influence the desired functionalities of food apps and their preferred activities among the respondents. Producers that are married and have more children, have higher income and education, and own larger land holdings, show very distinct patterns in terms of desirable functions and uses for food apps. Our research underscores the need for comprehensive approaches to the development and promotion of food-related ICTs when targeting small-scale food producers. The barriers and needs identified here can help ICT developers, development agencies and policy-makers design fit-for-purpose interventions and policies to facilitate ICT adoption among urban small-scale food producers in rapidly urbanizing areas.

KEYWORDS

urban agriculture, smallholders, small-scale farmers, digitalization, sustainable food systems, food security, livelihoods, Sub-Saharan Africa

1 Introduction

1.1 Urban small-scale food production in Sub-Saharan Africa

Small-scale food producers¹ are the backbone of the agricultural sector across Sub-Saharan Africa (Gassner et al., 2019), accounting for most of the food production (Giller et al., 2021). Small-scale food production is essential for the livelihoods and food security of most rural population in the region (Gollin, 2014), as well as many food producers that still operate in urban and peri-urban areas (Vidal Merino et al., 2021). At the same time, Sub-Saharan Africa is the fastest urbanizing region in the world (Githira et al., 2020). Urban food security has been emerging as a major development challenge for the 21st century (Crush and Frayne, 2011), especially as the COVID-19 pandemic clearly showed (Gebeyehu et al., 2022). With urban diets rapidly changing across the region, many urban households increasingly rely on unhealthy, unaffordable and unsustainable diets (Barker et al., 2021). In particular, urban diets increasingly rely on ultra-processed and frozen food, which is imported and accessed through major supermarket chains, ultimately having a negative effect to traditional small-scale food production systems, including those operating within cities (Djurfeldt, 2015; Battersby, 2017; Ahmed et al., 2022).

Urban agriculture² sits at this confluence of urbanization and food system transformation. On the one hand it has been a vital source of food in many Sub-Saharan African cities, including for the emerging niche market for locally grown vegetables (D'Alessandro et al., 2018; Ahmed et al., 2022). On the other hand, it is predominately practiced by small-scale producers operating in very diverse spaces such as backyard home gardens, community gardens and open spaces (Tevera, 2022) in inner cities (intra-urban agriculture) and urban peripheries (peri-urban agriculture) (Van Veenhuizen and Danso, 2007). A large portion of these small-scale urban food producers sell their output to low-income consumers in informal markets (Vorley, 2013), while others cater organic products to richer consumers (Coulibaly et al.,

2011; Kini et al., 2020). This growing demand of affluent urban consumers on locally-sourced organic vegetables presents new market opportunities for urban small-scale food producers (Orsini, 2020), but the competition with larger producers (especially large international supermarket chains) hinders their market entry (Greibitus, 2021; Ahmed et al., 2022).

Many studies have acknowledged the positive effects of urban agriculture for food security and livelihoods, especially for the urban poor (Zezza and Tasciotti, 2010; Poulsen et al., 2015). For example, urban agriculture can contribute to sustainable and resilient local food systems, especially in the context of growing urban populations and accelerating climate change (Mougeot, 2015; Moustier and Renting, 2015). However, the viability and sustainability of some urban agriculture practices has also been debated (Badami and Ramankutty, 2015; Weidner et al., 2019). As a result, innovative approaches such as vertical farming, rooftop gardens, and community-supported agriculture (CSA) are explored,³ as they can both improve the performance of urban agriculture systems but also offer several co-benefits (Specht et al., 2014; Orsini, 2020).

Despite their crucial role, small-scale food producers face numerous challenges, including in urban settings. Challenges include limited access to resources/markets/technologies/capital/credit, inability to undertake proper quality control and complex logistics, as well as vulnerability to market volatility (Chagomoka et al., 2017; Ricciardi et al., 2018; Lowder et al., 2021). Other common challenges include reliance on low-quality inputs, declining soil quality, exploitation from suppliers/traders/money lenders, and vulnerability to pests/diseases, weather events and climate change (Makate, 2019; Woodhill et al., 2020). This limited access to resources and these compounding vulnerabilities often marginalize them from decision-making processes (Benedek et al., 2021), and puts them at a disadvantage when competing in the increasingly globalized and distorted food marketplace observed in many Sub-Saharan African cities (Woodhill et al., 2020).

Various technological, economic and policy responses have been proposed to address such challenges facing small-scale producers in Sub-Saharan Africa, including in urban food systems. Examples include new technologies for food production and marketing, improved access to credit and financial services, extension services and training, the promotion of sustainable agricultural practices, and the enhancement of market linkages (Tambo and Mockshell, 2018; Bizikova et al., 2020; Mizik, 2021; Sarr et al., 2021; Wadumestrigie Dona et al., 2021). Participatory approaches that engage small-scale food producers in the design and implementation of such responses can be very effective in achieving such positive outcomes (Pamuk et al., 2015; Sergaki and Michailidis, 2020; Sachet et al., 2021; Doherty et al., 2023).

1 According to FAO (2018a) small-scale food producers can be defined as those whose cultivated land size, number of livestock and/or annual economic revenue from agricultural activities fall in the bottom 40% of the respective cumulative distribution at national level. UNEP (n.d.) characterizes small-scale food production as relying on low asset base, operating in small plots (<2ha), experiencing structural constraints (e.g., low access to resources, technology, and markets), struggling to be competitive, and having limited resource endowment compared to other farmers in the sector. Khalil et al. (2017) use the terms "smallholder" and "small-scale farmer" synonymously, stating that although "smallholder" refers more to tenure and "small-scale producer" refers more directly to production levels, the two refer to very similar entities. Acknowledging this slight difference, for the remainder of the paper we use the term "small-scale food producer."

2 Van Veenhuizen and Danso (2007) define urban agriculture as "the growing of plants and the raising of animals for food and other uses within and around cities and towns, and related activities such as the production and delivery of inputs, processing and marketing of products." Acknowledging similarities and slight differences with other terms such as "urban farming," for the remainder of the paper we use consistently the term "urban agriculture."

3 Vertical farming involves crop production in vertically stacked layers or on inclined surfaces (often indoors), achieving very high levels of productivity and low resource use. Rooftop gardens are unused rooftop spaces converted into green areas for food production, and the provision of benefits for urban biodiversity, air quality, and human wellbeing. CSA entails partnerships between local food producers and local food consumers, where subscribers (consumers) receive a portion of the harvest from the producers.

1.2 Information and Communication Technologies for food systems transformation

Information and Communication Technologies (ICTs) are a particularly promising technological option to improve small-scale food systems in Sub-Saharan Africa (Onyeneke et al., 2023). Collectively ICTs refer to any method of electronically sharing or storing data, including telephones, mobile broadband, the Internet, broadcasting, sensor networks, and data storage and analytics (FAO, 2018b). ICTs can improve information search capabilities and augment both the quality and quantity of accessible data, thereby reducing ambiguity and improving productive activities and market engagement (Bertolini, 2005).

On the production side, ICTs have facilitated access to agricultural advice, climate information, and extension services (Hlophe-Ginindza and Mpandeli, 2021). In particular, smartphone technology has afforded new ways of communicating information in interactive and multimedia formats (Harris and Achora, 2018), helping small-scale food producers make suitable decisions by accessing better market information (Hoang, 2020). Moreover, ICTs can facilitate the adoption of sustainable agricultural practices, such as precision farming and climate-smart agriculture, by providing farmers with access to information, decision support tools, and monitoring systems (Antle et al., 2017; Klerkx and Rose, 2020).

On the marketing side, ICTs can empower small-scale food producers to better participate in modern food value chains and markets (Aleke et al., 2011; Krone and Dannenberg, 2018). For example, access to real-time market information helps small-scale food producers make informed decisions about what to produce, when to sell, and at what price (Courtois and Subervie, 2015). Furthermore, ICTs can enable small-scale food producers to connect directly with buyers, reducing transaction costs and improving their bargaining power (Nakasone et al., 2014). For example, digital platforms, such as e-commerce and mobile money services, can enhance market access and financial inclusion for small-scale food producers (Agyekumhene et al., 2018). Additionally, ICTs can support the development of innovative business models, such as farmer cooperatives and agri-food e-commerce, which can help small-scale food producers overcome challenges related to economies of scale and market access (Berti and Mulligan, 2016; Alam et al., 2023), income diversification (Leng et al., 2020), increase farm productivity (Chandra and Collis, 2021), and enhance food security (Ayim et al., 2022).

However, many of the introduced ICT solutions targeting small-scale food producers in Sub-Saharan Africa have failed to achieve sustained positive impact. For instance, most such ICT solutions have relied on basic messaging services, which have a limited ability to boost commercialization as they simply broadcast standard market pricing information (Fafchamps and Minten, 2012). Conversely, many of the more promising advanced ICTs have tended to focus on large-scale food producers, often overlooking the unique constraints of small-scale food producers (Klerkx et al., 2019). Other complementary ICT solutions, such as helplines and advisory services, have frequently struggled with high maintenance expenses and continuous upgrading requirements to address evolving threats (e.g., pests, climate change) and user feedback (Baumüller, 2018).

Studies have identified three main reasons behind such failures. First, is the techno-centric design assumptions of many ICTs that

overestimate user digital literacy, resources, and access to smartphones and reliable internet, which is generally not the case for small-scale food producers. Second, is the lack of long-term viability and credible pathways to scale beyond scattered pilot trials (Baumüller, 2018; Chandra and Collis, 2021), sometimes due to their limited geographic coverage that cannot account for the diversity of contexts facing small-scale food producers across regions (Trendov et al., 2019). Third, is the insufficient institutional backing (Aker et al., 2016; FAO, 2018c).

Arguably, at the heart of this situation lie the persistent digital inequalities between large- and small-scale food producers (Mushi et al., 2022; Revenko and Revenko, 2022). This raises concerns on whether increased digitalization will be inclusive for small-scale food producers (Lajoie-O'Malley et al., 2020), considering their multiple constraints to ICTs adoption such as the high costs for using mobile phones, mobile network problems, and limited ICT skills (Hoang, 2020). Such constraints might force low-income users (a) opt out of services requiring additional payment for accessing information, (b) decide not to invest additional funds in services that do not clearly convey the benefits, or (c) require intermediaries to mediate trust and enable successful credit transactions through digital platforms (Agyekumhene et al., 2018; Harris and Achora, 2018). Taking all of the above into consideration, Weidner et al. (2019) argued that if not designed well, urban agriculture initiatives supported by ICTs may primarily benefit affluent consumers and entrepreneurs, while excluding marginalized groups and reinforcing existing power structures.

Various strategies have been proposed to address these challenges and ensure inclusive and equitable benefits from ICTs, such as investing in digital infrastructure and literacy, developing context-specific ICT solutions, and promoting multi-stakeholder partnerships (Deichmann et al., 2016; Tsan et al., 2021). Moving forward, future ICT initiatives for small-scale producers must carefully diagnose localized barriers, priorities, and digital literacy skills to design appropriate solutions (Roberts and Hernandez, 2019). These efforts will benefit tremendously from the sustained involvement of end-users in iterative ICT co-design and evaluation (Akinuwa et al., 2013; Koukou and Dekkers, 2024), as well as other relevant stakeholders such as extension services, policymakers, and consumers (Steinke et al., 2019; Alfonsi, 2024). Such participatory approaches can have significant positive outcomes for ICT design and adoption, and reduce digital divides (Chipidza and Leidner, 2019; Ortiz-Crespo et al., 2020). The success of such efforts would further benefit from (a) the proactive role of the government in facilitating the involvement of different stakeholders, and (b) the development of localized implementation frameworks to support the ICTs adoption and deployment (Smidt and Jokonya, 2022).

1.3 Knowledge gaps and research aims

Considering the above, there are significant gaps in the academic literature exploring the adoption and use of ICTs by small-scale food producers, including in urban settings. First, we lack a comprehensive understanding of their preferences, needs, skills, and capabilities to adopt and utilize ICTs, as well as effectively develop their skills and customize ICTs to meet their unique needs (Eitzinger et al., 2019; Mushi et al., 2022). This is particularly true in developing countries (Landmann, 2018). Second, the perspectives of small-scale food

producers are often not taken into consideration when designing ICTs for them (Chizema and van Greunen, 2023), which may result in ICTs that are not fit-for-purpose or do not meet their needs, affecting their sustained adoption (Aleke et al., 2011). Third, to maximise the potential of ICTs for small-scale food producers, it is crucial to understand how to address the more systemic factors influencing digital inequalities. Specifically, for Sub-Saharan Africa, more research is needed to identify how to remove the barriers of poor infrastructure, ineffective policies, and low level of ICT skills (Ayim et al., 2022). These three research gaps are especially prevalent in emerging and developing countries. While these research gaps are widespread across developing settings, examining them in a specific context can provide valuable insights.

South Africa is an ideal context to understand ICT adoption patterns among small-scale food producers, especially in urban contexts. On the one hand, South Africa has the most productive, modernized, and diverse agricultural sector in Sub-Saharan Africa (International Trade Administration, 2021), is highly urbanized with two thirds of the population living in urban areas (Bakker et al., 2020), and ranks 3rd in Sub-Saharan Africa in terms of ICT penetration on the ICT Development Index (International Telecommunication Unit, 2017; Malanga and Simwaka, 2021). On the other hand, urban agriculture is still very prevalent in the major cities, meeting many of the livelihood and nutritional needs of poor urban residents (see Section 2.1). However, this happens in a post-apartheid context marked by an increase in social inequality (Nthane et al., 2020), making South Africa the most unequal country in the world (World Bank, 2022). Moreover, the South African food system experiences multiple sustainability challenges (Termeer et al., 2018; Sobratee et al., 2022), with the large (and predominantly black) majority of small-scale food producers still waiting for further government efforts to correct the injustices of the apartheid era (Siebert, 2020).

In this context, emancipatory initiatives that employ digital technologies to confront existing inequalities and promote alternative visions of agriculture, emphasize the political nature of digital agriculture (Hackfort, 2021). The South African ICT Research, Development, and Innovation roadmap highlights the use of ICTs to improve agricultural production, specifically assisting small-scale food producers oriented towards commercial markets to contribute to food security, exports and mitigating environmental impacts (Department of Science and Technology, 2013). ICTs are regarded as crucial for development (Anwar, 2019) and are critical enablers for knowledge management for poverty eradication (Fombad, 2018). Arguably, understanding how South African small-scale food producers perceive and use ICTs, and the factors that influence their choices can assist in designing ICT tools that effectively aid in sustainable livelihood and food security strategies. Furthermore, understanding the challenges related to ICT adoption and use for small-scale food producers can aid policymakers and development agencies in developing policies and intervention strategies to enhance ICT adoption for pro-poor agricultural activities. Beyond South Africa, such insights can be relevant for other rapidly urbanizing and digitalizing Sub-Saharan African countries that still largely rely on small-scale food producers.

The aim of this study is to understand the adoption patterns and desirable characteristics of ICTs, as well as the factors influencing them, among small-scale food producers engaged in urban agriculture in South Africa. We achieve this through in-person surveys with 85 small-scale food producers in different areas of Johannesburg and Cape Town. Section 2 describes the data collection and analysis

methodology. Section 3 presents the main ICT adoption patterns, their desirable characteristics and the factors affecting user perspectives. Section 4 identifies critical areas for improvement at the interface of small-scale food production and ICT adoption in South Africa, and Sub-Saharan Africa more broadly.

2 Methodology

2.1 Study area

As in this study we seek to understand the challenges for current ICT use/non-use and the desirable characteristics and functionalities for future ICT tools for resource-constrained small-scale food producers (Section 1), we focus on such producers engaged in urban agriculture in the cities of Johannesburg and Cape Town. These cities represent two major conurbations in South Africa, with Johannesburg being the most populated and fastest-growing city, and Cape Town being the second most populated city in the country (Abrahams et al., 2018). Both cities are considered economic and technological hubs. Johannesburg is the largest economic hub and most densely urbanized area (Risimati and Gumbo, 2018), while Cape Town, labeled as 'the digital gateway to Africa' has seen significant investments in digital infrastructure and a center point for digital startups (Antenucci and Tomasello, 2022). Internet use rates are higher in such primary cities and lower in secondary cities and rural areas in South Africa (Lembani et al., 2020), and Sub-Saharan Africa more generally (Githira et al., 2020).

Importantly for this study, both cities have a vibrant urban agriculture sector that includes many small-scale food producers. Urban agriculture has emerged as a vital coping mechanism and safety net for many poor urban residents in the face of persistent unemployment and food insecurity. An array of small-scale food production activities unfolds across the intricate patchwork of urban agriculture spaces in South African cities, ranging from backyards and community gardens to school plots and unused public land (Tevera, 2022). While often small in size, such cultivated pockets integrated within neighborhoods provide vital sustenance and livelihood opportunities for residents (Figure 1). In particular, recent scholarship underscores the invaluable role of urban agriculture in addressing food access deficiencies and enhancing resilience for low-income households in Johannesburg and Cape Town (Kanosvamhira, 2019; Olivier, 2019; Atlink and Hart, 2023). For instance, urban agriculture spaces such as farms, community gardens, and homestead plots make meaningful nutritional and livelihood contributions in townships across metropolitan Cape Town (Battersby and Marshak, 2016). Likewise, in the Greater Johannesburg area, small-scale food producers cater to food insecure urban residents through farmers markets, informal trade, and other networks (Bbun and Thornton, 2013). Beyond fulfilling subsistence needs, urban agriculture also unlocks prospects for poverty alleviation, job creation, community-building, and youth engagement in these cities (Kanosvamhira, 2019).

Additionally, there are signs of ICT adoption, as well as a diverse mix of markets (e.g., informal markets, farmers' markets, supermarkets of various sizes) with links to small-scale food producers engaged in urban agriculture in the two cities. In more detail, there are many sites dedicated to urban agriculture across Johannesburg, including in the informal settlements (Atlink and Hart, 2023). Furthermore, there has been significant support for urban agriculture within Cape Town for



FIGURE 1
Urban agriculture site in Cape Town.

very long time (Rogerson, 2010 in [Kanosvamhira, 2019](#)) and the sole city in South Africa that has implemented an urban agriculture policy (Olivier and Heineken, 2017, in [Kanosvamhira, 2019](#)). Finally, urban agriculture in both cities has been significantly strengthened through the support of government agencies, non-governmental organizations, and citizen-led urban greening initiatives ([Cilliers et al., 2020](#)). This support has been instrumental in establishing urban agriculture in numerous areas across both cities and is possibly linked to the adoption of ICT tools by many small-scale food producers.

At the same time food insecurity is a major challenge for many urban residents in the two cities. More than 40% of urban households in Johannesburg are food insecure ([Atlink and Hart, 2023](#)) and approximately 68% of households are severely food insecure in selected township areas of Cape Town ([Battersby, 2011](#); [Hunter-Adams et al., 2019](#)). In such highly food insecure urban settings, urban agriculture could help markedly enhance food security ([Vidal Merino et al., 2021](#)), as well as job creation, poverty alleviation, community-building, public health, education, and economic empowerment ([Olivier, 2019](#); [Kanosvamhira, 2023](#)).

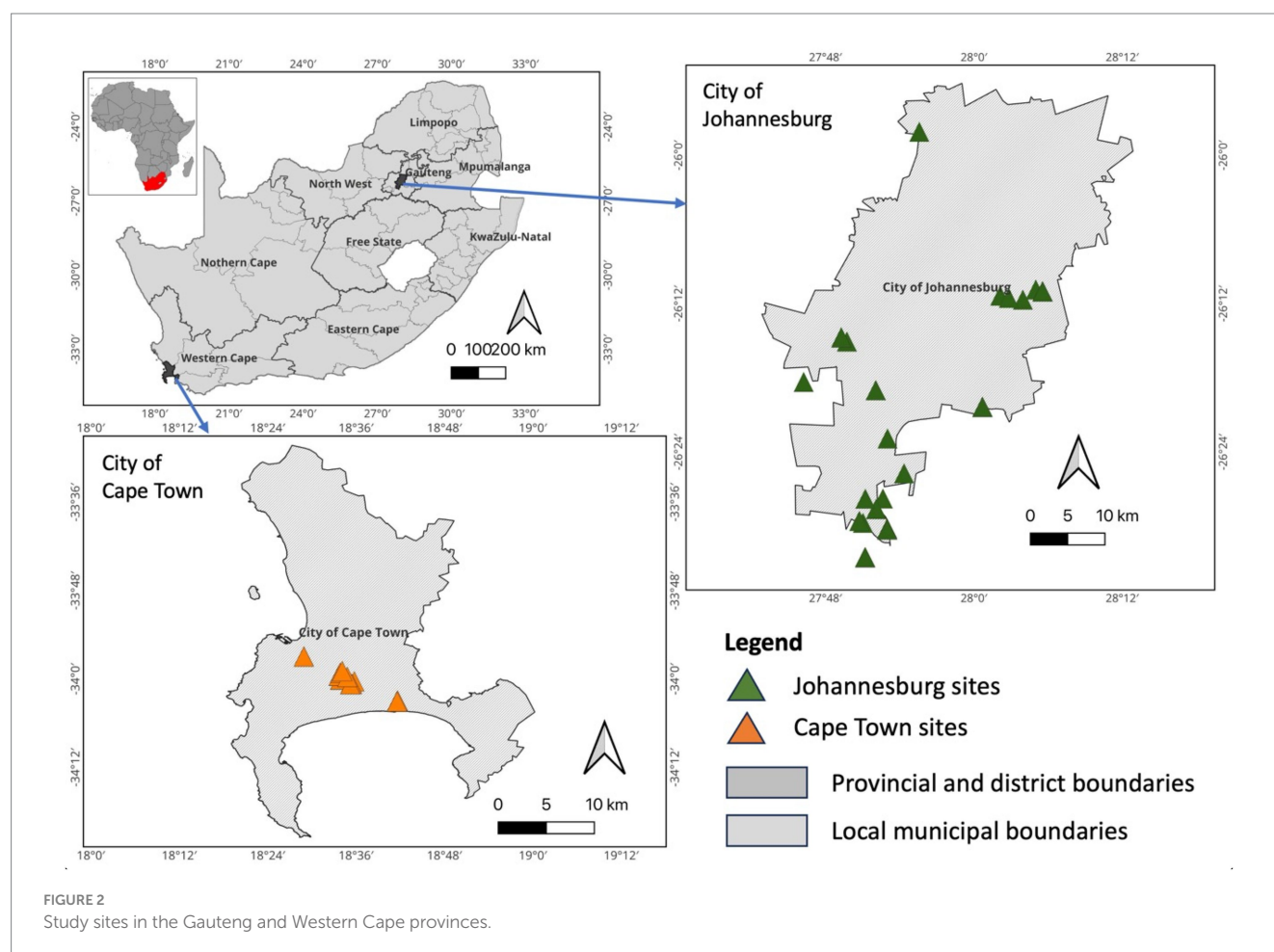
For this study we focus on exactly such underprivileged areas within Johannesburg (Johannesburg Central Business District, Soweto, Orange Farm), and Cape Town (Gugulethu, Philippi and Khayelitsha) ([Figure 2](#)). Encompassing the Central Business District, Soweto, and Orange Farm, the Johannesburg area is a bustling metropolis of approximately 4.8 million residents, with a slight male predominance, and about 33.3% of the population not attending any educational institution (5 to 24 years) ([Statistics South Africa, 2022a](#)). Despite grappling with food insecurity affecting many urban households, this region has emerged as a dynamic epicenter for urban agriculture, demonstrating its potential in bolstering food security, fostering job creation, alleviating poverty, and nurturing community

development. Urban agriculture is a thriving practice in Cape Town's areas of Gugulethu, Philippi, and Khayelitsha, where it serves as a vital lifeline in addressing the food insecurity faced by many people, while also contributing to public health, education, and economic empowerment. The city of Cape Town, home to approximately 4.8 million residents, is marked by a female predominance of 51.7% and 31.2% of the population (5 to 24 years) not engaged in any educational institution ([Statistics South Africa, 2022b](#)). This region, grappling with socio-economic challenges such as poverty, low-income distribution, high unemployment rates, and various social issues, underscores the critical role of urban agriculture in these communities.

2.2 Data collection

In total 85 surveys were collected from small-scale food producers engaged in urban agriculture between 28 February and 18 March 2019. Of these, 64 were located in Johannesburg, specifically in Johannesburg Central Business District (19%, $n = 16$), Soweto (22%, $n = 19$), Orange Farm (34%, $n = 29$). Twenty-one respondents were located in Cape Town, specifically in Gugulethu (9%, $n = 8$), Philippi (7%, $n = 6$), and Khayelitsha (8%, $n = 7$).

To access the urban agriculture communities in the two cities, the research team identified key informants in each study area that provided information pertaining to local small-scale urban agriculture initiatives. These key informants connected the team with lead farmers, specifically those holding leadership roles among their peers due to experience, reputation, or formal appointment. As community liaisons proficient in English, these lead farmers introduced the research team to other local small-scale food producers. Thus, a snowball sampling method was



employed to identify additional potential respondents through these referrals. During the initial interviews, respondents were asked to recommend other local small-scale food producers who could potentially participate in the study. These respondents were then contacted and also invited to suggest other respondents, allowing researchers to gradually build up a sample through referral chains.

Several on the ground realities dictated the adoption of this snowball sampling approach for respondent identification. First, there was no comprehensive list containing all small-scale food producers engaged in urban agriculture in each study area, thereby precluding the possibility of using proportionate or randomized sampling from lists. Second, other respondent identification and randomization techniques such as transect walks were deemed as unfeasible due to safety and security concerns, and general wariness of local residents to outsiders considering the high criminality within the study site areas. Despite some methodological concerns and limitations (see Section 4.5), many scholars have argued that snowball sampling can prove highly effective in accessing hidden or hard-to-reach populations (e.g., Gray, 2014; Kammerer et al., 2019), often requiring collaboration with gatekeepers (whether individual or organizations) that facilitate this process. Furthermore, snowball sampling can foster trust among respondents, especially in contexts where respondents can be cautious to external entities (Bonevski et al., 2014), as has been the case in our study areas. For such reasons, several studies have adopted snowball sampling approaches for

similar surveys in small-scale food production contexts in Sub-Saharan Africa (Barau and Oladeji, 2017), including urban agriculture (Brown et al., 2020).

Data was collected through a structured, face-to-face, and paper-based survey consisting of predominantly closed-ended quantitative and semi-quantitative questions divided into four sections: (a) producer socioeconomic and demographic characteristics, (b) agricultural production and practices, (c) adoption and use of smart devices, (d) actual adoption and use of mobiles and apps (ICTs) for food production and sale, as well as preferences and attitudes towards food apps. The few open-ended questions were intended to capture qualitative insights to complement the quantitative and semi-quantitative data. However, the overall approach centered on the standardized survey instrument (see [Supplementary material](#) for the full survey). The survey was written and administered in English, as this is the working language in South Africa. In case some respondents struggled with understanding certain questions, the local lead farmer accompanying the research team (see above) clarified those questions in Zulu, Xhosa and Sotho, depending on the primary language of the respondent.

Lastly, the Ethics Review Committee of the University of Tokyo confirmed that this research study did not require ethical review in accordance with the governmental research ethics guideline in Japan ("Ethical Guidelines for Life Science and Medical Research Involving Human Subjects"), and "The University of Tokyo's Research Ethics Regulation." Informed consent was obtained orally from participants

after explaining the purpose of the survey and assuring them of their anonymity.

2.3 Data analysis

All data was manually digitized, entered an MS Excel (Version 16) spreadsheet to generate descriptive statistics and then imported into R (Version 2022.07.2) for further analysis. First, descriptive statistics were used to summarize respondents' socioeconomic, demographic and farming/food production characteristics, as well as the use and desirable characteristics of ICTs (Section 3.1–3.2).

Regression analysis was used to assess the strength of relationships between a series of dependent variables and independent variables (Corporate Finance Institute, 2022). As dependent variables we used “smartphone use,” “confidence in smartphone use,” “daily internet use” and “food app use” (Section 3.3.1). As independent variables we used various socioeconomic and demographic factors such as age, education level, number of children, land size and income (Section 3.3.1).

Redundancy analysis (RDA) was used to summarize the linear relationships between multiple dependent and independent variables in a matrix (Xia, 2020). In the RDA figures provided in Section 3.3.2, arrows are used to depict the relationships between dependent (outcome) variables and independent (explanatory) variables. The length of an arrow signifies the strength of the relationship, with longer arrows indicating a stronger correlation with the dependent variable. The direction of an arrow, on the other hand, represents the nature of the relationship. An arrow pointing towards the dependent variable suggests a positive relationship, while an arrow pointing away implies a negative relationship. For the RDA analysis in Section 3.3.2 we used as dependent variables the desired functions, and the desired uses for food apps identified in Section 3.2. As independent variables we use the socioeconomic and demographic variables used in the association analysis (Section 3.3.1). The statistical significance of the Redundancy Analysis (RDA) was assessed using R and a permutation test with 999 permutations. This test was conducted under a reduced model incorporating response and explanatory variables. The anova function was utilized to compare the full model against a reduced one and to ascertain the significance of each constrained axis. *p*-values for each axis were subsequently calculated. Any canonical axis from the RDA yielding a *p*-value less than 0.05 was deemed statistically significant.

Supplementary Table S1 contains the explanatory independent variables and the outcome dependent variables used for the regression analysis (Section 3.3.1) and the RDA (Section 3.3.2).

2.4 Positionality statement

As researchers, we recognize that our own backgrounds and experiences inherently shape the lens through which we approach a study. It is thus pertinent to articulate our positionality. The first author is a white male Italian national who has lived and worked for over a decade in South Africa as an academic on the topic of ICT for development. The second author is a woman of Indian heritage who is a South African national and has worked as an academic specializing on sustainability science in her native country. The third author is a

white male Greek national with no living experience in South Africa, but extensive experience conducting similar empirical research across Sub-Saharan Africa.

The first co-author possesses both extensive in-country expertise on ICT research and teaching hundreds of undergraduate students on ICT, as well as an external vantage point that comes from not being a native South African. The second co-author lends crucial knowledge and direct experience with the on-the-ground cultural, social, political, and economic realities in South Africa, as well as through an academic network that facilitated access and trust-building. The third co-author has extensive experience in designing, conducting and analyzing >20 large-scale surveys on food production and nutrition in rural and urban contexts of nine countries in Sub-Saharan Africa. In summary, this complementarity has enabled the research team to bring both insider and outsider perspectives that enrich research design, data analysis and interpretation, and reduce possible biases to the extent possible.

3 Results

3.1 Household characteristics

Table 1 contains summary statistics for the sample. In summary, 49% of participants are female and 51% are male, with their average age being 47 years old. Most participants (78%) have children, with an average of 2.16 children per producer. In terms of education, 60% of producers have not completed high school, 26% are high school graduates, 12% have an undergraduate degree and 2% have a graduate degree.

All participants are considered small-scale food producers, with 27% allocating <100 m² (0.01 ha) of land for cultivation, while 16% >10,000 m² (1 ha). Most producers (89%) do not own the land they cultivate, with practically all (97%) of these small-scale food producers accessing the land through a government department. Most of the respondents (82%) did not pay any fees to utilize the land.

All producers cultivated vegetables on their land, and many cultivated maize, fruit, legumes and herbs. Almost all producers cultivate organic products (96%) citing health, safety, and overall wellbeing of the local community as the main reasons to do so. Most producers (69%) earn below USD 800 *per annum* from their produce, followed by 18% who earn between USD 800–1,600, and 5% who earn between USD 1,600–2,400. Finally, most producers (83.5%) sell their produce at farmers markets at least once a week, 11.8% sell once or twice a month, and 2.4% never sell at farmer markets. Regarding sales at supermarkets, most producers (88.2%) do not sell their produce to these markets, while the remainder sell their produce to supermarkets at least once a week (4.8%) once or twice a month (4.8%). Finally, almost all respondents (98.8%) do not sell online, indicating that this type of market is still out of their reach.

3.2 Perceptions and attitudes for ICTs

Approximately 60% of participants own a smartphone. The reasons for not owning a smartphone articulated from the remainder of respondents include inability to afford purchase (44%), lack of knowledge how to use a smartphone (15%), feeling too old to own a

TABLE 1 Household characteristics.

Variable	Fraction
Gender	Female: 49% Male: 51%
Marital status	Single: 65% Married: 32% Other: 3%
Children in household	Yes: 78% No: 22%
Education	Did not complete high school: 60% High school degree: 26% Undergraduate degree: 12% Graduate degree: 2%
Cultivated land size	<0.01 ha: 27% 0.01–0.05 ha: 20% 0.05–0.1 ha: 20% 0.1–1.0 ha: 17% >1.0 ha: 16%
Land ownership	Not own cultivated land: 89% Own cultivated land: 11%
Access to land	Through a government department: 97% Other: 3%
Fees for land use	82% Did Not Pay Any Fees
Production of organic products	Yes: 96% No: 4%
Annual agricultural income	<USD 800: 69% USD 800–1,600: 18% USD 1,600–2,400: 5% USD 2,400–3,200: 2% USD 3,200–4,000: 4% >USD 4,000: 2%
Sales at farmers markets	No: 2.4% Sell at least once a week: 83.5% Sell once or twice a month: 11.8% Other: 2.3%
Sales at supermarkets	Not sell: 88.2% Sell at least once a week: 4.8% Sell once or twice a month: 4.8% Other: 2.2%
Sales online	Yes: 1.2% No: 98.8%

smartphone (12%), dislike of smartphone technology (6%), and other reasons including the possibility of smartphone being stolen/lost or lack of interest in the specific technology (23%). Among smartphone owners, 10% spent <USD 1.60 per month, 10% spent between USD 1.60–4.00 per month, 23% spent USD 4.00–8.00 per month, 37% spent USD 8–40 per month, 18% spent USD 40–160 per month, and 2% >USD 160 per month. About 35% of the respondents owning a smartphone stated that they are extremely confident when using their device, 51% that are moderately confident, 10% that are somewhat confident, 4% that are slightly confident (no respondents stated that they are not confident at all). Finally, most producers owning a smartphone reported affordability as the most desirable characteristic (82%), followed by brand reputation

(51%), customer assistance (49%), social status (18%), low environmental impact (12%) and being trendy (12%).

Of the 51 producers that use a smartphone, 78% ($n=40$) actively use at least one mobile application to help them produce and/or sell food. Most common were social media applications such as WhatsApp (98%) and Facebook (50%), with only one mobile application, Khula!,⁴ designed especially for small-scale food producers (13%). According to Figure 3A, they actively use the app to specifically learn new information (42%), expand their networks (34%) and marketing (26%) (Figure 3A). When asked about the desirable functions that a hypothetical app should have to improve their food production and/or sales, respondents identified mainly functions for enabling price comparisons (73%), sharing of best practices (73%), and obtaining health tips (67%) (Figure 3B). When asked about the desirable characteristics that a hypothetical app should have to improve their food production and/or sales, respondents identified ease of use (86%), low internet data consumption (76%), and affordability (67%) (Figure 3C). Finally, when asked about the most desirable activities to use such apps, respondents identified assistance with finding sale points (84%), keeping financial records (84%), cultivating crops (84%), undertaking logistics (73%), and keeping inventory (53%) (Figure 3D).

3.3 Factors associated with ICT perceptions and attitudes

3.3.1 Association analysis

Table 2 present the associations between different demographic and socioeconomic characteristics of the respondents with smartphone use, confidence in smartphone use, daily internet use, and food app use. Education level and land size are significantly associated with smartphone use (Table 2). Age is significantly and negatively associated with confidence in smartphone use (i.e., older respondents are less likely to be confident in smartphone use), while education level is significantly and positively associated with confidence in smartphone use (Table 2). Land size is significantly associated with daily internet use (Table 2), while age has a significant negative association with daily internet use (i.e., older respondents are less likely to use the internet daily). Finally, and interestingly, the number of children is the only variable significantly and positively associated with food app use (Table 2). This might reflect that children might influence parents to actually adopt and use food apps.

3.3.2 Redundancy analysis

Figure 4 outlines the RDA exploring the relationship between socioeconomic/demographic factors (Table 1) and desirable functions for hypothetical food apps among producers (Figure 4). The results suggests that older respondents would tend to prefer app functions that allow them read about product reviews. Conversely, younger respondents would be more inclined to prefer app functions that help

⁴ Khula! is a mobile app and web-based platform designed to assist small-scale food producers to access the formal marketplace and connect to suppliers (Agüera et al., 2020). The app enables farmers to list their produce, track real-time inventory and meet market demand (Born et al., 2021). Refer to www.khula.co.za.

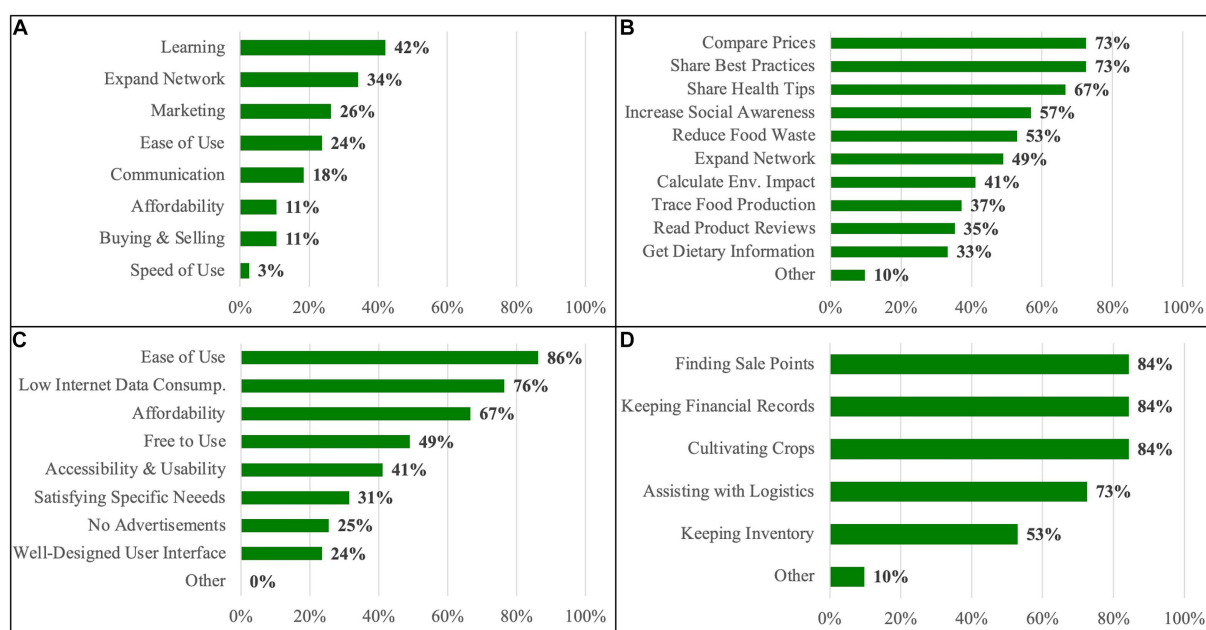


FIGURE 3

Actual uses of food mobile apps (A) and desirable app functions (B), characteristics (C) and uses (D).

them compare prices, share health information, expand their network, and calculate their own environmental impact. Female and married respondents, as well as respondents with higher levels of education, higher incomes, more children, and larger land holdings would tend to prefer app functions that allow them to access dietary information, share best practices, increase social awareness about food, reduce food waste, and trace food along the supply chain. The RDA indicates a statistically significant association between socioeconomic and demographic factors with desired functions for food apps ($p=0.04$, from 999 permutations). The first two axes explain 11.08% (8.14% for RDA1, 2.94% for RDA2) of the total variance, and the biplot of the RDA is shown in Figure 4.

Figure 5 outlines the RDA examining the relationship between socioeconomic/demographic factors, with the desired uses for food apps among producers (Figure 5). The results reveal that producers with more children, larger land holdings, that are married, and older would tend to prefer food apps for keeping financial records, cultivating crops, and assisting with logistics. Conversely, male respondents and those with higher levels of education and income would tend to prefer a food app that can assist them with inventory management and finding new customers. The RDA indicates a statistically significant association between socioeconomic and demographic factors with desired uses for food apps ($p=0.002$, from 999 permutations). The first two axes explain 20.15% (13.7% for RDA1, 6.45% for RDA2) of the total variance, and the biplot of the RDA is shown in Figure 5.

4 Discussion

4.1 Synthesis of main findings

Most participants are relatively old with comparatively low levels of formal education, and do not possess the land they cultivate,

which make them heavily dependent on governmental and other forms of support for their agricultural activities. Most producers have adopted organic cultivation methods. These findings reflect the characteristics of small-scale food producers engaging in urban agriculture in South African cities quite well (Bun and Thornton, 2013; Bisaga et al., 2019; Cilliers et al., 2020; Atlink and Hart, 2023), as well as other parts of Sub-Saharan Africa (Davies et al., 2021; Maina et al., 2023).

A substantial fraction of these small-scale producers engaged in urban agriculture does not use smartphones or similar smart electronic devices. Among those owning and using smart devices, the average monthly expenditure on internet data is considerably high, which aligns well with findings from studies which underscore the elevated cost of internet data in South Africa compared to other developing nations (Gillwald et al., 2018; Venter and Daniels, 2020). In particular, South Africans can spend as much as ZAR 85 (equivalent to USD 5.29) per GB of data, a cost that translates to nearly 4 hours of labor for individuals earning the minimum wage, which is stark contrast to the approximate cost of USD 1.53 per GB in North Africa and USD 2.47 in Western Europe (Harrisberg and Mensah, 2022). According to Gillwald et al. (2018) such high costs of mobile phones and data are obstacles for the adoption and utilization of ICTs in South Africa.

The majority of respondents possessing a smartphone reported using some apps to aid in the cultivation and sale of their produce. Interestingly, with the exception of Khula!, a dedicated food-related app used by few food producers, all other apps were social media platforms (Fawole and Olajide, 2012). However, this can be linked to sub-optimal outcomes among adopters due to lack of development and adoption of dedicated apps for small-scale food producers or the poor-quality information provided in generalist apps (Costopoulou et al., 2016). Most advancements in digital agriculture are geared

TABLE 2 Relationship between socioeconomic and demographic characteristics with smartphone use, confidence in smartphone use, daily internet use, and food app use.

Respondent characteristics	(a) Smartphone use				(b) Confidence in smartphone use				(c) Daily internet use				(d) Food app use			
	Estimate	Std. error	z-value	Pr (> z)	Estimate	Std. error	t-value	Pr (> t)	Estimate	Std. error	t-value	Pr (> t)	Estimate	Std. error	z-value	Pr (> z)
(Intercept)	-2.4773	1.8665	-1.327	0.18442	3.74227	0.65602	5.704	1.14E-06****	4.67889	1.0073	4.645	3.49E-05****	-4.9711	3.1085	-1.599	0.1098*
Location province	1.8227	1.3313	1.369	0.17096	0.37493	0.49635	0.755	0.45434	-0.18202	0.76213	-0.239	0.8124	3.0683	2.7476	1.117	0.2641
Location group	-1.2172	0.7579	-1.606	0.10828	-0.14722	0.23890	-0.616	0.54114	-0.08768	0.36682	-0.239	0.8123	-2.5345	1.3671	-1.854	0.0637*
Gender	-0.8995	0.7537	-1.193	0.23270	0.17319	0.21427	0.808	0.42358	0.19602	0.329	0.596	0.5546	0.8960	1.2573	0.713	0.4761
Marital status	0.3292	0.7382	0.446	0.65566	0.00359	0.22059	0.016	0.98709	-0.1294	0.33871	-0.382	0.7044	0.9821	1.7195	0.571	0.5679
Age	-0.4956	0.2858	-1.734	0.08287*	-0.29626	0.09478	-3.126	0.00325****	-0.33443	0.14553	-2.298	0.0267**	-0.7269	0.5319	-1.367	0.1717
Children number	0.3559	0.2603	1.367	0.17155	0.07297	0.08274	0.882	0.38300	0.23838	0.12705	1.876	0.0678*	1.6579	0.6622	2.504	0.0123**
Education	1.6006	0.6802	2.353	0.01862**	0.23172	0.11048	2.097	0.04216**	0.26854	0.16964	1.583	0.1211	1.7658	0.9555	1.848	0.0646*
Income	-0.2234	0.6889	-0.324	0.74571	-0.05669	0.10985	-0.516	0.60856	-0.05811	0.16867	-0.345	0.7322	-0.8045	0.6762	-1.190	0.2341
Land size	0.7363	0.2548	2.889	0.00386****	0.03787	0.05786	0.655	0.51643	0.1999	0.08884	2.25	0.0259**	0.3799	0.3728	1.019	0.3082

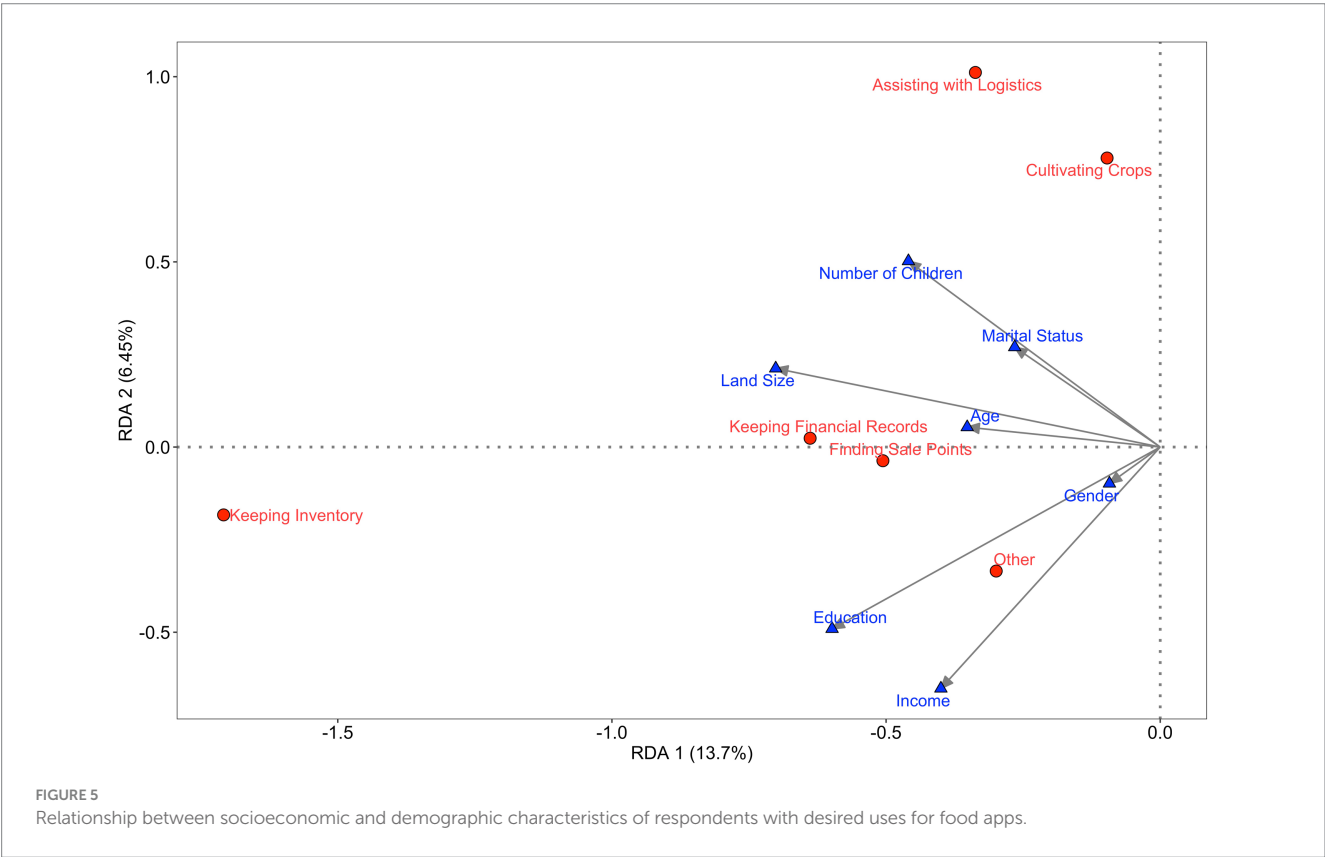
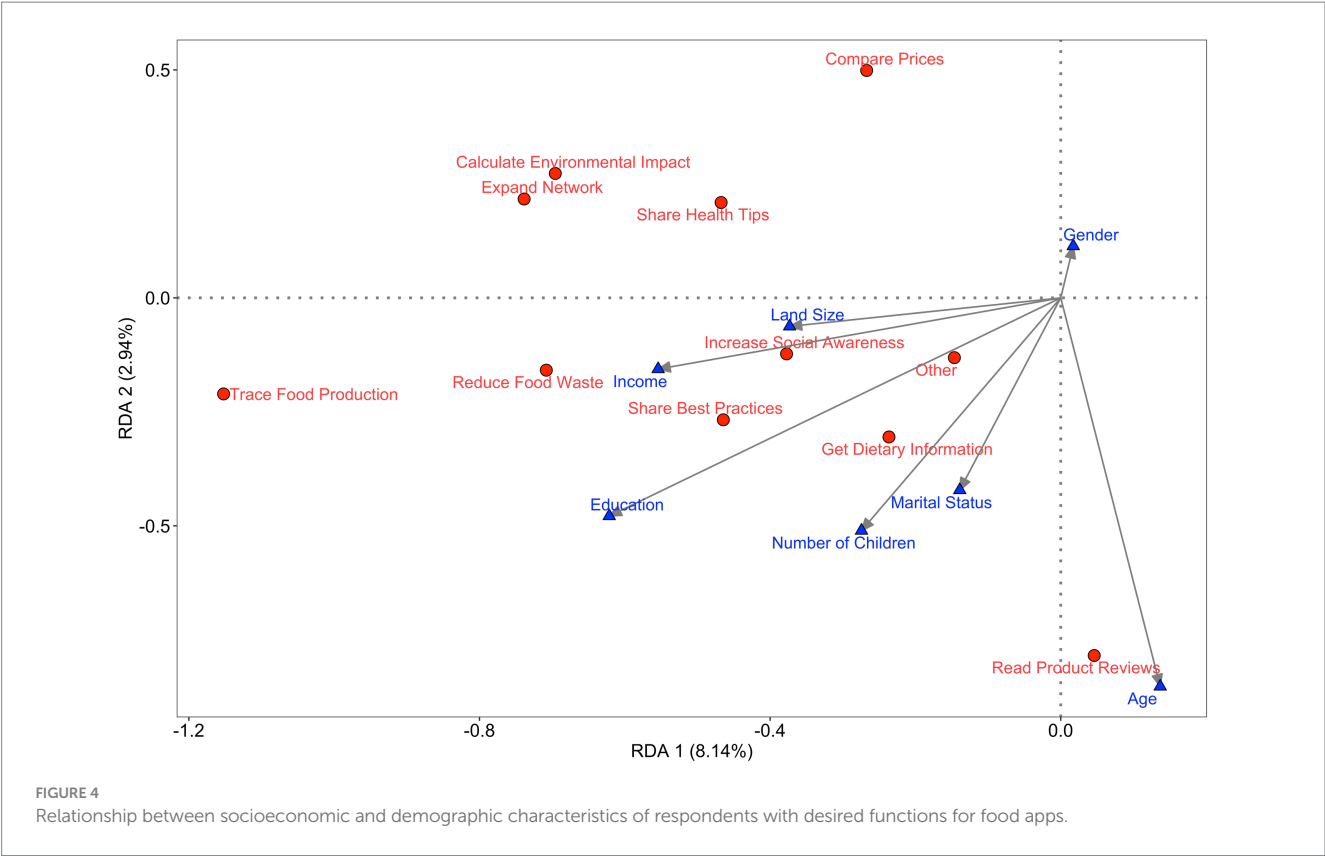
Signif. codes: ****p<0.001; ***p<0.01; **p<0.05; *p<0.1.

towards high income countries and large-scale food production, with few tailored for low- and middle-income countries and small-scale food producers (Chandra and Collis, 2021).

Overall, our findings suggest that producers favor ICTs that facilitate the easy access to (and dissemination of) information for pricing comparisons, best practices, and health-related information (Figure 3B). Such functions can be highly valuable to food producers, as according to Eitzinger et al. (2019) their use can enhance crop output and improve farm management by sharing both their successes and challenges with each other (and with experts). Furthermore, respondents identified ease of use, low internet data consumption, and affordability (i.e., low cost for ICT purchase) as the most crucial desired characteristics for food apps (Figure 3C). This is not surprising considering the very low economic status of most respondents, with research indicating that for poor food producers to adopt and consistently use these applications, the associated costs must be kept at a minimum (Qiang et al., 2012; Chandra and Collis, 2021). Additionally, the perceived ease of use and usefulness of technology can significantly impact willingness to adopt it (Wu, 2022).

The socioeconomic and demographic factors mostly associated with the adoption, perceptions, and choice of ICTs (Table 2) include age, education level, and family size (especially number of children). Older respondents are less likely to own a smartphone, and be confident in smartphone and internet use, often citing their lower digital literacy as a key reason for non-adoption (Table 2). Howland et al. (2015), for example, have suggested that older farmers often experience a general sense of anxiety towards using modern ICTs and lack the necessary skills for functions beyond making telephone calls. Similarly, Hoang (2020) have found that the use of mobile phones for fruit marketing was inversely related to the age of farmers. One of the more interesting findings was that the only characteristic significantly associated with actual app use was the number of children (Table 2). Studies have alluded that larger households are more probable to have at least one member that uses some app (influencing the others) (Maina et al., 2023) or that younger and more digitally literate family members can indeed influence older members to adopt ICTs as they can get some initial help for their operation (Winstone et al., 2021; Vassilakopoulou and Hustad, 2023). Additionally, Wu (2022) found that the number of family farm laborers has a significant positive impact on the willingness to adopt ICT technologies.

Producers with more children, higher levels of education and those who are married, are more likely to adopt food-related applications with desired functions to share best practices and acquire dietary information (Figure 4). Furthermore, the number of children and the size of the farm were found to significantly influence the desired use of food apps by producers to cultivating crops, assisting with logistics and keeping financial records (Figure 5). This corroborates the findings of Mittal and Mehar (2016), who found a positive and significant association between the use of mobile phone-based information among farmers and farm size. Similarly, Parmar et al. (2018) discovered that landholding size positively influences farmers' access to ICT systems, while Min et al. (2020) suggest that larger farm sizes encourage the use of smartphones in households. Moreover, Wu (2022) found that family farms with a larger area of arable land were more luckily to adopt new technologies compared to smaller sized farms.



4.2 Comparison with knowledge from other developing countries

The findings of this study align with other research conducted in developing regions that have examined the adoption of ICT by small-scale food producers. For instance, a study conducted by [Awuor and Rambim \(2022\)](#) on the use of ICT for marketing agricultural produce among small-scale food producers in Kenya found that most of these farmers are still using basic mobile feature phones. They suggested that there is a need for capacity building initiatives to help these farmers transition to the use of smartphones.

Similarly, research conducted by [Ayim et al. \(2022\)](#) in Ghana revealed that older farmers are less likely to adopt e-agriculture platforms. They recommended the development of interfaces that are more user-friendly for older users. In Nigeria, a study found that the cost of ICT tools and the lack of a stable electricity supply are the major constraints that farmers face when it comes to using ICTs ([Idu et al., 2023](#)).

The importance of app characteristics such as affordability, ease of use, and low data consumption on ICT adoption is also highlighted in research focusing on agricultural development in Sub-Saharan Africa. A review by [Baumüller \(2018\)](#) emphasized that many existing tools have been designed without considering the abilities, accessibility, and actual information needs of small-scale food producers. Therefore, ease of use remains a key criterion for the adoption of these tools. The [International Telecommunication Unit \(2022\)](#) also found that high costs are a major constraint for users of ICT services in Africa, calling for the development of affordable and context-specific ICT solutions.

The findings of this study confirm that collaboration between multiple stakeholders and sustained support from the government are crucial for the successful development and adoption of ICT innovations focused on small-scale food producers. This is supported by studies from [Nonet et al. \(2022\)](#) examining sustainable agriculture development in Africa and [Asongu et al. \(2020\)](#) focusing on ICT, governance, and insurance in Sub-Saharan Africa. These studies highlight the need for focused policies and public-private partnerships (PPPs) for inclusive ICT development in the agriculture sector. In particular, the multi-stakeholder approach aims to ensure that the benefits of ICT reach all farmers, including small-scale food producers, and contribute to sustainable agricultural development.

4.3 Effects of the COVID-19 pandemic on ICT adoption and use

This research was conducted in early 2019, thereby offering insights into the pre-COVID landscape regarding ICT adoption and usage among small-scale food production. Thus, the elicited perspectives and patterns should be viewed with this in mind, considering that the COVID-19 pandemic had profound effects on ICT adoption and use ([Plekhanov et al., 2022](#); [Kafi et al., 2023](#)). As outlined in the literature scan below, such effects were also observed on ICT applications in agriculture globally and within rural small-scale food production contexts in South Africa.

For example, multiple studies have found that lockdowns and mobility restrictions compelled food producers to harness digital solutions to sustain operations, access markets, and minimize supply chain disruptions ([Kansiime et al., 2021](#); [Alam et al., 2023](#)). For

instance, digital tools enabled farmers to pivot to online sales, tap mobile money platforms, benefit from digitally enabled logistics, and access agriculture and market information ([Mabhaudhi et al., 2022](#)). In South Africa, there has been some evidence that small-scale food producers have harnessed ICTs as coping mechanisms, with rural communities relying extensively on mobile phones and social media platforms to coordinate planting, access inputs, connect with traders, and engage government support schemes during lockdown periods ([Sekabira et al., 2023](#)). However, persistent obstacles like network availability, cost barriers, and sub-optimal content have continued hampering usage and benefits ([Ayim et al., 2022](#)).

In a sense, the pandemic necessitated an accelerated uptake of ICTs, serving as an impetus to digital transformation across food systems ([Tricarico, 2021](#)). However, it is not clear whether such patterns are observed following the pandemic ([Singh and Srivastava, 2023](#)).

4.4 Implications for policy and practice

Overcoming the barriers related to ICT design and access is crucial for their successful adoption and sustained utilization for sustainable food systems in developing countries, including Sub-Saharan Africa, especially food systems anchored on small-scale food producers. Below we discuss some of the implications of the findings and make recommendations for the design and promotion of ICTs.

First, it would be essential that the characteristics and functionalities of such ICTs cater to the needs, priorities, and capabilities of such producers, while their development approaches should follow to some extent a co-design mentality to ensure that these are reflected in the ICTs. For example, our results strongly suggest that such ICTs should be multifunctional and pro-poor, taking into account literacy levels (simple interface, ease of use), broadband consumption (low data needs, offline capabilities), user age and household structure (convenient access to tech support, intergenerational relevance and benefits), and farmer priorities (access to pricing information, information on best practices, sharing of health-related information, and affordability). Considering that producers with children tend to exhibit a greater willingness to adopt ICTs, ICTs for small-scale food producers should be designed in a way that allows their usage and benefits across different generations within the households. Given that the average age of South African farmers is over 60 years old ([Born et al., 2021](#)), and older farmers are generally hesitant to adopt unfamiliar technologies, while younger farmers are more receptive to ICTs ([Mdoda and Mdiya, 2022](#)), younger family members could play a crucial role in supporting the adoption of ICTs for farming activities. However, this support is contingent upon these tools being perceived as beneficial for their households and communities. This could potentially foster intergenerational learning and possibly stimulate the entry of more young black entrepreneurs into the South African agricultural sector.

Second, our research implies that organic farming can offer a promising niche for ICT tools. On the one hand, most respondents have adopted organic production practices and have sold their produce at farmers markets. On the other hand, organic products can offer higher incomes to small-scale food producers for certain market

segments compared to those engaged in conventional agriculture (Qiao et al., 2018; Benedek et al., 2021), having positive implications for food security (Ume, 2023). In this sense, fit-for-purpose ICT tools that can help farmers properly implement agroecological crop production practices, find related markets, facilitate cooperative operation, and strengthen bargaining power could play a pivotal role in achieving this objective (Gamage et al., 2023).

Third, significant efforts should be directed towards two key areas: (a) optimizing the development, maintenance, and promotion of ICT tools, and (b) addressing broader systemic barriers, such as economic and digital divides. Regarding the development of ICT tools, it is crucial to recognize that this process is time-consuming, expensive, and requires advanced programming skills as well as substantial long-term investments. As for the systemic barriers, it is essential to acknowledge that ICTs has the potential to perpetuate or even exacerbate existing power imbalances between resource-constrained small-scale food producers and well-established large-scale commercial food producers. Achieving inclusive development and widespread use of technology that empowers small-scale food producers would likely require targeted public policy and investment (Woodhill et al., 2020). To accomplish these multi-faceted objectives, it is essential to develop multi-sectoral collaboration involving stakeholders from various sectors including telecommunications, banking, health, and agriculture, as well as non-governmental organizations, academics, and government departments working in the domains of food security, sustainable development, and ICTs. For example, reducing the costs of internet data for small-scale food producers or providing financial support for the adoption and use of livelihood-related ICTs to facilitate broader adoption and sustained use of such tools would require the coordinated efforts of multiple stakeholders.

4.5 Study limitations and future research

The overall study has three primary limitations related to: (a) possible biases arising from the use of snowball sampling, (b) the limited size of the study sample and the focus on only the two largest metropolitan areas in the country, and (c) the data collection taking place prior to the COVID-19 pandemic. Given these limitations, the findings of the study should be generalized with caution.

Regarding (a), due to the practical constraints outlined in Section 2.2 (i.e., lack of comprehensive farmer lists, safety concerns, reluctance of local communities to engage with outsiders), we adopted a snowball sampling approach. While this sampling method offers certain advantages in study contexts such as ours, it has also been associated to potential biases (Biernacki and Waldorf, 1981; Illenberger et al., 2008; Kirchherr and Charles, 2018; Parker et al., 2019). For example, although the local guides/translators were invaluable in building trust and facilitating community entry, they might have introduced sampling biases by selecting respondents with specific characteristics, viewpoints, or locations, or interpretation biases stemming from their crucial role as cultural brokers in the community. To minimize such biases to the extent possible we employed the following strategies: (i) ensuring that diverse areas were covered in each city/community, (ii) explaining to lead farmers that we aimed to achieve a representative cross-section of the small-scale food producers in each study area, and (iii) obtaining a comprehensive understanding of the underlying

phenomena related to ICT adoption by small-scale producers, and the characteristics of urban agriculture in the study cities through extensive literature reviews and expert interviews (Alfonsi, 2024; Alfonsi et al., 2024).

Regarding (b), despite the robust findings reported here, it is essential to acknowledge various methodological decisions that readers should consider when generalizing the results. First, the relatively small sample size ($n=85$) and focus on the two major South African cities might limit generalization across geographic areas and demographic segments. Future research should address these gaps by providing insights into the realities experienced in secondary cities or rural regions of South Africa, and other parts of Sub-Saharan Africa. Second, while the statistical tools employed in this study (i.e., descriptive statistics, association analysis, RDA) can help establish relationships between ICT preferences/use and sociodemographic characteristics, they do not imply causality. Future research should aim to expand the current knowledge by using more appropriate tools for causal inference, such as randomized control trials, propensity score matching, or structural equation modelling. Third, the technocentric approach rooted in empirical social sciences adopted here can elicit some of the factors affecting ICT user preferences, adoption, and use patterns. However, this approach risks overlooking deeper socio-cultural and political-economic forces shaping technology adoption. Further studies should adopt more interdisciplinary framings capable of capturing systemic barriers related to resource access and power relations.

Regarding (c), it is important to acknowledge that our findings reflect the pre-COVID19 pandemic situation. As such, this study should be considered a baseline that mapped pre-pandemic ICT adoption/use patterns and barriers among small-scale food producers engaged in urban agriculture. By identifying these pre-existing patterns and barriers, our findings can inform targeted interventions tailored to the needs of small-scale food producers as the technology landscape continues to evolve. While the accelerating technology integration driven by COVID-19 necessitates updated research, this pre-pandemic baseline study remains valuable for pinpointing systemic gaps and intervention needs. Further research tracking post-2020 shifts in ICT adoption, use and perspectives would enable a more comprehensive understanding of the catalysts, persistent barriers, and support required at the intersection of ICT and small-scale food systems.

5 Conclusion

This study investigates the perceptions of small-scale food producers engaged in urban agriculture in various low-income areas of Johannesburg and Cape Town about the adoption and desirable characteristics of food-related ICTs, as well as the factors influencing user perspectives. Through 85 surveys with producers, we identify: (a) the patterns and reasons for adopting or not adopting ICTs, (b) the desirable functions and characteristics of ICTs prioritized by producers, and (c) the production activities for which ICTs are most needed.

Our findings reveal clear preferences for multi-functional, user-friendly, and affordable ICT tools that facilitate price comparisons, best practice sharing, and access to health tips. User age, education, income, and family size are significant factors influencing technology

perspectives and use. By highlighting key limitations related to ICT suitability, cost, and digital literacy while emphasizing farmer priorities and capabilities, this research contributes to the emerging literature on ICTs for small-scale food producers in urban contexts of South Africa, and Sub-Saharan Africa more broadly.

Such user-centered insights can inform the development of customized ICT tools and interventions, that effectively empower small-scale food producers engaged in urban agriculture across rapidly growing cities in the region. Specifically, our findings suggest that pro-poor mobile applications offering value-adding informational, networking, and selling functionalities in local languages can meet many of the needs of urban small-scale food producers. However, deliberate design adaptations and policy support are essential to overcome prevailing systemic barriers related to affordability, skills development, and social inclusion.

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 requirement of ethical approval was waived by the Ethics Review Committee of the University of Tokyo for the studies involving humans because this research does not require ethical review in accordance with the governmental research ethics guideline in Japan, “Ethical Guidelines for Life Science and Medical Research Involving Human Subjects” and “The University Research Ethics Regulation.” The studies were conducted in accordance with the local legislation and institutional requirements. Written informed consent for participation was not required from the participants or the participants’ legal guardians/next of kin because verbal consent was obtained from all participants prior to the commencement of the survey. Written informed consent was not obtained from the individuals for the publication of any potentially identifiable images or data included in this article because verbal consent was obtained from all participants prior to the commencement of the survey.

References

- Abrahams, C., Everatt, D., Van Den Heever, A., Mushongera, D., Nwosu, C., Pilay, P., et al. (2018). South Africa: National urban policies and city profiles for Johannesburg and Cape Town, GCRF Centre for Sustainable, Healthy and Learning Cities and Neighbourhoods (SHLC).
- Aguera, P., Berglund, N., Chinembiri, T., Comninos, A., Gillwald, A., and Govan Vassen, N. (2020). *Paving the way towards digitalising agriculture in South Africa*, Cape Town: Research ICT Africa. 1–42.
- Agyekumhene, C., de Vries, J. R., van Paassen, A., Macnaghten, P., Schut, M., and Bregt, A. (2018). Digital platforms for smallholder credit access: the mediation of trust for cooperation in maize value chain financing. *NJAS Wageningen J. Life Sci.* 86–87, 77–88. doi: 10.1016/j.njas.2018.06.001
- Ahmed, A., Lazo, D. P. L., Alatinga, K. A., and Gasparatos, A. (2022). From Ampesie to French fries: systematising the characteristics, drivers and impacts of diet change in rapidly urbanising Accra. *Sustain. Sci.*, 1–25. doi: 10.1007/s11625-022-01195-y
- Aker, J. C., Ghosh, I., and Burrell, J. (2016). The promise (and pitfalls) of ICT for agriculture initiatives. *Agric. Econ.* 47, 35–48. doi: 10.1111/agec.12301
- Akinuwa, B. A., Uzoka, F. M., Olabiyisi, S. O., Omidiora, E. O., and Fiddi, P. (2013). An empirical analysis of end-user participation in software development projects in a developing country context. *Electron. J. Inf. Syst. Dev. Countries* 58, 1–25. doi: 10.1002/j.1681-4835.2013.tb00413.x
- Alam, G. M., Khatun, M. N., Sarker, M. N. I., Joshi, N. P., and Bhandari, H. (2023). Promoting agri-food systems resilience through ICT in developing countries amid COVID-19. *Front. Sustainable Food Syst.* 6:972667. doi: 10.3389/fsufs.2022.972667
- Aleke, B., Ojiako, U., and Wainwright, D. W. (2011). ICT adoption in developing countries: perspectives from small-scale agribusinesses. *J. Enterp. Inf. Manag.* 24, 68–84. doi: 10.1108/17410391111097438
- Alfonsi, R. M. (2024). “Development of an information and communication technology (ICT) framework for local food systems in South Africa,” in *The Graduate Program in Sustainability Science - Global Leadership Initiative (GPSS-GLI)*. Kashiwa, Japan: The University of Tokyo.
- Alfonsi, R. M., Naidoo, M., and Gasparatos, A. (2024). “Stakeholder perspectives for information and communication technologies (ICTs) for sustainable food systems in

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RMA: Conceptualization, Formal analysis, Investigation, Methodology, Software, Writing – original draft. MN: Writing – review & editing. AG: Writing – review & editing.

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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.

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Supplementary material

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South Africa: challenges, opportunities, and a proposed ICT framework" in *Environment, development and sustainability*. Amsterdam: Springer Nature.

Antenucci, I., and Tomasello, F. (2022). Three shades of 'urban-digital citizenship': borders, speculation, and logistics in Cape Town. *Citizen Stud.* 27, 247–270. doi: 10.1080/13621025.2022.2073088

Antle, J. M., Jones, J. W., and Rosenzweig, C. E. (2017). Next generation agricultural system data, models and knowledge products: introduction. *Agric. Syst.* 155, 186–190. doi: 10.1016/j.agsy.2016.09.003

Anwar, M. A. (2019). "Connecting South Africa: ICTs, uneven development and poverty debates" in *The geography of South Africa* (eds.) J. Knight and C. M. Rogerson, (Cham: Springer), 261–267.

Asongu, S., Nnanna, J., and Acha-Anyi, P. (2020). Information technology, governance and insurance in sub-Saharan Africa. *Soc. Responsib. J.* 16, 1253–1273. doi: 10.1108/SRJ-05-2019-0167

Atlink, H., and Hart, T. (2023). Feeding the community: urban farming in Johannesburg. *HSRC Rev.* 20, 24–27.

Awuor, F. M., and Rambim, D. A. (2022). *Adoption of ICT-in-agriculture innovations by smallholder farmers in Kenya*. Wuhan: Scientific Research Publishing.

Ayim, C., Kassahun, A., Addison, C., and Tekinerdogan, B. (2022). Adoption of ICT innovations in the agriculture sector in Africa: a review of the literature. *Agric. Food Secur.* 11, 1–16. doi: 10.1186/s40066-022-00364-7

Badami, M. G., and Ramankutty, N. (2015). Urban agriculture and food security: A critique based on an assessment of urban land constraints. *Glob. Food Sec.* 4, 8–15. doi: 10.1016/j.gfs.2014.10.003

Bakker, J. D., Parsons, C., and Rauch, F. (2020). Migration and urbanization in post-apartheid South Africa. *World Bank Econ. Rev.* 34, 509–532. doi: 10.1093/wber/lhy030

Barau, A. A., and Oladeji, D. O. (2017). Participation of urban women in agricultural production activities in the Sokoto Metropolis, Nigeria. *J. Nat. Resour. Dev.* 7, 84–90. doi: 10.5027/jnrd.v7i10

Barker, M. E., Hardy-Johnson, P., Weller, S., Hailemalak, A., Jarju, L., Jesson, J., et al. (2021). How do we improve adolescent diet and physical activity in India and sub-Saharan Africa? Findings from the transforming adolescent lives through nutrition (TALENT) consortium. *Public Health Nutr.* 24, 5309–5317. doi: 10.1017/S1368980020002244

Battersby, J. (2011). Urban food insecurity in Cape Town, South Africa: an alternative approach to food access. *Dev. South. Afr.* 28, 545–561. doi: 10.1080/0376835X.2011.605572

Battersby, J. (2017). Food system transformation in the absence of food system planning: the case of supermarket and shopping mall retail expansion in Cape Town, South Africa. *Built Environ.* 43, 417–430. doi: 10.2148/benv.43.3.417

Battersby, J., and Marshak, M. (2016). *Mapping the invisible: The informal food economy of Cape Town, South Africa*. Oxford: African Books Collective.

Baumüller, H. (2018). The little we know: an exploratory literature review on the utility of mobile phone-enabled services for smallholder farmers. *J. Int. Dev.* 30, 134–154. doi: 10.1002/jid.3314

Bbun, T. M., and Thornton, A. (2013). A level playing field? Improving market availability and access for small scale producers in Johannesburg, South Africa. *Appl. Geogr.* 36, 40–48. doi: 10.1016/j.apgeog.2012.04.004

Benedek, Z., Fertő, I., Galamba Marreiros, C., Aguiar, P. M. D., Pocol, C. B., Čechura, L., et al. (2021). Farm diversification as a potential success factor for small-scale farmers constrained by COVID-related lockdown. Contributions from a survey conducted in four European countries during the first wave of COVID-19. *PLoS One* 16:e0251715. doi: 10.1371/journal.pone.0251715

Berti, G., and Mulligan, C. (2016). Competitiveness of small farms and innovative food supply chains: the role of food hubs in creating sustainable regional and local food systems. *Sustain. For.* 8:616. doi: 10.3390/su8070616

Bertolini, R. (2005). *Making information and communication technologies work for food security in Africa*, No. 566-2016-38945, pp. 1–6.

Biernacki, P., and Waldorf, D. (1981). Snowball sampling: problems and techniques of chain referral sampling. *Sociol. Methods Res.* 10, 141–163. doi: 10.1177/004912418101000205

Bisaga, I., Parikh, P., and Loggia, C. (2019). Challenges and opportunities for sustainable urban farming in South African low-income settlements: a case study in Durban. *Sustain. For.* 11:5660. doi: 10.3390/su11205660

Bizikova, L., Nkonya, E., Minah, M., Hanisch, M., Turaga, R. M. R., Speranza, C. I., et al. (2020). A scoping review of the contributions of farmers' organizations to smallholder agriculture. *Nature Food* 1, 620–630. doi: 10.1038/s43016-020-00164-x

Bonevski, B., Randell, M., Paul, C., Chapman, K., Twyman, L., Bryant, J., et al. (2014). Reaching the hard-to-reach: a systematic review of strategies for improving health and medical research with socially disadvantaged groups. *BMC Med. Res. Methodol.* 14, 1–29. doi: 10.1186/1471-2288-14-42

Born, L., Chirinda, N., Mabaya, E., Afun-Ogidan, O., Girvetz, E., Jarvis, A., et al. (2021). *Digital agriculture profile: South Africa*. Rome, Italy: FAO.

Brown, B., Nuberg, I., and Llewellyn, R. (2020). From interest to implementation: exploring farmer progression of conservation agriculture in eastern and southern Africa. *Environ. Dev. Sustain.* 22, 3159–3177. doi: 10.1007/s10668-019-00340-5

Chagomoka, T., Drescher, A., Glaser, R., Marschner, B., Schlesinger, J., and Nyandoro, G. (2017). Contribution of urban and periurban agriculture to household food and nutrition security along the urban–rural continuum in Ouagadougou, Burkina Faso. *Renew. Agric. Food Syst.* 32, 5–20. doi: 10.1017/S1742170515000484

Chandra, R., and Collis, S. (2021). Digital agriculture for small-scale producers: challenges and opportunities. *Commun. ACM* 64, 75–84. doi: 10.1145/3454008

Chipidza, W., and Leidner, D. (2019). A review of the ICT-enabled development literature: Towards a power parity theory of ICT4D. *The Journal of Strategic Information Systems* 28, 145–174. doi: 10.1016/j.jsis.2019.01.002

Chizema, T. R., and van Greunen, D. (2023). Is there value in using ICTs to manage and monitor climate change: perspectives of small-scale farmers in Chitungwiza, Zimbabwe. In *2023 IST-Africa conference (IST-Africa)* (pp. 1–9). IEEE.

Cilliers, E. J., Lategan, L., Cilliers, S. S., and Stander, K. (2020). Reflecting on the potential and limitations of urban agriculture as an urban greening tool in South Africa. *Front. Sustain. Cities* 2:43. doi: 10.3389/frsc.2020.00043

Corporate Finance Institute (2022). Regression analysis. The estimation of relationships between a dependent variable and one or more independent variables. Available at <https://corporatefinanceinstitute.com/resources/data-science/regression-analysis/> (Accessed February 13, 2022).

Costopoulou, C., Ntaliani, M., and Karetos, S. (2016). Studying mobile apps for agriculture. *IOSR J. Mob. Comput. Appl.* 3, 44–49. doi: 10.9790/0050-03064449

Coulbaly, O., Nouhohefin, T., Aitchedji, C. C., Cherry, A. J., and Adegbola, P. (2011). Consumers' perceptions and willingness to pay for organically grown vegetables. *Int. J. Veg. Sci.* 17, 349–362. doi: 10.1080/19315260.2011.563276

Courtois, P., and Subervie, J. (2015). Farmer bargaining power and market information services. *American Journal of Agricultural Economics*, 97, 953–977. doi: 10.1093/ajae/aau051

Crush, J. S., and Frayne, G. B. (2011). Urban food insecurity and the new international food security agenda. *Dev. South. Afr.* 28, 527–544. doi: 10.1080/0376835X.2011.605571

D'Alessandro, C., Hanson, K. T., and Kararach, G. (2018). Peri-urban agriculture in southern Africa: miracle or mirage? *Afr. Geogr. Rev.* 37, 49–68. doi: 10.1080/19376812.2016.1229629

Davies, J., Hannah, C., Guido, Z., Zimmer, A., McCann, L., Battersby, J., et al. (2021). Barriers to urban agriculture in sub-Saharan Africa. *Food Policy* 103:101999. doi: 10.1016/j.foodpol.2020.101999

Deichmann, U., Goyal, A., and Mishra, D. (2016). Will digital technologies transform agriculture in developing countries? *Agric. Econ.* 47, 21–33. doi: 10.1111/agec.12300

Department of Science and Technology. (2013) ICT RDI Roadmap. Towards Digital Advantage: Roadmapping South Africa's ICT RDI Future. Available at: https://www.dst.gov.za/images/ict_rdi_roadmap.pdf. (Accessed August 1, 2022).

Djurfeldt, A. A. (2015). Urbanization and linkages to smallholder farming in sub-Saharan Africa: implications for food security. *Glob. Food Sec.* 4, 1–7. doi: 10.1016/j.gfs.2014.08.002

Doherty, F., Tayse, R., Kaiser, M., and Rao, S. (2023). "The farm has an insatiable appetite": A food justice approach to understanding beginning farmer stress. *J. Agric. Food Sys. Community Dev.* 12, 1–24. doi: 10.5304/jafscd.2023.123.011

Eitzinger, A., Cock, J., Atzmanstorfer, K., Binder, C. R., Läderach, P., Bonilla-Findji, O., et al. (2019). Geo farmer: A monitoring and feedback system for agricultural development projects. *Comput. Electron. Agric.* 158, 109–121. doi: 10.1016/j.compag.2019.01.049

Fafchamps, M., and Minten, B. (2012). Impact of SMS-based agricultural information on Indian farmers. *World Bank Econ. Rev.* 26, 383–414. doi: 10.1093/wber/lhr056

FAO (2018a) Proposed international definition of small-scale food producers for monitoring the sustainable development goal indicators 2.3.1 and 2.3.2. Agricultural and rural statistics, Office of the Chief Statistician and the statistics division. FAO, Rome, Italy. Available at: <https://unstats.un.org/unsd/statcom/49th-session/documents/BG-Item3j-small-scale-food-producers-definition-FAO-E.pdf>. (Accessed September 27, 2022).

FAO (2018b) Seven factors to empowering rural women through ICTs. Using technology to transform lives. Available at <https://www.fao.org/fao-stories/article/en/c/1105823/> (Accessed September 8, 2022).

FAO (2018c) Leveraging ICT innovations to support farmers and farmers' organisations. Available at: <https://www.fao.org/e-agriculture/news/leveraging-ict-innovations-support-farmers-and-farmers-organisations> (Accessed February 10, 2024).

Fawole, O. P., and Olajide, B. R. (2012). Awareness and use of information communication technologies by farmers in Oyo state, Nigeria. *J. Agri. Food Inf.* 13, 326–337. doi: 10.1080/10496505.2012.717003

Fombad, M. (2018). Knowledge management for poverty eradication: a South African perspective. *Journal of information communication and ethics in society*, 16, 193–213. doi: 10.1108/JICES-04-2017-0022

Gamage, A., Gangahagedara, R., Gamage, J., Jayasinghe, N., Kodikara, N., Suraweera, P., et al. (2023). Role of organic farming for achieving sustainability in agriculture. *Farming Syst.* 1:100005. doi: 10.1016/j.farsys.2023.100005

Gassner, A., Harris, D., Matusch, K., Terheggen, A., Lopes, C., Finlayson, R. F., et al. (2019). Poverty eradication and food security through agriculture in Africa: rethinking objectives and entry points. *Outlook Agric.* 48, 309–315. doi: 10.1177/0030727019888513

- Gebeeyehu, D. T., East, L., Wark, S., and Islam, M. S. (2022). Impact of COVID-19 on the food security and identifying the compromised food security dimension: A systematic review protocol. *PLoS One* 17:e0272859. doi: 10.1371/journal.pone.0272859
- Giller, K. E., Delaune, T., Silva, J. V., van Wijk, M., Hammond, J., Descheemaeker, K., et al. (2021). Small farms and development in sub-Saharan Africa: farming for food, for income or for lack of better options? *Food Secur.* 13, 1431–1454. doi: 10.1007/s12571-021-01209-0
- Gillwald, A., Mothobi, O., and Rademan, B. (2018). The state of ICT in South Africa. Policy Paper No. 5, Series 5, International Development Research Centre.
- Githira, D., Wakibi, S., Njuguna, I. K., Rae, G., Wandera, S., and Ndirangu, J. (2020). *Analysis of multiple deprivations in secondary cities in sub-Saharan Africa: Analysis report*. Marylebone: UN-Habitat and UNICEF.
- Gollin, D. (2014). Smallholder agriculture in Africa. An overview and implications for policy. IIED Work Pap IIED, London.
- Gray, D. E. (2014). *Doing research in the real world*. London: Sage Publications Ltd.
- Grebitus, C. (2021). Small-scale urban agriculture: drivers of growing produce at home and in community gardens in Detroit. *PLoS One* 16:e0256913. doi: 10.1371/journal.pone.0256913
- Hackfort, S. (2021). Patterns of inequalities in digital agriculture: a systematic literature review. *Sustain. For.* 13:12345. doi: 10.3390/su132212345
- Harris, C. G., and Achora, J. C. (2018). Designing ICT for agriculture (ICT4A) innovations for smallholder farmers: the case of Uganda. In Proceedings of the XIX International Conference on Human Computer Interaction (pp. 1–9).
- Harrisberg, K., and Mensah, K. (2022). As young Africans push to be online, data cost stands in the way. Available at: <https://bdnews24.com/world/africa/as-young-africans-push-to-be-online-data-cost-stands-in-the-way> (Accessed August 11, 2022).
- Hlophe-Ginindza, S. N., and Mpandeli, N. S. (2021). “The role of small-scale farmers in ensuring food security in Africa” in *Food security in Africa*. ed. B. Mahmoud, London: IntechOpen.
- Hoang, H. G. (2020). Determinants of the adoption of mobile phones for fruit marketing by Vietnamese farmers. *World Dev. Perspect.* 17:100178. doi: 10.1016/j.wdp.2020.100178
- Howland, F. C., Muñoz, L. A., Staiger, S., Cock, J., and Alvarez, S. (2015). Data sharing and use of ICTs in agriculture: working with small farmer groups in Colombia. *Knowl. Manag. Dev. J.* 11, 44–63.
- Hunter-Adams, J., Battersby, J., and Oni, T. (2019). Food insecurity in relation to obesity in peri-urban Cape Town, South Africa: implications for diet-related non-communicable disease. *Appetite* 137, 244–249. doi: 10.1016/j.appet.2019.03.012
- Idu, E. E., Ola, I. A., Sennuga, S. O., Bamidele, J., Alabuja, F. O., Osho-Lagunju, B., et al. (2023). Evaluation of factors influencing the use of information and communication technologies (ICTs) among smallholder Rice farmers in Kuje Area Council of FCT, Abuja. *Int. J. Res. Innov. Soc. Sci.* VII, 1025–1036. doi: 10.47772/IJRISS.2023.7685
- Illenberger, J., Flötteröd, G., and Nagel, K. (2008). An approach to correct biases induced by snowball sampling. Retrieved January, 26 (2010), pp. 08–16.
- International Telecommunication Unit. (2017). Measuring the information society Report, volume 1. Available at: https://www.itu.int/en/ITU-D/Statistics/Documents/publications/misr2017/MISR2017_Volume1.pdf (Accessed November 1, 2023).
- International Telecommunication Unit. (2022). The affordability of ICT services 2021. Policy brief. Available at: https://www.itu.int/en/ITU-D/Statistics/Documents/publications/prices2021/ITU_A4AI_Price_Brief_2021.pdf (Accessed February 5, 2024).
- International Trade Administration (2021). South Africa – Country commercial guide. Agriculture Sector. US Department of Commerce. Available at: <https://www.trade.gov/country-commercial-guides/south-africa-agricultural-sector> (Accessed August 8, 2022).
- Kafi, A., Zainuddin, N., Saifudin, A. M., Shahron, S. A., Razalli, M. R., Musa, S., et al. (2023). Meta-analysis of food supply chain: pre, during and post COVID-19 pandemic. *Agric. Food Secur.* 12:27. doi: 10.1186/s40066-023-00425-5
- Kammerer, K., Falk, K., Herzog, A., and Fuchs, J. (2019). *How to reach ‘hard-to-reach’ older people for research: The TIBaR model of recruitment. Survey Methods: Insights from the Field*. Lausanne: FORS (Swiss Centre of Expertise in the Social Sciences).
- Kanosvumhira, T. P. (2019). The organisation of urban agriculture in Cape Town, South Africa: A social capital perspective. *Dev. South. Afr.* Pretoria: Government Technical Advisory Centre (GTAC). 36, 283–294. doi: 10.1080/0376835X.2018.1456910
- Kanosvumhira, T. P. (2023). “Urban agriculture and the sustainability Nexus in South Africa: past, current, and future trends” in *Urban Forum* (Dordrecht: Springer Netherlands), 1–18. doi: 10.1007/s12132-023-09480-4
- Kansiime, M. K., Tambo, J. A., Mugambi, I., Bundi, M., Kara, A., and Owuor, C. (2021). COVID-19 implications on household income and food security in Kenya and Uganda: findings from a rapid assessment. *World Dev.* 137:105199. doi: 10.1016/j.worlddev.2020.105199
- Khalil, C. A., Conforti, P., Ergin, I., and Gennari, P. (2017). Defining smallholders to monitor target 2.3. Of the 2030 agenda for sustainable development. FAO statistics division. Rome, Italy. Available at: <https://www.fao.org/publications/card/en/c/e7f3e6f7-59ee-42e7-9cce-36c18af2daea/> (Accessed September 27, 2022).
- Kini, J., Pouw, N., and Gupta, J. (2020). Organic vegetables demand in urban area using a count outcome model: case study of Burkina Faso. *Agric. Food Econ.* 8, 1–16. doi: 10.1186/s40100-020-00166-0
- Kirchherr, J., and Charles, K. (2018). Enhancing the sample diversity of snowball samples: recommendations from a research project on anti-dam movements in Southeast Asia. *PLoS One* 13:e0201710. doi: 10.1371/journal.pone.0201710
- Klerkx, L., Jakku, E., and Labarthe, P. (2019). A review of social science on digital agriculture, smart farming and agriculture 4.0: new contributions and a future research agenda. *NJAS Wageningen J. Life Sci.* 90-91:100315, 1–16. doi: 10.1016/j.njas.2019.100315
- Klerkx, L., and Rose, D. (2020). Dealing with the game-changing technologies of agriculture 4.0: how do we manage diversity and responsibility in food system transition pathways? *Glob. Food Sec.* 24:100347. doi: 10.1016/j.gfs.2019.100347
- Koukou, M., and Dekkers, R. (2024). “Exploring conditions for successful end-user involvement in new product development” in *European perspectives on innovation management* (eds.) R. Dekkers and L. Morel, (Cham: Springer International Publishing), 197–221.
- Krone, M., and Dannenberg, P. (2018). Analysing the effects of information and communication technologies (ICTs) on the integration of East African farmers in a value chain context. *Z. Wirtschaftsgeogr.* 62, 65–81. doi: 10.1515/zfw-2017-0029
- Lajoie-O’Malley, A., Bronson, K., van der Burg, S., and Klerkx, L. (2020). The future(s) of digital agriculture and sustainable food systems: an analysis of high-level policy documents. *Ecosyst. Serv.* 45:101183. doi: 10.1016/j.ecoser.2020.101183
- Landmann, D. H. (2018). *Capacity development of small-scale farmers in developing countries: Analysis of preferences and the role of information and communication technologies* (Doctoral dissertation, Niedersächsische Staats- und Universitätsbibliothek Göttingen).
- Lembani, R., Gunter, A., Breines, M., and Dalu, M. T. B. (2020). The same course, different access: the digital divide between urban and rural distance education students in South Africa. *J. Geogr. High. Educ.* 44, 70–84. doi: 10.1080/03098265.2019.1694876
- Leng, C., Ma, W., Tang, J., and Zhu, Z. (2020). ICT adoption and income diversification among rural households in China. *Appl. Econ.* 52, 3614–3628. doi: 10.1080/00036846.2020.1715338
- Lowder, S. K., Sánchez, M. V., and Bertini, R. (2021). Which farms feed the world and has farmland become more concentrated? *World Dev.* 142:105455. doi: 10.1016/j.worlddev.2021.105455
- Mabhaudhi, T., Senzanje, A., Modi, A. T., Jewitt, G., and Massawe, F. (2022). *Water-energy-food nexus narratives and resource securities: A global south perspective*. Amsterdam: Elsevier.
- Maina, F., Mburu, J., and Nyang’anga, H. (2023). Access to and utilization of local digital marketing platforms in potato marketing in Kenya. *Heliyon* 9:e19320. doi: 10.1016/j.heliyon.2023.e19320
- Makate, C. (2019). Effective scaling of climate smart agriculture innovations in African smallholder agriculture: A review of approaches, policy and institutional strategy needs. *Environ. Sci. Pol.* 96, 37–51. doi: 10.1016/j.envsci.2019.01.014
- Malanga, D., and Simwaka, K. (2021). “ICTs as potential enablers of the green economy in the southern African development community” in *Technology, the environment and sustainable development: responses from the global south. Global Information Society Watch 2020*. ed. A. Finlay, Johannesburg: Association for Progressive Communications (APC). 57–63.
- Mdoda, L., and Mdiya, L. (2022). Factors affecting the using information and communication technologies (ICTs) by livestock farmers in the Eastern Cape Province. *Cogent Soc. Sci.* 8:2026017. doi: 10.1080/23311886.2022.2026017
- Min, S., Liu, M., and Huang, J. (2020). Does the application of ICTs facilitate rural economic transformation in China? Empirical evidence from the use of smartphones among farmers. *J. Asian Econ.* 70:101219. doi: 10.1016/j.asieco.2020.101219
- Mittal, S., and Mehar, M. (2016). Socio-economic factors affecting adoption of modern information and communication technology by farmers in India: analysis using multivariate probit model. *J. Agric. Educ. Ext.* 22, 199–212. doi: 10.1080/1389224X.2014.997255
- Mizik, T. (2021). Climate-smart agriculture on small-scale farms: A systematic literature review. *Agronomy* 11:1096. doi: 10.3390/agronomy11061096
- Mougeot, L. (2015). “Urban agriculture in cities of the global south: four logics of integration” in *Food and the city: Histories of culture and cultivation*, ed. D. Imbert, (Washington: Dumbarton Oaks Research Library and Collection). 163–193.
- Moustier, P., and Renting, H. (2015). “Urban agriculture and short chain food marketing in developing countries” in *Cities and agriculture. Developing resilient urban food systems* (eds.) H. de Zeeuw and P. Drechsel, (London: Routledge), 121–138.
- Mushi, G. E., Di Marzo Serugendo, G., and Burgi, P. Y. (2022). Digital technology and services for sustainable agriculture in Tanzania: a literature review. *Sustain. For.* 14:2415. doi: 10.3390/su14042415
- Nakasone, E., Torero, M., and Minten, B. (2014). The power of information: the ICT revolution in agricultural development. *Annu. Rev. Resour. Econ.* 6, 533–550. doi: 10.1146/annurev-resource-100913-012714

- Nonet, G. A. H., Gössling, T., Van Tulder, R., and Bryson, J. M. (2022). Multi-stakeholder engagement for the sustainable development goals: introduction to the special issue. *J. Bus. Ethics* 180, 945–957. doi: 10.1007/s10551-022-05192-0
- Nthane, T. T., Saunders, F., Gallardo Fernández, G. L., and Raemaekers, S. (2020). Toward sustainability of South African small-scale fisheries leveraging ICT transformation pathways. *Sustain. For.* 12:743. doi: 10.3390/su12020743
- Olivier, D. W. (2019). Urban agriculture promotes sustainable livelihoods in Cape Town. *Dev. South. Afr.* 36, 17–32. doi: 10.1080/0376835X.2018.1456907
- Onyeneke, R. U., Ankrah, D. A., Atta-Ankomah, R., Agyarko, F. F., Onyeneke, C. J., and Nejad, J. G. (2023). Information and communication technologies and agricultural production: new evidence from Africa. *Appl. Sci.* 13:3918. doi: 10.3390/app13063918
- Orsini, F. (2020). Innovation and sustainability in urban agriculture: the path forward. *J. Consum. Prot. Food Saf.* 15, 203–204. doi: 10.1007/s00003-020-01293-y
- Ortiz-Crespo, B., Steinke, J., Quirós, C. F., van de Gevel, J., Daudi, H., Gaspar Msimiloko, M., et al. (2020). User-centred design of a digital advisory service: enhancing public agricultural extension for sustainable intensification in Tanzania. *Int. J. Agric. Sustain.* 18, 35–51. doi: 10.1080/14735903.2020.1720474
- Pamuk, H., Bulte, E., Adekunle, A., and Diagne, A. (2015). Decentralised innovation systems and poverty reduction: experimental evidence from Central Africa. *Eur. Rev. Agric. Econ.* 42, 99–127. doi: 10.1093/erae/jbu007
- Parker, C., Scott, S., and Geddes, A. (2019). “Snowball sampling” in *SAGE research methods foundations*. (eds.) P. Atkinson, S. Delamont, A. Cernat, J. W. Sakshaug, and R. A. Williams, (London: SAGE Publications).
- Parmar, I. S., Soni, P., Salin, K. R., and Kuwornu, J. K. (2018). Assessing farmers access to ICT and non-ICT sources for agricultural development in semi-arid region in India. *J. Consum. Inf.* 9, 22–39. doi: 10.17700/jai.2018.9.2.459
- Plekhanov, D., Franke, H., and Netland, T. H. (2022). Digital transformation: A review and research agenda. *Eur. Manag. J.* 41, 821–844. doi: 10.1016/j.emj.2022.09.007
- Poulsen, M. N., McNab, P. R., Clayton, M. L., and Neff, R. A. (2015). A systematic review of urban agriculture and food security impacts in low-income countries. *Food Policy* 55, 131–146. doi: 10.1016/j.foodpol.2015.07.002
- Qiang, C. Z., Kuek, S. C., Dymond, A., and Esselaar, S. (2012). *Mobile applications for agriculture and rural development*. Washington, DC: World Bank.
- Qiao, Y., Martin, F., Cook, S., He, X., Halberg, N., Scott, S., et al. (2018). Certified organic agriculture as an alternative livelihood strategy for small-scale farmers in China: A case study in Wanzai County, Jiangxi Province. *Ecol. Econ.* 145, 301–307. doi: 10.1016/j.ecolecon.2017.10.025
- Revenko, L. S., and Revenko, N. S. (2022). Digital divide and digital inequality in global food systems. *Vestn. RUDN. Int. Relat.* 22, 372–384. doi: 10.22363/2313-0660-2022-22-2-372-384
- Ricciardi, V., Ramankutty, N., Mehrabi, Z., Jarvis, L., and Chookolingo, B. (2018). How much of the world's food do smallholders produce? *Glob. Food Sec.* 17, 64–72. doi: 10.1016/j.gfs.2018.05.002
- Risimati, B., and Gumbo, T. (2018). Examining the role of public transport interchange hubs in supportive public transport integration in City of Johannesburg. *REAL CORP*, pp. 207–214.
- Roberts, T., and Hernandez, K. (2019). Digital access is not binary: the 5 A's of technology access in the Philippines. *Electron. J. Inf. Syst. Dev. Countries* 85:e12084. doi: 10.1002/isd2.12084
- Sachet, E., Mertz, O., Le Coq, J. F., Cruz-García, G. S., Francesconi, W., Bonin, M., et al. (2021). Agroecological transitions: A systematic review of research approaches and prospects for participatory action methods. *Front. Sustainable Food Syst.* 5:709401. doi: 10.3389/fsufs.2021.709401
- Sarr, M., Ayele, M. B., Kimani, M. E., and Ruhinduka, R. (2021). Who benefits from climate-friendly agriculture? The marginal returns to a rainfed system of rice intensification in Tanzania. *World Dev.* 138:105160. doi: 10.1016/j.worlddev.2020.105160
- Sekabira, H., Tepa-Yotto, G. T., Ahouandjinou, A. R., Thunes, K. H., Pittendrigh, B., Kaweesa, Y., et al. (2023). Are digital services the right solution for empowering smallholder farmers? A perspective enlightened by COVID-19 experiences to inform smart IPM. *Front. Sustainable Food Syst.* 7:983063. doi: 10.3389/fsufs.2023.983063
- Sergaki, P., and Michailidis, A. (2020). Small-scale food producers: challenges and implications for SDG2. *Zero Hunger*, 787–799. doi: 10.1007/978-3-319-95675-6_48
- Siebert, A. (2020). Transforming urban food systems in South Africa: unfolding food sovereignty in the city. *J. Peasant Stud.* 47, 401–419. doi: 10.1080/03066150.2018.1543275
- Singh, S., and Srivastava, S. K. (2023). Analysis of enablers facilitating ICT adoption in technical education in the post-pandemic era: A framework for future preparedness using ISM approach. In *AIP conference proceedings* (2909, 1). AIP Publishing.
- Smidt, H. J., and Jokonya, O. (2022). Factors affecting digital technology adoption by small-scale farmers in agriculture value chains (AVCs) in South Africa. *Inf. Technol. Dev.*, 28, 558–584. doi: 10.1080/02681102.2021.1975256
- Sobratee, N., Davids, R., Chinzila, C. B., Mabhaudhi, T., Scheelbeek, P., Modi, A. T., et al. (2022). Visioning a food system for an equitable transition towards sustainable diets—a South African perspective. *Sustain. For.* 14:3280. doi: 10.3390/su14063280
- Specht, K., Siebert, R., Hartmann, I., Freisinger, U. B., Sawicka, M., Werner, A., et al. (2014). Urban agriculture of the future: an overview of sustainability aspects of food production in and on buildings. *Agric. Hum. Values* 31, 33–51. doi: 10.1007/s10460-013-9448-4
- Statistics South Africa (2022a). *Census 2022: City of Johannesburg*. [Online] Available at: <https://census.statssa.gov.za/#/province/7/2> (Accessed October 31, 2023).
- Statistics South Africa (2022b). *Census 2022: City of Cape Town*. [Online] Available at: <https://census.statssa.gov.za/#/province/1/2> (Accessed October 31, 2023).
- Steinke, J., Achieng, J. O., Hammond, J., Kebede, S. S., Mengistu, D. K., Msimiloko, M. G., et al. (2019). Household-specific targeting of agricultural advice via mobile phones: feasibility of a minimum data approach for smallholder context. *Comput. Electron. Agric.* 162, 991–1000. doi: 10.1016/j.compag.2019.05.026
- Tambo, J. A., and Mockshell, J. (2018). Differential impacts of conservation agriculture technology options on household income in sub-Saharan Africa. *Ecol. Econ.* 151, 95–105. doi: 10.1016/j.ecolecon.2018.05.005
- Termeer, C. J., Drimie, S., Ingram, J., Pereira, L., and Whittingham, M. J. (2018). A diagnostic framework for food system governance arrangements: the case of South Africa. *NJAS Wageningen J. Life Sci.* 84, 85–93. doi: 10.1016/j.njas.2017.08.001
- Tevera, D. (2022). “Secondary cities and urban agriculture in sub-Saharan Africa” in *Transforming urban food systems in Secondary Cities in Africa* (eds.) L. Riley and J. Crush, (Cham: Springer International Publishing), 133–147.
- Trendov, M., Varas, S., and Zeng, M., (2019). *Digital technologies in agriculture and rural areas: Status report*.
- Tricarico, D. (2021). COVID-19: how is digital agriculture helping farmers? Mobile for Development. Available at: <https://www.gsma.com/mobilefordevelopment/programme/agritech/covid-19-how-is-digital-agriculture-helping-farmers/> (Accessed February 10, 2024).
- Tsan, M., Totapally, S., Hailu, M., and Addom, B. K. (2021). *The digitalisation of African agriculture report 2018–2019*. Wageningen, The Netherlands: CTA/Dalberg Advisers.
- Ume, C. (2023). The role of improved market access for small-scale organic farming transition: implications for food security. *J. Clean. Prod.* 387:135889. doi: 10.1016/j.jclepro.2023.135889
- UNEP. (n.d.) Small-scale farming. Available at: <https://leap.unep.org/knowledge/glossary/small-scale-farming>. (Accessed August 29, 2022).
- Van Veenhuizen, R., and Danso, G. (2007). *Profitability and sustainability of urban and peri-urban agriculture, vol. 19*. Rome, Italy: Food & Agriculture Organization (FAO).
- Vassilakopoulou, P., and Hustad, E. (2023). Bridging digital divides: A literature review and research agenda for information systems research. *Inf. Syst. Front.* 25, 955–969. doi: 10.1007/s10796-020-10096-3
- Venter, I. M., and Daniels, A. D. (2020). Towards bridging the digital divide: the complexities of the South African story. In *INTED2020 proceedings* (pp. 3250–3256). IATED.
- Vidal Merino, M., Gajjar, S. P., Subedi, A., Polgar, A., and Van Den Hoof, C. (2021). Resilient governance regimes that support urban agriculture in sub-Saharan cities: learning from local challenges. *Front. Sustainable Food Syst.* 5:692167. doi: 10.3389/fsufs.2021.692167
- Vorley, B. (2013). *Meeting small-scale farmers in their markets: Understanding and improving the institutions and governance of informal Agri-food trade*: International Institute for Environment and Development (IIED).
- Wadumestridge Dona, C. G., Mohan, G., and Fukushi, K. (2021). Promoting urban agriculture and its opportunities and challenges—a global review. *Sustain. For.* 13:9609. doi: 10.3390/su13179609
- Weidner, T., Yang, A., and Hamm, M. W. (2019). Consolidating the current knowledge on urban agriculture in productive urban food systems: learnings, gaps and outlook. *J. Clean. Prod.* 209, 1637–1655. doi: 10.1016/j.jclepro.2018.11.004
- Winstone, L., Mars, B., Haworth, C. M., and Kidger, J. (2021). Social media use and social connectedness among adolescents in the United Kingdom: A qualitative exploration of displacement and stimulation. *BMC Public Health* 21, 1–15. doi: 10.1186/s12889-021-11802-9
- Woodhill, J., Hasnain, S., and Griffith, A. (2020) Farmers and food systems: What future for small-scale agriculture. Environmental change institute, University of Oxford, Oxford. Available at: https://beamexchange.org/uploads/filer_public/bc/8b/bc8b1dd3-8ca9-4adc-ac64-a709399ab77f/future_for_small-scale_agriculture.pdf. (Accessed August 29, 2022).
- World Bank (2022) In Southern Africa, leveling the playing field at birth critical to reducing inequality, intergenerational poverty. Available at: <https://www.worldbank.org/en/region/afr/publication/in-southern-africa-leveling-the-playing-field-at-birth-critical-to-reducing-inequality-intergenerational-poverty>. (Accessed October 3, 2022).
- Wu, F. (2022). Adoption and income effects of new agricultural technology on family farms in China. *PLoS One* 17:e0267101. doi: 10.1371/journal.pone.0267101
- Xia, Y. (2020). Correlation and association analyses in microbiome study integrating multiomics in health and disease. *Prog. Mol. Biol. Transl. Sci.* 171, 309–491. doi: 10.1016/b.pmbts.2020.04.003
- Zeza, A., and Tasciotti, L. (2010). Urban agriculture, poverty, and food security: empirical evidence from a sample of developing countries. *Food Policy* 35, 265–273. doi: 10.1016/j.foodpol.2010.04.007



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Exploring young consumer's understanding of local food through proximity and social representations

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The ever-changing nature of consumers' understanding of local food highlights the need for in-depth research. This study explores how Gen-Z consumers define, perceive and experience local food. Through the analysis, we extend the existing conceptualization of local food by differentiating three aspects of proximity: geographical, value, and relational proximity. We contribute novel insights into the differentiation of proximity to the established understanding for this specific consumer group. Methodologically, we use a free association game played with Gen-Z consumers in Hungary. Theoretical frameworks, including social representation, central core and proximity theories, are used to uncover implicit knowledge about local food. The results reveal a consumer understanding that associates health, freshness, taste, quality and trustworthiness as the central core of the local food concept. Surprisingly, value and relational proximity gain importance, while geographical proximity takes a peripheral role. This study facilitates a re-evaluation of the local food concept in light of evolving consumer understanding, while also establishing a link between proximity theories and social representation theory. The findings provide practical implications that distinguish different aspects of proximity that are relevant to farmers and policy makers in light of evolving consumer understandings.

KEYWORDS

local food, consumer perception, food consumption, proximity, free association game

1 Introduction

In recent years, local and alternative food networks have received increasing attention (Goodman et al., 2014). The dynamic nature of consumers' understanding of local food highlights the need for comprehensive research to understand food system change, while the conceptualization of local food lacks clarity (Enthoven and Van Den Broeck, 2021). Eriksen (2013) notes that different understandings of local food have practical consequences. A variety of interpretations of local food could also hinder further development of the sector (Anderson, 2008; Pearson et al., 2011). With a better understanding, several other practical opportunities could be initiated. While the concept of "distance" or "proximity" may mean different, non-exclusive things to participants in the food chain, it remains vague and ambiguous to many consumers (Sirieix et al., 2008).

The notion of "local" is subjective and culturally and regionally specific. European consumers associate local products with more environmentally friendly production methods, a smaller carbon footprint, higher quality standards (e.g. freshness, nutritional

value) and healthy eating (Augère-Granier, 2016; Penney and Prior, 2014). In Northern and Western Europe, local is associated with quality criteria such as environmental sustainability and animal welfare. In Eastern and Central Europe, local food is associated with culture, rural tradition and local knowledge. In Southern Europe, the local context of production determines quality: culture, tradition, climate, soil and local knowledge (Fonte, 2008). Local food systems are often farmers' markets, farm-gate sales, box schemes, community-supported agriculture or public procurement schemes.

In Hungary, where this study was conducted, local products have clear positive attributes: food is tastier, more natural and more environmentally friendly. The understanding of local food is better than that of average food (Szegedyné Fricz et al., 2020). According to a representative consumer survey (Szente et al., 2014), the vast majority of Hungarian consumers (72.9%) are either partly or completely in favor of locally produced food. Local food is preferred over imported food when the price is the same (Szente et al., 2014). This high level of support suggests that Hungarian consumers are particularly interested in locally produced food. By comparison, organic food was important to only 38.9% of respondents. Nagy-Peto et al. (2023) found that 91.2% of Hungarian consumers have specific ideas about what they consider to be local food. Their main expectations include the involvement of Hungarian producers and traditional production technology. However, their expectations regarding the distance of origin of local food were quite different.

Besides the regional variations, local food understandings may vary across generations as well, therefore the examination of Gen Z consumers has recently gained prominence. Gen Z comprises people born between 1995 and 2010 (Williams and Page, 2011) and this generation seems to consume differently from previous generations (Schlossberg, 2016 cited by Orea-Giner and Fusté-Forné, 2023). Many of them follow healthy eating habits and their consumption is linked to sustainable activities (Su et al., 2019). According to the EIT Food research (2021), they want a healthy food system in which they can actively participate. Food is a relevant attribute for Gen Z consumers when they seek to discover a sense of place (Alton, 2012), and they are willing to pay more for organic (Fromm and Read, 2018). The foodservice industry is also interested in Gen Z because they enjoy eating out and are willing to try new dishes (Lee et al., 2022). According to Robinson and Schänzel (2019), Generation Z consumers make new acquaintances, interact with locals when they travel, and seek a deeper meaning for personal life and self-development. Awareness of the environmental consequences of personal behavior can be applied to the study of local food consumption when traveling (Orea-Giner and Fusté-Forné, 2023).

Looking at the local food models and definitions in general, several conceptualisations of local food focus on spatial proximity, but the phenomenon of local food is much more complex and nuanced. Proximity is not simply geographical distance, but closeness in space, time, relationship or similarity. It's important to reassess these geographically focused concepts, given how much both the local food landscape and consumer preferences have evolved. Although local food has received considerable attention, what consumers consider local is still controversially debated (Blake et al., 2010; Chicoine et al., 2022; Hinrichs, 2003; Meyerding and

Trajer, 2019; Pearson et al., 2011). It is also unclear which types of proximity dominate consumers' understanding of food locality.

Therefore, the aim of this study is to answer the following research question: How do Hungarian Gen Z consumers perceive food locality? In pursuing this investigation, we aim to explore the social representation of local food and contribute to a better understanding of local food for this locality and this specific age group. In this paper, theories of proximity and social representation are used to develop deeper knowledge. In the following, we outline our theoretical background that contributes to a better understanding of the local in local food. We then describe our methodological approach, a free association game.

1.1 Theoretical background - local food and proximity

Empirical studies on local food are numerous, but the conceptualization of local food is often unclear (Enthoven and Van Den Broeck, 2021). While spatial aspects predominate in characterizing local food, relational or qualitative terms are also important (Ostrom, 2006, cited in Chicoine et al., 2022). Eriksen (2013) suggests that proximity provides a comprehensive framework for understanding the different conceptions of local food, encompassing spatial, temporal and relational dimensions (Torre, 2010).

Geographical proximity, which measures the distance between production and consumption, is a commonly used criterion (Feldmann and Hamm, 2015; Fernández-Ferrín et al., 2018; Hasanazade et al., 2022). This dimension focuses on spatial factors, such as production location and distribution radius. Fernández-Ferrín et al. (2017) classify geographic proximity into geographic and political-administrative categories, where geographic proximity directly refers to the physical distance between production and consumption, while political-administrative proximity takes into account borders and regions.

Social or relational proximity emphasizes the relationships between local farmers and consumers, and significantly influences consumers' understanding and practices of local food (Denver et al., 2019; Fernández-Ferrín et al., 2018; Jensen et al., 2019). This dimension includes direct relationships between local actors, facilitated by alternative distribution practices such as farmers' markets (Kneafsey et al., 2013). Zhong (2023) also expands the definition of local food beyond geographical boundaries to include relational proximity between consumers and producers, enriching our understanding of local food dynamics by highlighting how food system actors interact in local contexts.

We further propose the inclusion of value proximity, which incorporates shared values and perspectives within the food supply chain (Reckinger, 2022). Eriksen (2013) identifies value proximity as exploring the intrinsic values associated with local food, such as authenticity and freshness. Autio et al. (2013) also highlight that consumers value the perceived safety benefits, ethical associations and improved taste of local food. Similarly, Zhong (2023) groups consumer perspectives on local food into three categories: place-based native food, culture-based hometown food, and value-based

ecological food, and argues that the definition of local food should transcend geographical boundaries and include value proximities between consumers, places, cultures, and producers as robust parameters. For some consumers, local food is preferred because of its “taste, freshness and quality” or because it is perceived to be “healthy” (Anderson, 2008). These attributes are seen as intrinsic to local food and include notions of greater authenticity and higher quality (Weatherell et al., 2003), as well as being fresher (Jekanowski et al., 2000; Trobe, 2001), more nutritious, tastier and safer (Seyfang, 2004).

In order to understand consumers’ understandings and the qualities they attribute to local food, it is necessary to use sophisticated qualitative tools and methods to gain deep insights into consumers’ understandings. In our quest for deeper understanding, we use social representation theory as a guiding framework.

1.2 Social representation

Social representation theory provides insights into how individuals and groups collectively construct shared meanings and understandings of the world. People develop “common sense” knowledge through everyday interactions, which forms the basis of social representations (Moscovici, 1961). Moscovici builds on Durkheim’s (1912) idea of collective representations, viewing them not as individual characteristics but as systems of values, ideas and practices that enable social exchange and communication. Social representations provide a code for social exchange, naming and classifying aspects of the environment. While this theoretical approach has been applied to diverse fields such as public understanding of science (Bauer and Gaskell, 2002), health (Aim et al., n.d.), sustainability (Techio et al., 2016), rurality (Halfacree, 2017), ethical and unethical food (Mäkinen et al., 2011), healthy food (Gaspar et al., 2020), eating insect (Bisconsin-Júnior et al., 2022) or sustainable food consumption (László, 2022), the social representation of food locality remains unexplored.

In order to apply representation theory to the concept of local food, the incorporation of central core theory is essential. Abric’s (1976) Central Core Theory provides a structured approach to social representations by organizing representations around central and peripheral areas. This distinction includes peripheral elements organized around a core, where the core contains stable beliefs with significant consensus within the group. Peripheral beliefs, on the other hand, are numerous, unevenly shared and prone to change over time (Moliner and Abric, 2015). A representation undergoes a radical transformation when the central core changes. Therefore, identifying this central core is crucial for understanding a concept. Abric’s (1976) central core method has been utilized for decades to explore social representations and has shown significant relevance in the food sector (Gómez-Corona et al., 2016; Melendrez-Ruiz et al., 2020; Patinho et al., 2021; Rodrigues et al., 2017; quoted by Bisconsin-Júnior et al., 2022). To uncover the central core, various methods are available (Guimelli, 1993), with the most widely used being the frequency-importance matrix, which identifies four categories of associations, as shown in the Table 1.

TABLE 1 The Frequency-importance matrix.

Frequency	Central core	First periphery
	High frequency and high importance	High frequency and low importance
	Contrast zone	Second periphery
	Low frequency and high importance	Low frequency and low importance

Self-edited table based on (Abric, 2003).

In the matrix the first quadrant in the top left-hand corner represents the central core, with high frequency and high importance, signifying the most salient and significant terms for the population studied (Vergès, 1994). The second quadrant on the top right represents the first periphery, with high frequency but low importance. The third quadrant in the lower left is the contrast zone with low frequency but high importance. The fourth and last quadrant on the bottom right is the second periphery with low frequency and low salience. The contrast zone and the first periphery represent a potentially destabilizing zone, a source of change and the development of reasoned arguments (Ramognino and Vergès, 2005, p. 155).

The core moderates the meaning of all peripheral elements and shapes the global meaning of a representation. Moreover, this core is the most stable and resistant part of a representation, so that involving more participants in research is unlikely to lead to changes in the central core (Abric, 1984; Guimelli, 1993; Sammut et al., 2015). The central core comprises a limited number of elements that form the common and consensual basis of collective memory and the system of norms to which a group refers (Abric, 2003).

The two theoretical lenses, proximity and social representation, offer different perspectives for exploring assumptions for the local food context. In the local food literature, geographical proximity is the most common focus in defining local food, while other types of proximity, such as value or relational proximity, offer subsidiary values to the local food concept. As observed in the diverse field of proximity theories, a geographical approach appears consistently in all theories, while other domains vary from author to author, such as people and objects (Torre, 2010), tradition and ethnicity (Fernández-Ferrín et al., 2019), and social, organizational and cognitive aspects (Boschma, 2005). Based on this, we expect associations related to geographical proximity to take place in the central core, and associations related to value or relational proximity to occupy peripheral areas of the representational fields.

2 Materials and methods

2.1 The free association game

The free association game technique, along with its variations, is commonly employed to understand social representations. This technique has the potential to reveal implicit relationship between core and periphery and gain insights into consumers’ understanding of “local food.” The free association game is an

exercise in which players express the first thing that comes to mind when they hear or experience something. When questions are asked directly about consumer understandings, the responses are unlikely to reflect consumer attitudes in their full reality and complexity, but the free association technique can provide a window into implicit content (Joffe and Elsey, 2014). The brevity of the technique ensures that participants do not feel that their competence is being tested and that they have no difficulty in understanding the task (De Rosa, 2002). Association exercises are governed by specific rules to minimize the influence of the participants and to reduce external stimuli (noise).

The free association game technique, while insightful, has limitations. It is important to recognize that certain unavoidable external factors such as setting, location, time of day and the participant's mood can influence the process, and social desirability bias may lead to answers that do not fully reflect true attitudes. No technique can perfectly reveal social representations, and they inherently have a contextual and situated position within a relational system of meaning. Interpretation of stimulus words varies among individuals, complicating generalization. Facilitator influence, even subtle, may shape responses, and the choice of stimulus words may limit the range of associations.

Designing the free association game for this research, we base our methodological considerations on the associative network technique (De Rosa, 2002). In this self-designed game (László, 2022), the first step was to explain the general rules to the participants. It was emphasized that the aim was not to give a definition of the stimulus word, but to spontaneously express the first thoughts that came to mind. The game had one stimulus word ("local food") and participants were asked to associate words that immediately came to mind. Participants were then asked to rate each associated word individually, categorizing it as a negative, positive or neutral expression for them (polarity). The next task was to rank the terms in order of perceived importance. The final step of the game was to collect demographic data from the participants.

2.2 Data collection and analysis

The free association games were played between January and March 2023 in Hungary, Anonym. From the total sample, 103 players were included in this analysis. Main inclusion criteria were nationality and age in order to obtain a homogeneous sample (Hungarian Gen Z consumers). Homogeneous group was also used by Bisconsin-Júnior et al. (2022) in their similar study investigating insect consumption through social representation theory, as a more specific group might share similar needs, wishes. Exclusion criteria were not fully playing free association games (e.g. not being able to put them in order, or only recalling the stimulus). A total of 75 female and 28 male respondents participated. All participants were university students aged between 18 and 25, with a mean age of 20.64 years. Five expressions were collected from each participant ($n = 515$ in total) for the stimulus "local food." The majority of the participants, 40.71%, live in a settlement, 38.83% of them in a town, 16.50% in a county town and only 3.88% in the capital.

TABLE 2 Associations evoked 10 or more times: frequency (f), order of importance (OI), polarity (p) and share of the total database.

Expression	f	OI	p	Share of total data base
Health	34	1.62	1.00	6.60%
Expensive	33	3.15	−0.97	6.41%
Fresh	27	1.63	0.96	5.24%
Tasty	26	2.27	0.92	5.05%
Hungarian	25	3.16	0.72	4.85%
Vegetable/fruit	23	3.35	0.61	4.47%
Shop	15	3.40	0.13	2.91%
Bio	12	3.67	0.75	2.33%
Local	12	3.83	0.92	2.33%
Small farmer	12	3.33	0.58	2.33%
Market	12	3.50	0.42	2.33%
Quality	11	1.73	0.82	2.14%
Red pepper	11	4.45	0.09	2.14%
Trustworthy	10	2.10	1.00	1.94%

2.3 Analytical procedure—Lemmatization, categorization, translation

Associations were collected in person and recorded on accompanying sheets. The recorded data underwent stemming and lemmatization. Stemming refers to a process of cutting off the ends of words, often including the removal of derivational affixes, while lemmatization refers to the use of vocabulary and morphological analysis of words with the aim of returning the base or dictionary form of a word (Manning et al., 2008). Therefore, the associations were cleaned of commas, punctuation marks, and missing/incomplete data. In a second step, synonyms were identified. The search for synonyms is necessary because the importance of a phenomenon with different versions would be underestimated without unification. Terms mentioned more than once were translated into English. Data analysis was carried out in Microsoft Excel and Atlas TI, presented in full detail in the results.

3 Results

3.1 Accessibility, importance, and polarity

After completing the analytical procedure, the dataset was sufficient for more nuanced calculations and indicator assessments. First, associations were thoroughly examined for accessibility, importance and polarity, as explained in this chapter.

An important aspect of the associated words is frequency (f), which indicates how many participants evoked a given association, in other words frequency counts the mentions of a given word. Rank indicates the average position of the words and were sorted according to their frequency (the rows in Table 2). Out of the 515 associations collected, the most frequently evoked words (i.e.

those that could be close to the core of the local food connection phenomenon) are “health” ($f = 34$), “expensive” ($f = 33$), “fresh” ($f = 27$), “tasty” ($f = 26$), “Hungarian” ($f = 25$) and “vegetable, fruit” ($f = 23$).

Table 2 outlines the attributes of the most frequently evoked terms, with further explanation of the indices later in this chapter. In addition to frequency, order of importance (OI) is also taken into account. This metric reflects the significance of an association beyond its mere frequency, acknowledging that the most commonly mentioned term may not necessarily hold the greatest importance for participants; it may simply be the most socially shared term. Evaluating the evoked terms and ranking each word by order implies a more rational cognitive process. To calculate the OI, we simply averaged the importance scores given by the participants. Thus, the smaller the number, the more important the expression is on average for the participants.

The polarity and neutrality indices allow us to explore whether given expressions carry emotional weight (and of what kind) or are neutral for the participants. The polarity index (P) serves as a synthetic measure of implicit evaluation and attitude within the representational field (De Rosa, 2002). As a control measure, the neutrality index is examined, where high positive polarity corresponds to a lack of neutrality (no emotional charge) and vice versa. To calculate polarity (see Equation 1) and neutrality (see Equation 2), players were asked to rate each expression individually as positive, neutral or negative, providing data for polarity and neutrality ratings.

Index of polarity:

$$(P) = \frac{[(N^\circ \text{ of “+” words}) - (N^\circ \text{ of “-” words})]}{N^\circ \text{ of total words associated}} \quad (1)$$

(P) ranges between $(-1; 1)$. If (P) is between -1 and -0.5 most words are connotated negatively. If (P) is between -0.4 and $+0.4$ positive and negative words tend to be equal. If (P) is between $+0.4$ and $+1$, most words are connotated positively.

Index of neutrality:

$$(N) = \frac{[(N^\circ \text{ of “0” words}) - (N^\circ \text{ of “+” words}) + N^\circ \text{ of “-” words}]/N^\circ \text{ of total words associated}}{2} \quad (2)$$

(N) ranges between $(-1; 1)$. If (N) is between -1 and -0.5 few words are neutral. If (N) is between -0.4 and $+0.4$ neutral words tend to equal to the sum of positive and negative words. If (N) is between $+0.4$ and $+1$ most words are neutral, and there is a high neutrality.

The polarity index of local food is 0.5282, indicating that the majority of associations are positive. Conversely, the neutrality index of local food is -0.6078 , indicating that few words are neutral. This suggests that people have strong opinions about local food, as this concept evokes expressions with an emotional component.

3.2 Central core of local food

The central core of local food was identified using the frequency-importance matrix. To establish the baselines, the

average of frequency (F) and importance (OI) was considered first, but these averages can be very misleading due to the high number of associations mentioned only once ($n = 106$). Therefore, a strict rule was introduced to use only higher frequency expressions ($f > 2$), and the baseline averages were set at $f = 9.05$ and $OI = 2.99$.

According to the frequency-importance matrix (Table 3), the central core, i.e. the stable part of the local food concept, is healthy, fresh, tasty, quality and trustworthy. As a second step, the associations presented in the frequency-importance matrix were also qualified based on proximity, considering the three domains of proximity (Eriksen, 2013); in order to better understand the central and peripheral nature of the different proximities regarding local food.

Product-related characteristics were categorized as value proximity, including attributes such as freshness, organic or traditional. Interpersonal or person-related associations were classified as relational proximity, including terms such as trustworthy, small farmer or support. Associations related to physical distance or administrative region were grouped under geographic proximity, such as local, Hungarian or garden. Associations related to value proximity are both numerous and significant, dominating the central core. Relational proximity seems to be important but is rarely encountered. Associations related to geographical proximity are found only in the peripheral areas of the cognitive structure.

3.3 Stability of the representational field

To ensure the reliability of the results and conclusions, it is essential to assess the stability of the representational field, as well as to examine the cognitive structure and its stability through diversity and hapax (Hollósy-Vadász, 2017; Vergès, 1994). Diversity (D) measures the extent of consensus regarding the meaning of a specific representation. In contrast, hapax (H) reflects the stability of the cognitive organization related to that object.

Diversity:

$$(D) = T/N \quad (3)$$

(D) lies between $(0; 1)$. The closer D is to 1, the greater the variability, and hence the lower the consensus. The group of different words (T) (the categories in which the words are coded) and the quotient of all words (N) are examined. There are a total of 515 mentions, 60 words are mentioned more than once and there are a total of 166 different expressions, so the diversity is $166/515 = 0.322$. The diversity is higher than ideal, but still in the acceptable range. With more participants, the diversity approaches zero.

Hapax:

$$(H) = (N \text{ where } f = 1) / T \quad (4)$$

(H) ranges between $(0; 1)$.

Its value is always between 0 and 1; the higher the value, the more unstable the cognitive organization of the phenomenon. The number of words mentioned by only one respondent divided by the total number of words mentioned is examined. For local food $Hapax = 106/166 = 0.638$ we see that there is a rather

TABLE 3 Frequency-importance matrix.

Central core			First periphery		
<i>f</i> > 9.05 (high)			<i>f</i> > 9.05(high)		
OI < 2.99 (high)	<i>f</i>	OI	OI > 2.99 (low)	<i>f</i>	OI
Health	34	1.62	Expensive	33	3.15
Fresh	27	1.63	Hungarian	25	3.16
Tasty	26	2.27	Vegetable fruit	23	3.35
Quality	11	1.73	Shop	15	3.40
Trustworthy	10	2.10	Bio	12	3.67
			Local	12	3.83
			Small farmer	12	3.33
			Market	12	3.50
			Red pepper	11	4.45
Contrast zone			Second periphery		
<i>f</i> < 9.05 (low)			<i>f</i> < 9.05 (low)		
OI < 2.99 (high)	<i>f</i>	OI	OI > 2.99 (low)	<i>f</i>	OI
Sustainable	7	2.29	Settlement	8	3.13
Penny	5	2.60	Agriculture	6	3.17
Wheat	4	3.00	Cheap	6	3.17
Free of packaging	4	2.75	Domestic	5	3.60
Bread	4	3.00	Pasta	5	4.20
Milk	4	2.50	Support	4	4.00
Egg	4	2.00	Restaurant	3	3.33
Sausage	3	2.33	Garden	3	4.00
Flour	3	2.67	Potato	3	3.67
Bakery product	3	3.00	Workplace	3	3.67
Nutrient-dense	3	1.67	Tomato	3	4.33
Natural	3	1.67	Bakery	3	3.33
Tradition	3	2.00	Juicy	3	3.33
Chemical-free	3	3,00			

unstable cognitive structure describing local food, which can be strengthened by involving more people. However, the levels of diversity and hapax conclusions to be drawn from the data.

4 Discussion

Consumer understanding of local food was explored using free association games and then examined through the lenses of proximity and the core and periphery of social representation. Descriptive analysis was carried out to provide a basis for understatement, including calculations of the frequency of associated words, their salience and their polarity (emotional charge) or neutrality. Building on this, more nuanced calculations were carried out. The central core (the most stable and important part of the phenomenon) was examined by splitting associations based on importance and frequency, revealing the stable part of

the consumer’s understanding through the frequency-importance matrix. The central core and the representational field were then re-examined through the lens of the different areas of proximity (geographical, relational and value). This investigation allowed us to discern the types of associations within the core and to identify shifts in proximity types toward the contrast zone or peripheries. Exploring the different domains of proximity facilitates our goal of uncovering consumers’ understanding of local food, which we will now explore in more detail.

4.1 Geographical proximity in the periphery

In line with the existing literature, our initial expectation was that geographical proximity would form the central core of the local food concept. However, our findings from Hungarian Gen Z

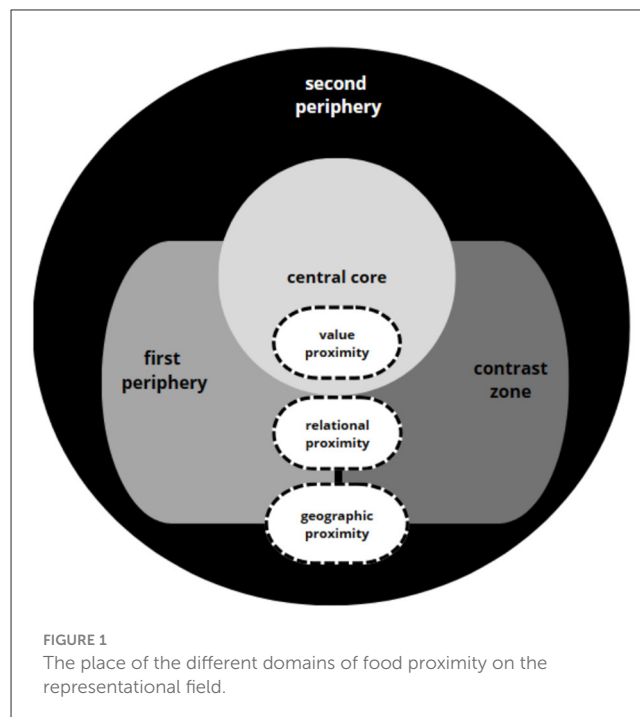
consumers indicate that expressions such as “local” or “Hungarian,” appear only in the first periphery. Nagy-Peto et al. (2023) suggests that expectations about the distance of origin of local food were quite diverse amongst Hungarian consumers, suggesting that geographical proximity may not be the most important or at least stable attribute of the understanding of local food. Terms referring to geographical distance were in the periphery and contrast zone, meaning that they are not a stable part of the representation, there is no consensus among consumers.

An unanticipated outcome was the emergence of national iconic products (such as “red pepper” or “unicum”) and the term “Hungarian” among the representations, while truly local products (typical of the region of data collection) only occasionally emerged. The question also arises as to whether or not consumers make a significant distinction between local and national food products. Several studies suggest that consumers do not significantly differentiate between domestic and local products, e.g. Eriksen (2013) mentions that “for others, food is considered local if it is produced in the same country where it is consumed” (p. 47). Regional boundaries “can range from the municipal to the national level or even beyond, and can vary for different types of products” (Schönhart et al., 2009, p. 244). Our findings also support the idea that consumers are deeply confused about these phenomena, which should be further explored in the future.

Sirieux et al. (2008) suggested that although consumers are aware of distance and associate it with the complexity of food supply chains, they do not choose food products based on food miles criteria, and consumers are more concerned with how distance hides the environmental and social conditions of production, delivering a message quite similar to our research; geographical proximity plays a peripheral role in consumers’ understanding of food proximity, while the social and value attributes are more important. Therefore, producers should shift their marketing strategies to emphasize attributes like quality, health benefits, and trust, rather than concentrating exclusively on the geographical distance between where food is produced and consumed.

4.2 The emergence of relational proximity

According to our findings, relational proximity emerges as a key aspect of social representation, demonstrating the importance of social connections in consumer understanding. Local food transcends mere geographical distance; it embodies fewer intermediaries and fosters stronger interpersonal ties, particularly through increased trust within the system. The inclusion of “trustworthy” in the central core underlines its importance. As highlighted by Benson et al. (2020), consumer trust is the foundation of any market, and this resonates in the food sector. Building sustainable food systems depends on fostering consumer trust. Critical factors that foster trust in food include transparency, proactivity, collaboration and a consumer-centered approach—qualities often found in local food systems. Despite its centrality, trust often receives little attention in conventional definitions of “local.” Yet it is undeniably a fundamental element of the concept. Our research findings highlight the complex



interplay between trust and local food and encourage exploration in future studies. Building direct and meaningful relationships with consumers can be a powerful strategy for local food producers, as it can also create a competitive advantage in the market. By fostering trust through transparency, direct communication, and involvement in community food initiatives (Morrow et al., 2023) such as farmers’ markets and box schemes, producers can solidify their place in the local food system.

4.3 The dominance of value proximity

There is a general agreement in the literature that local food is considered positive (Feldmann and Hamm, 2015; Zepeda and Li, 2006). This is in line with the findings of this research, as the low neutrality index in our results suggests an emotional charge of the representation, and the polarity index proves it to be positive.

Our results are also in line with the suggestion of Szegedyne Fricz et al. (2020) that Hungarian consumers see local food as delicious, natural and environmentally friendly. Taste is at the core of consumers’ understanding of local food, while “natural” was rarely mentioned in our study, nor was “sustainability” important, both falling in the contrast zone. Other product attributes gained in importance, such as “freshness” and “quality,” as well as trust itself. Health is the strongest element of the central core, but there are also some other evocations related to health, such as “nutritious,” “good for me”; therefore, health should be considered as part of the local food concept. Our findings are also in line with Kovács et al. (2022), who suggest that for young Hungarian consumers, the characteristics associated with local products are freshness, quality, nutritional value, reliability, safety, evocation of local flavors, naturalness, healthiness,

TABLE 4 The place of the different domains of food proximity on the representational field based on the results.

Representational field		Central core	First periphery	Contrast zone	Second periphery
		$f > 9.05$	$f > 9.05$	$f > 9.05$	$f > 9.05$
		OI < 2.99	OI > 2.99	OI < 2.99	OI > 2.99
Type of proximity (Eriksen, 2013)	Value proximity	Health, fresh, tasty quality	Vegetable, fruit, expensive, red pepper, bio	Sustainable, wheat, free of packaging, bread, milk, egg, sausage, flour, bakery product, nutrient-dense, natural, tradition, chemical-free	Tomato, bakery, juicy, cheap, pasta, potato
	Relational proximity	Trustworthy	Small farmer		Support
	Geographic proximity		Shop, Hungarian, marker, local	Penny	Workplace, settlement, restaurant, garden, domestic, agriculture

environmental friendliness, etc., while Benedek et al. (n.d.) indicates that freshness is less important for consumers than sustainable packaging.

Szente et al. (2014) argued that the organic origin is not a very important aspect of the local food concept in Hungary (38.9% of respondents), which is further proved by this study, as the term “bio” (referring to organic) was in the first periphery; often mentioned but with low importance. Nagy-Peto et al. (2023) found that Hungarian consumers’ expectations of local food include the involvement of Hungarian producers and labor, and traditional production technology. This is questionable according to our results, as “tradition” was not an important attribute, nor were Hungarian producers. These differences could be due to the fact that younger consumers may have quite different expectations on the innovative-traditional scale of local food.

Looking at the result, there is an unexpected association with the second highest frequency; “expensive” ($f = 33$) and almost every time it was judged as a negative term, with an average polarity of -0.970 . It can be concluded that one of the main weaknesses of local food may be that young consumers find it too expensive. The perception of local food as expensive presents a challenge that producers must tackle. Exploring innovative pricing strategies or emphasizing the added value of local products, such as superior freshness and reduced environmental impact, may increase consumers’ willingness to pay; however, further research is needed to address this issue effectively.

4.4 Consumer understanding of food proximity on the representational field

We propose a theoretical concept (Figure 1) that situates local food proximities within the representational field, as outlined in Table 4, and incorporates all the lessons learned discussed previously. Here, the core of the consumer’s understanding of food locality relates to values: the most stable part of the concept in the consumer’s mind is product-value oriented, supported by a strong

presence of relational proximity, which is gaining ground, while geographical proximity is losing its importance.

Based on our analysis of the free association game, the primary factor influencing consumers’ understanding of food locality is value proximity. This implies that specific product attributes are at the core of consumer identification of food locality. Value proximity encompasses different values attributed to local food by different stakeholders. While relational proximity is also a factor at the core of consumer understanding, its importance appears to be somewhat diminished. Consumers’ understanding of locality is closely linked to their relationships with farmers or other consumers. Direct connections between local actors are being re-established through alternative modes of production and distribution, such as farmers’ markets, farm shops, cooperatives, box schemes and food networks (Eriksen, 2013). We argue that these direct relationships are gaining prominence in consumer understanding.

Contrary to initial assumptions, explicit spatial or geographical locality appears to be marginal in consumer associations. Various theories and definitions have traditionally considered locality through the lens of area, place or geographical boundaries, as well as distance or radius metrics (Eriksen, 2013). However, we argue that these explicitly spatial elements do not have a significant impact on consumers’ understanding of food locality. Consequently, we argue for theories that delve deeper into the evolving dynamics of locality, considering both relational and value perspectives.

5 Limitations of the research

This study acknowledges several limitations that may affect the reliability and generalizability of the findings. Firstly, increasing the sample size would enhance the robustness of the results. The demographic homogeneity of the current sample limits the ability to draw broad conclusions, as the findings may not be fully applicable to more diverse populations. Additionally, potential biases in data collection methods, particularly due to the qualitative nature of the research, could influence the results. The free association game used in the study may be influenced by the

situational context, which could shape the associations made by participants. These contextual factors may result in responses that do not necessarily reflect participants' genuine perceptions or beliefs, further impacting the study's findings. Translation from Hungarian to English introduces challenge, as subtle differences in meaning may be lost, leading to potential inaccuracies and affecting the integrity of the data.

6 Conclusion

Ambiguities in the definition of local food in the literature, coupled with the dynamically changing nature of consumer understanding, highlight the need for comprehensive research. This study focuses on the evolving understanding of local food among Generation Z consumers, with a particular focus on the Hungarian context. Through an exploratory qualitative analysis using free association games and proximity lenses, this research has illuminated several key insights into the complex landscape of consumer perceptions surrounding local food.

A primary conclusion of this study is the redefinition of geographical proximity in the context of local food. Contrary to traditional assumptions, our findings suggest that geographical factors play a peripheral role in consumers' understanding of local food. Instead, relational and value proximity emerge as dominant themes, highlighting the importance of social connections and intrinsic product attributes such as freshness, taste and quality. Furthermore, trust emerges as a critical determinant of consumer understanding of local food. The centrality of trust underlines the importance of transparent and consumer-oriented food systems in fostering trust and loyalty among consumers and within the food supply chain. The dominance of proximity values in consumers' understanding of local food presents both opportunities and challenges for food industry stakeholders. Understanding and harnessing consumer values such as health and authenticity can inform marketing strategies and product development initiatives aimed at appealing to the preferences of Generation Z consumers.

At a practical level, the findings of this research have implications for policy makers, marketers and producers alike. By recognizing the evolving dynamics of consumer perceptions around local food, stakeholders can adapt their approaches to better meet changing consumer needs and preferences. This may involve redesigning marketing campaigns to emphasize product attributes that align with consumer values, or implementing initiatives to increase transparency and trust within local food systems.

Our findings challenge conventional beliefs about Hungarian consumers' expectations of local food. Contrary to previous studies, our research suggests that taste and health are prioritized over traditional aspects such as the involvement of Hungarian producers. Furthermore, it appears that some consumers might not distinguish between local and domestic food products, suggesting that this should be explored in future studies. However, the association of local food with higher costs, as indicated by the frequent use of the term "expensive," poses an economic challenge. As consumer preferences evolve, it is imperative to rethink theories centered on geographical

proximity and to adopt new perspectives in line with consumers' evolving understanding of local food. By unraveling the multifaceted social representation of local food among Hungarian consumers, this research lays the groundwork for promoting sustainable and economically viable local food systems in the region.

Data availability statement

The datasets presented in this study can be found in online repositories. The names of the repository/repositories and accession number(s) can be found at: <https://doi.org/10.5281/zenodo.12731046>.

Author contributions

VL: Conceptualization, Resources, Visualization, Writing – original draft, Writing – review & editing, Data curation, Formal analysis, Funding acquisition, Methodology. SW: Conceptualization, Resources, Visualization, Writing – original draft, Writing – review & editing, Supervision.

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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.

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References

- Abrie, J.-C. (1976). Méthodologie et étude expérimentale des relations sociales: tâche, partenaire et comportement en situation de jeu. *Bull. Psychol.* 29, 735–746. doi: 10.3406/bupsy.1976.1580
- Abrie, J. C. (1984). L'artisan et l'artisanat : analyse Du Contenu et de La Structure d'une Représentation Sociale. *Bull. Psychol.* 37, 861–875. doi: 10.3406/bupsy.1984.12621
- Abrie, J. C. (Ed.) (2003). "La recherche du noyau central et de la zone muette des représentations sociales," in *Méthodes d'étude Des Représentations Sociales* (Ramonville Saint-Agne: Erès), 296. doi: 10.3917/puf.jodel.2003.01.0203
- Aim, M.-A., Decarsin, T., Bovina, I., and Dany, L. (n.d). "Health and social representations: a structural approach," in *Papers on Social Representations* 27. Available at: <https://amu.hal.science/hal-02527771> (accessed March 2, 2024).
- Alton, L. (2012). How millennials and Gen Z forever changed travel marketing. *Pixlee TurnTo Blog*. Available at: <https://www.pixlee.com/blog/how-millennials-and-gen-z-forever-changed-travel-marketing/> (accessed October 22, 2023).
- Anderson, M. D. (2008). Rights-based food systems and the goals of food systems reform. *Agric. Hum. Values* 25, 593–608. doi: 10.1007/s10460-008-9151-z
- Augère-Granier, M.-L. (2016). *Short Food Supply Chains and Local Food Systems in the EU*. EPRS. Available at: <https://policycommons.net/artifacts/1340881/short-food-supply-chains-and-local-food-systems-in-the-eu/1951844/> (accessed November 30, 2023).
- Autio, M., Collins, R., Wahlen, S., and Anttila, M. (2013). Consuming nostalgia? The appreciation of authenticity in local food production: consuming nostalgia. *Int. J. Consum. Stud.* 37, 564–568. doi: 10.1111/ijcs.12029
- Bauer, M. W., and Gaskell, G. (2002). *Biotechnology - the Making of a Global Controversy*. Cambridge: Cambridge University Press.
- Benedek, Z., Zoltán Lajos, B., and Nemes, G. (n.d.). *Mennyire Isermek Fogyasztóikat a Helyi Élelmiszertermelők? A Gazdaságföldrajzi És Településmarketing Központ 2022. Évi Kutatásai*. Available at: https://start.uni-neumann.hu/telemarket/kiadvanyok/2022-4/03_Benedek.pdf (accessed May 2, 2024).
- Benson, T., Lavelle, F., Spence, M., Elliott, C. T., and Dean, M. (2020). The development and validation of a toolkit to measure consumer trust in food. *Food Control* 110:106988. doi: 10.1016/j.foodcont.2019.106988
- Bisconsin-Júnior, A., Rodrigues, H., Behrens, J. H., da Silva, M. A. A. P., and Mariutti, L. R. B. (2022). "Food made with edible insects": exploring the social representation of entomophagy where it is unfamiliar. *Appetite* 173:106001. doi: 10.1016/j.appet.2022.106001
- Blake, M. K., Mellor, J., and Crane, L. (2010). Buying local food: shopping practices, place, and consumption networks in defining food as "local". *Ann. Assoc. Am. Geogr.* 100, 409–426. doi: 10.1080/00045601003595545
- Boschma, Ron. (2005). Proximity and innovation: a critical assessment. *Reg. Stud.* 39, 61–74. doi: 10.1080/0034340052000320887
- Chicoine, M., Rodier, F., and Durif, F. (2022). Local food: a constellation of perceived proximity. *Br. Food J.* 124, 4755–4768. doi: 10.1108/BFJ-11-2021-1252
- De Rosa, A. S. (2002). The "associative network": a technique for detecting structure, contents, polarity and stereotyping indexes of the semantic fields. *Eur. Rev. Appl. Psychol.* 52, 181–200.
- Denver, S., Jensen, J. D., Olsen, S. B., and Christensen, T. (2019). Consumer preferences for "localness" and organic food production. *J. Food Prod. Mark.* 25, 668–89. doi: 10.1080/10454446.2019.1640159
- Durkheim, E. (1912). *Lecciones de sociología: La moral cívica*. Madrid: Akal.
- Enthoven, L., and Van Den Broeck, G. (2021). Local food systems: reviewing two decades of research. *Agric. Syst.* 193:103226. doi: 10.1016/j.agsy.2021.103226
- Eriksen, S. N. (2013). Defining local food: constructing a new taxonomy – three domains of proximity. *Acta Agric. Scand. B Soil Plant Sci.* 63, 47–55. doi: 10.1080/09064710.2013.789123
- Feldmann, C., and Hamm, U. (2015). Consumers' perceptions and preferences for local food: a review. *Food Qual. Prefer* 40, 152–164. doi: 10.1016/j.foodqual.2014.09.014
- Fernández-Ferrín, P., Bande, B., Calvo-Turrientes, A., and Galán-Ladero, M. M. (2017). The choice of local food products by young consumers: the importance of public and private attributes. *Agribusiness* 33, 70–84. doi: 10.1002/agr.21470
- Fernández-Ferrín, P., Bande, B., Galán-Ladero, M. M., Martín-Consuegra, D., Díaz, E., Castro-González, S., et al. (2019). Geographical indication food products and ethnocentric tendencies: the importance of proximity, tradition, and ethnicity. *J. Clean. Prod.* 241:118210. doi: 10.1016/j.jclepro.2019.118210
- Fernández-Ferrín, P., Calvo-Turrientes, A., Bande, B., Artaraz-Miñón, M., and Galán-Ladero, M. M. (2018). The valuation and purchase of food products that combine local, regional and traditional features: the influence of consumer ethnocentrism. *Food Qual. Prefer* 64, 138–147. doi: 10.1016/j.foodqual.2017.09.015
- Fonte, M. (2008). Knowledge, food and place. a way of producing, a way of knowing. *Sociol. Rural.* 48, 200–222. doi: 10.1111/j.1467-9523.2008.00462.x
- Fromm, J., and Read, A. (2018). *Marketing to Gen Z: The Rules for Reaching This Vast-And Very Different-Generation of Influencers*. New York, NY: Amacom.
- Gaspar, M. C. D. M. P., Garcia, A. M., and Larrea-Killinger, C. (2020). How would you define healthy food? Social representations of Brazilian, French, and Spanish dietitians and young laywomen. *Appetite* 153:104728.
- Gómez-Corona, C., Lelievre-Desmas, M., Buendía, H. B. E., Chollet, S., and Valentin, D. (2016). Craft beer representation amongst men in two different cultures. *Food Qual. Prefer.* 53, 19–28. doi: 10.1016/j.foodqual.2016.05.010
- Goodman, D., DuPuis, E. M., and Goodman, M. K. (2014). *Alternative Food Networks: Knowledge, Practice, and Politics*. 1. publ. in paperback. Routledge Studies of Gastronomy, Food and Drink. London: Routledge.
- Guimelli, C. (1993). Locating the central core of social representations: towards a method. *Eur. J. Soc. Psychol.* 23, 555–559. doi: 10.1002/ejsp.2420230511
- Halfacree, K. H. (2017). "Locality and social representation: space, discourse and alternative definitions of the rural," in *The Rural*, ed. R. Munton (London: Routledge), 245–260. doi: 10.4324/9781315237213-14
- Hasanzade, V., Elshiewy, O., and Toporowski, W. (2022). Is it just the distance? Consumer preference for geographical and social proximity of food production. *Ecol. Econ.* 200:107533. doi: 10.1016/j.ecolecon.2022.107533
- Hinrichs, C. C. (2003). The practice and politics of food system localization. *J. Rural Stud.* 19, 33–45. doi: 10.1016/S0743-0167(02)00040-2
- Hollós-Vadász, G. (2017). *A Községi Szociális Reprerzentációjának Tesztelése. Államtudományi Műhelytanulmányok*. Available at: <https://real.mtak.hu/50624/1/megjelent.pdf> (accessed August 30, 2024).
- Jekanowski, M. D., Williams, D. R., and Schiek, W. A. (2000). Consumers' willingness to purchase locally produced agricultural products: an analysis of an indiana survey. *Agric. Resour. Econ. Rev.* 29, 43–53. doi: 10.1017/S1068280500001428
- Jensen, J. D., Christensen, T., Denver, S., Ditlevsen, K., Lassen, J., Teuber, R., et al. (2019). Heterogeneity in consumers' perceptions and demand for local (organic) food products. *Food Qual. Prefer.* 73, 255–265. doi: 10.1016/j.foodqual.2018.11.002
- Joffe, H., and Elsej, J. W. B. (2014). Free association in psychology and the grid elaboration method. *Rev. Gen. Psychol.* 18, 173–185. doi: 10.1037/gpr0000014
- Kneafsey, M., Venn, L., Schmutz, U., Balázs, B., Trenchard, L., Eyden-Wood, T., et al. (2013). Short food supply chains and local food systems in the EU. A state of play of their socio-economic characteristics. *JRC Sci. Policy Rep.* 123:129.
- Kovács, I., Lendvai, M. B., and Beke, J. (2022). The importance of food attributes and motivational factors for purchasing local food products: segmentation of young local food consumers in Hungary. *Sustainability* 14:3224. doi: 10.3390/su14063224
- László, V. (2022). A fenntartható élelmiszer-fogyasztás szociális reprezentációja Veszprém megyében. *GAZDÁLKODÁS* 66, 62–75.
- Lee, W. L., Liu, C. H., and Tseng, T. W. (2022). The multiple effects of service innovation and quality on transitional and electronic word-of-mouth in predicting customer behaviour. *J. Retail. Consum. Serv.* 64:102791.
- Mäkinen, J. P., Pirttilä-Backman, A. M., and Pieri, M. (2011). Ethical and unethical food: Social representations among Finnish, Danish, and Italian students. *Appetite* 56, 495–502.
- Manning, C. D., Raghavan, P., and Schütze, H. (2008). *Introduction to Information Retrieval*. Cambridge: Cambridge University Press.
- Melendrez-Ruiz, J., Arvisenet, G., Laugel, V., Chambaron, S., and Monnery-Patris, S. (2020). Do French consumers have the same social representations of pulses as food industry professionals? *Foods* 9:147. doi: 10.3390/foods9020147
- Meyerding, S. G. H., and Trajer, N. M. (2019). What is local food? The case of consumer preferences for local food labeling of tomatoes in Germany. *J. Clean. Prod.* 207, 30–43. doi: 10.1016/j.jclepro.2018.09.224
- Moliner, P., and Abrie, J.-C. (2015). "Central core theory," in *The Cambridge Handbook of Social Representations*, 1st Edn, eds. G. Sammut, E. Andreouli, G. Gaskell, and J. Valsiner (Cambridge: Cambridge University Press), 83–95. doi: 10.1017/CBO9781107323650.009
- Morrow, O., Veen, E., and Wahlen, S. (2023). *Community Food Initiatives – A critical Reparative Approach*. London: Routledge. doi: 10.4324/9781003195085
- Moscovici, S. (1961). La représentation sociale de la psychanalyse. *Bull. Psychol.* 14, 807–810. doi: 10.3406/bupsy.1961.8539
- Nagy-Peto, D. T., Szakály, Z., and Kiss, V. A. (2023). Fogyasztói asszociációk és vásárlási szokások a rövid ellátási láncok kapcsán. *Gazdálkodás* 67, 315–324. doi: 10.53079/GAZDALKODAS.67.4.tpp.315-324

- Orea-Giner, A., and Fusté-Forné, F. (2023). The way we live, the way we travel: Generation Z and sustainable consumption in food tourism experiences. *Br. Food J.* 125, 330–351.
- Ostrom, M. (2006). Everyday meanings of “local food”: views from home and field. *Community Dev.* 37, 65–78. doi: 10.1080/15575330609490155
- Patinho, I., Saldaña, E., Selani, M. M., Teixeira, A. C. B., Menegali, B. S., Merlo, T. C., et al. (2021). Original burger (traditional) or burger with mushroom addition? A social representation approach to novel foods. *Food Res. Int.* 147:110551. doi: 10.1016/j.foodres.2021.110551
- Pearson, D., Henryks, J., Trott, A., Jones, P., Parker, G., Dumaresq, D., et al. (2011). Local food: understanding consumer motivations in innovative retail formats. *Br. Food J.* 113, 886–899. doi: 10.1108/00070701111148414
- Penney, U., and Prior, C. (2014). Exploring the urban consumer's perception of local food. *Int. J. Retail Distrib. Manag.* 42, 580–594. doi: 10.1108/IJRDM-09-2012-0077
- Ramognino, N., and Vergès, P. (2005). *Sociologie et Cognition Sociale*. Aix-en-Provence: Publications de l'Université de Provence.
- Reckinger, R. (2022). Values-based territorial food networks: qualifying sustainable and ethical transitions of alternative food networks. *Reg. Cohes.* 12, 78–109. doi: 10.3167/reco.2022.120305
- Robinson, V. M., and Schänzel, H. A. (2019). A tourism inflex: Generation Z travel experiences. *J. Tour. Futures* 5, 127–141.
- Rodrigues, D. P., Cielo, C., Gómez-Corona, C., Silveira, A. A. S., Marchesan, T. A., Galmarini, M. V., et al. (2017). Eating flowers? Exploring attitudes and consumers' representation of edible flowers. *Food Res. Int.* 100, 227–234. doi: 10.1016/j.foodres.2017.08.018
- Sammut, G., Andreouli, E., Gaskell, G., and Valsiner, J. (2015). The Cambridge Handbook of Social Representations. *Cambridge Handbooks in Psychology*. Cambridge: Cambridge University Press. doi: 10.1017/CBO9781107323650
- Schlossberg, M. (2016). Teen Generation Z is being called ‘Millennials on steroids’ and that could be terrifying for retailers. *Business Insider*.
- Schönhart, M., Penker, M., and Schmid, E. (2009). Sustainable local food production and consumption: challenges for implementation and research. *Outlook Agric.* 38, 175–82. doi: 10.5367/000000009788632313
- Seyfang, G. (2004). *University of East Anglia, The Centre for Social and Economic Research on the Global Environment (CSERGE), Norwich*. CSERGE Working Paper EDM No. 04-09. Available at: <https://www.econstor.eu/handle/10419/80260> (accessed March 10, 2024).
- Sirieix, L., Grolleau, G., and Schaer, B. (2008). Do consumers care about food miles? An empirical analysis in France. *Int. J. Consum. Stud.* 32, 508–515. doi: 10.1111/j.1470-6431.2008.00711.x
- Su, C. H., Tsai, C. H., Chen, M. H., and Lv, W. Q. (2019). U.S. Sustainable food market generation Z consumer segments. *Sustain.* 11:3607. doi: 10.3390/su11133607
- Szegedyné Fricz, Á., Ittész, A., Ózsvári, L., Szakos, D., and Kasza, G. (2020). Consumer perception of local food products in Hungary. *Br. Food J.* 122, 2965–2979. doi: 10.1108/BJFJ-07-2019-0528
- Szente, V., Jasák, H., Szucs, A., and Kalmár, S. (2014). Helyi élelmiszerek fogyasztói megítélése. *GAZDÁLKODÁS: Sci. J. Agric. Econ.* 58, 452–460.
- Techio, E. M., Gonçalves, J. P., and Costa, P. N. (2016). Social representation of sustainability in civil construction among college students. *Ambiente Soc.* 19, 187–204. doi: 10.1590/1809-4422ASOC130991V1922016
- Torre, A. (2010). Jalons pour une analyse dynamique des proximités. *Rev. Econ. Rég. Urbaine* 3, 409–437. doi: 10.3917/reru.103.0409
- Trobe, H. L. (2001). Farmers' markets: consuming local rural produce. *Int. J. Consum. Stud.* 25, 181–192. doi: 10.1046/j.1470-6431.2001.00171.x
- Vergès, P. (1994). Approche du noyau central: propriétés quantitatives et structurales. *Struct. Transform. Représentations Soc.* 277, 233–253.
- Weatherell, C., Tregear, A., and Allinson, J. (2003). In search of the concerned consumer: UK Public perceptions of food, farming and buying local. *J. Rural Stud.* 19, 233–244. doi: 10.1016/S0743-0167(02)00083-9
- Williams, K. C., and Page, R. A. (2011). Marketing to the generations. *J. Behav. Stud. Bus.* 3, 37–53.
- Zepeda, L., and Li, J. (2006). Who buys local food?. *J. Food distr. Res.* 37, 1–11. doi: 10.22004/ag.econ.7064
- Zhong, S. (2023). Relational proximity: The search for local food in China. *Food, Cult. Soc.* 1–19.



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Agronomic and organizational aspects of Barcelona's community gardens

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As food security becomes a growing concern in urban areas worldwide, municipal authorities are actively seeking ways to enhance and complement the food systems of their respective cities. Integrating a food system's productive components within city limits has emerged as a promising strategy to achieve these goals. However, it is impractical to undertake urban agriculture to the extent of rural agriculture, such as livestock rearing and large-scale field crop production, due to insufficient and inadequate space within cities. Producing high-value crops, however, is feasible and already practiced in many urban areas around the world within community gardens. This study investigates the agronomic practices and organizational aspects of community gardens within Barcelona's municipal boundaries. It does so through surveys of community garden members and visual inspections of the gardens. The results show that 10 of the 22 most consumed vegetables in Barcelona are harvested within the city's community gardens, highlighting their agrobiodiversity. Based on observed crop yields, if monoculture for each crop produced in the community gardens were practiced across all available urban areas in Barcelona, the city could achieve significant self-sufficiency in those crops. However, to realize this potential, urban horticulture would need to be professionalized, and the city's municipal authorities would have to play a coordinating role.

KEYWORDS

agrobiodiversity, city, food system, production, yield

1 Introduction

Interest in integrating the productive elements of food systems into urban environments has grown significantly in recent years (Besthorn, 2013; Godoi et al., 2018; MUFPP, 2015; Opitz et al., 2016). This interest has been fueled by a growing awareness of urban social equity, as well as environmental and food justice concerns, which have prompted deeper discussions about sustainable urban development (Thornton, 2018). Concerns about the long-term sustainability of cities (Deelstra and Girardet, 2000; Specht et al., 2014) and the declining availability of natural public spaces (McDonald et al., 2013) have further increased the urgency of these discussions. Urban planners and policymakers are now placing greater emphasis on urban food security and exploring the benefits of integrating food production within city boundaries (Zeunert and Waterman, 2018). As a result, municipal governments worldwide are actively exploring the potential of producing food within their jurisdictions (MUFPP, 2015).

Urban agriculture (UA) presents a promising approach to produce food within cities. In addition to providing numerous social and environmental benefits (Bell et al., 2016; Camps-Calvet et al., 2016; Maheshwari et al., 2014; Menconi et al., 2020; Zimmerer et al., 2021), UA can enhance a city's food self-sufficiency and bolster the resilience of its food

system (Diehl et al., 2020; Fantini, 2023; Grewal and Grewal, 2012; Langemeyer et al., 2021). However, the ability of UA to meet a city's food consumption needs largely depends on the local urban context and the types of food demanded by its residents (Badami and Ramankutty, 2015; Davidson, 2017; Siegner et al., 2018). The extent to which UA contributes to food self-sufficiency depends on the availability of suitable spaces, the practices used, the methods applied, and the people or groups managing its operations. Moreover, the productivity of UA varies widely, often depending on the technology and methods employed. Reported high yields are frequently derived from controlled experiments conducted by researchers, highlighting the potential of advanced systems. High-tech approaches, such as rooftop greenhouses and plant factories, can deliver significantly higher yields compared to the low-tech systems commonly used in community gardens (CGs) (Diekmann et al., 2020; Drottberger et al., 2023; Oh and Lu, 2023; WinklerPrins, 2017). However, the adoption of high-tech UA to undertake urban horticulture (UH), is frequently limited by the substantial financial and energy costs associated with its implementation and operation (Weidner et al., 2021). Consequently, low-tech UH systems in CGs remain the most widespread form of UA globally, owing to their accessibility and lower resource requirements (WinklerPrins, 2017).

CGs can be described as “safe havens that provide residents with a sense of nature, community, rootedness, and power” (Schmelzkopf, 1995, p. 364). In terms of food, UH in CGs empowers residents to grow their own fruits and vegetables while also delivering intangible benefits that enrich urban living (Barthel et al., 2015; Bassett, 1981; Castañeda-Navarrete, 2021; Furness and Gallaher, 2018). Despite their widespread presence, significant gaps remain in our understanding of key aspects of CGs, including the types of crops cultivated in them, the demographics of participants, and the urban farmer organizational structures that support their operation (Raneng et al., 2023). Barcelona serves as an excellent case study for addressing these knowledge gaps, given its rich tradition of UH within its CGs. While previous research in the city has primarily highlighted the social and environmental benefits of UH in CGs (Camps-Calvet et al., 2016; Domene and Saurí, 2007), little attention has been paid to their agronomic practices, urban farmer organizational structures, or their potential contribution to the city's vegetable supply.

Barcelona, the capital of Catalonia in Northeastern Spain, is home to 1.62 million residents and spans across 101.4 km², of which 0.8 km² is dedicated to agriculture (idescat, 2025). The city has a long-standing commitment to UA, beginning with the establishment of the Xarxa d'Horts Urbans de Barcelona (Barcelona Network of Urban Gardens, BNUG) in 1997. This initiative encompasses 15 CGs located both within and beyond the city boundaries (Ajuntament de Barcelona, 2024; Morán, 2008). Building on this foundation, Barcelona launched the 2019–2030 Urban Agriculture Strategy as part of the broader “Plan Natura Barcelona 2021–2030.” This strategy aims to promote agroecological UH and expand agricultural spaces within the city (Ajuntament de Barcelona, 2019; Gerència d'Àrea d'Ecologia Urbana et al., 2021). Further reflecting its dedication to sustainable urban food systems, Barcelona is a signatory of the Milan Urban Food Policy Pact. Article 20 of this framework, under the section “Recommended actions: food production,” explicitly calls for strengthening urban and peri-urban food production (MUFPP,

2015). This strong foundation and commitment to UA underscore the relevance of studying Barcelona's CGs, providing valuable insights into their impact and potential for addressing critical gaps in sustainable food systems.

This study examines the demographics, organizational structures, and agronomic practices of CGs within Barcelona's municipal boundaries. Data were collected through member surveys and on-site visits. Understanding these organizational frameworks is crucial for assessing the scalability of observed agronomic practices to a city-wide level. Furthermore, this research addresses four key empirical gaps identified by Guitart et al. (2012) and reaffirmed by Raneng et al. (2023): the variety of crops grown, UH production modalities, organizational structures within CGs, and their land tenure status. By bridging these gaps, the analysis offers valuable insights into the potential of these practices to contribute to Barcelona's food self-sufficiency and overall urban sustainability goals.

2 Materials and methods

A thirty-question questionnaire, comprising 11 multiple-choice and 19 open-ended questions, was developed based on an extensive review of literature on CGs, UA, horticulture, and agronomy (Annex I). The questionnaire was structured into six sections, each addressing key aspects of the agronomic and organizational characteristics of CGs: (i) the history of the CG, (ii) its physical and social characteristics, (iii) the characteristics of its members, (iv) communication among members, (v) decision-making processes, and (vi) agronomic practices. These sections formed the basis for semi-structured interviews conducted with CG members. Ethics approval for this study was obtained from the Comisión de Ética en la Experimentación Animal y Humana of the Autonomous University of Barcelona on July 15, 2022. Interviews were conducted face-to-face with CG members who provided informed consent. To ensure participant anonymity, no identifiable personal information was collected, and CGs were assigned generic codes rather than being explicitly named in the study. Community gardens included in the analysis were identified and contacted through multiple methods. These included searches on municipal websites for the BNUG and the Empty Urban Spaces with Territorial and Social Involvement (Pla BUTS) program, a component of the Plan Natura Barcelona 2021–2030. Additional CGs were identified through exploratory visits across Barcelona, including the location of informal “squatter” gardens. Snowball sampling was also employed in one instance to recruit participants (Goodman, 1961).

In addition to gathering demographics, organizational structures, and agronomic practices data, a specialized assessment tool was developed to visually document five key physical characteristics of the CGs visited during the study (Annex II). This tool facilitated the recording of: (i) the geometric shape of the area over which the garden spans, (ii) the presence and type of barriers surrounding it, (iii) whether these barriers obstruct sunlight, (iv) the slope of the garden relevant to water drainage, and (v) the destination of water runoff, such as infrastructure for water retention or treatment, or direct drainage into the municipal sewer system. While self-reported data from interviews may introduce potential biases, such as recall bias or social desirability bias, which

TABLE 1 Visited community garden typology.

Community garden type and number of complete interviews done	Garden code	Garden's stated purpose	Garden size ^a (m ²)	Garden shape	CG decision-making mechanism
Community (2)	COM1	Nature in urban area	1,088	Rectangular	Neighbor Managed ^b
	COM2	Social cohesion & therapy	422	Square	Administrator takes major decisions
	COM3	Youth centre	456	Irregular	Administrator takes major decisions
Empty urban spaces with territorial and social involvement (0)	EUSTS1	Temporary administration of unused municipal land	101	Triangular	How decisions about the CG are to be made is left up to CG members
	EUSTS2		662	Rectangular	
Civic centre (1)	CIV1	Hobby for its members	355	Rectangular	Administrator makes sure rules are followed
Squatter (1)	S1	Social cohesion	478	Square	Unknown
	S2	Social cohesion	463	Square	Unknown
	S3	Stop real estate development	225	Rectangular	Majority vote
Barcelona network of urban gardens ^b (8)	BNUG1	≥ 65-year-old Barcelona citizen involvement in UA	369	D-Shaped	The municipality has set forth a set of rules members must comply with. The CG administrator enforces the rules.
	BNUG2		5,620	Square + Rectangular (L-Shaped)	
	BNUG3		2,807	Square	
	BNUG4		532	Triangular	
	BNUG5		736	Square	
	BNUG6		667	Rectangular	
	BNUG7		1,462	Rectangular	
	BNUG8		10,115	Rectangular	
	BNUG9		1,111	Triangular	

Only CGs inside of Barcelona's municipal boundaries that are part of this network were visited. Garden sizes are rounded to nearest whole number. Total garden area visited: 27,669 m².

^aGarden sizes were measured using Google Maps' total area estimation tool after a visit.

^bThe amount of influence in the garden's management is a function of garden attendance (how often a volunteer visits the garden).

could influence the findings, the agronomic characteristics of the CGs were documented directly by the researchers to the extent possible. The primary objective of documenting these features was to identify potential constraints affecting the optimal use of CG spaces and to analyze how water runoff is managed. Such insights are vital for agronomists, as they enable the formulation of tailored recommendations for improving horticultural practices in these gardens. Notably, [Eriksen-Hamel and Danso \(2011\)](#) highlight the scarcity of such detailed physical data in existing CG literature, underscoring the importance of this contribution.

3 Results

3.1 Typification of visited CGs

A total of 18 gardens, with varying stated main purposes or objectives were visited between July and November 2022 ([Table 1](#)). Though all 18 gardens were community CGs, they could be classified further based on their stated main objective into: Empty Urban Spaces with Territorial and Social Involvement Gardens (Pla BUITs), Civic Center Garden, Squatter Gardens, and the BNUG. Of the 18 CGs visited, full interviews were conducted with members of 12 gardens. The remaining six gardens provided only limited

information, as their members did not agree to participate in full interviews. All 18 CGs possessed some form of artificial barrier designed to restrict its access only to members or authorized people. It was explained by most members interviewed that without a barrier, theft of crop production would occur.¹ Interestingly, interviewed CG members seldom knew about the existence of other CGs throughout the city. Therefore, snowball sampling was only possible in one instance (i.e., one CG was visited, and thanks to this visit another CG was visited). Moreover, identifying squatter gardens was simple but interviewing a member of one of these gardens was only possible in one instance. Visited squatter gardens were either some form of protest or project in social cohesion,² but their members were very reluctant to discuss any aspect of the CG with the researchers undertaking this study. The reluctance of members to discuss their CG, particularly those product of grassroot efforts, is not unique to Barcelona as [Schmelzkopf \(1995\)](#) previously encountered the same phenomenon in CGs in New York.

1 One member expressed that theft of crops and garden tools has occurred in his CG.

2 This was determined because all three visited squatter gardens had signs stating their purpose.

3.2 Community garden history

The first community garden visited was established in 2013, the second in 2019, and the one in the civic center in 2006. As previously mentioned, the BNUG began in 1997 and has grown to include 15 gardens. Community gardens established through the Pla BUTTS scheme are a newer and more dynamic phenomenon throughout the city. These gardens are mainly managed by schools, neighborhood associations, and NGOs. Their establishment dates vary since they are created whenever the municipality designates suitable idle land for their establishment. Members of these gardens understand that the municipality can reclaim the land at any time. Furthermore, the establishment dates for two of the visited squatter gardens were unknown, while the third was established in 2019. Due to their physical constraints, being surrounded by residential buildings or roads, it is unlikely these squatter gardens have expanded since their inception. No other visited CG has changed in size since its foundation.

Members of the BNUG and one community garden were the only ones confident that their gardens would still exist five years from now, totaling 10 gardens. In contrast, members of the eight other gardens expressed doubts about their permanence. The BNUG maintains accurate membership records, requiring members to live within the district where the garden is located to be assigned a plot. Plots, varying in size depending on the garden, are assigned for a single five-year period. After this period, plots are reassigned to new incoming members, and those who vacate a plot cannot solicit a new one within the network. In other gardens, determining the number of members was challenging due to a lack of record-keeping. COM3, for example, focuses on serving at-risk youth, resulting in fluctuating membership. COM1 reported having over 500 registered members, but fewer than 20 visit regularly (at least once a week), according to an interviewed member. The member from the S3 garden noted that while new members are regularly added, their activity levels vary. It was impossible to determine the membership numbers of the two squatter gardens. Only COM1, COM2, and COM3 reported having regular volunteers, who are typically retirees, assisting with the gardens' activities.

3.3 Garden decision-making mechanism, member aspects, and communication

All visited CGs were found to have an organizational structure created by or adhered to by their members, directly influencing how decisions are made within these spaces. In the BNUG, garden administrators are appointed to ensure compliance with rules established by Barcelona's municipal authorities. Members of these gardens reported that "minor events" are typically referred to the garden administrator, who is responsible for enforcing the Network's rules or mediating disputes. However, interviewees emphasized that such occurrences are rare. Notably, all BNUG members interviewed were aged 65 or older (Table 1). In contrast, members of self-administered gardens whether community, private, or squatter reported no instances of conflict.

Three distinct decision-making mechanisms were observed across the CGs studied. For CGs administered through the Pla BUTTS initiative, entities are free to adopt decision-making processes that best suit their needs. Conversely, BNUG members voluntarily follow a top-down decision-making structure aligned with the Network's regulations. One

unique example is the COM2 garden, where three separate entities coexist and manage their allocated spaces within the CG using two distinct decision-making mechanisms: (i) majority voting and (ii) consensus-based decisions. Each of the three entities within COM2 pursues a distinct objective. One entity focuses on scaling up UH innovations and uses a majority-vote mechanism for decision-making. The second entity works with individuals with special needs, employing UH as a form of therapy. The third entity provides UH opportunities for African refugees. Despite their differing goals and decision-making structures, these entities co-inhabit the space harmoniously due to clear delineation of their respective areas. The member interviewed from this CG noted that conflicts have not arisen, largely because two of the three entities prioritize member interaction over food production, resulting in minimal competition for limited gardening space.

Communication among CG members occurs primarily in person, via social messaging apps (including text messages), or a combination of both. Among the 12 members fully interviewed, communication among all garden members was described as rare. This is because activities within these gardens are typically not collective. Instead, members have individual plots or designated areas that they manage independently, reducing the need for interaction or coordination with others.

3.4 Crop cultivation practices and sustainability in community gardens

The crops listed in Table 2 were observed to be cultivated in all visited CGs. Artichoke (*Cynara scolymus*) and chayote (*Sechium edule*) were observed in small quantities in only one garden and were therefore excluded from Table 2. Among the crops, tomato was the most extensively cultivated, present in the majority of individual plots across all visited CGs and grown in all observed modalities: directly in the ground, in elevated beds, and on elevated tables. Quantifying the cultivated area for individual crops was not feasible due to the predominant agricultural production system in the visited CGs, namely polyculture (Figure 1). This system is characterized by the cultivation of multiple crop species within a single area and the absence of synthetic inputs for crop management (Adamczewska-Sowińska and Sowiński, 2020). Similarly, it was not possible to quantify crop yield per square meter for the same reason. To address this limitation, average yield data from organic horticultural systems, considered a comparable production model, were used. These organic yields were then contrasted with conventional horticultural yields to provide context.³ Polyculture, a production modality at the low-tech end of the urban horticulture (UH) spectrum, typically results in lower yields compared to high-tech UH systems. For instance, Edmondson et al. (2020) reported that controlled environment horticulture in the United Kingdom produces tomato yields of 42.9 kg/m² per year, significantly higher than the 22.4 kg/m² per year achieved in Barcelona.

CG members reported that the crops grown in their respective gardens have remained consistent since they began participating,

³ Conventional agriculture is understood here as agriculture that makes use of synthetic inputs (fertilizers, pesticides, etc.).

TABLE 2 Crops grown in Barcelona's community gardens.

Common name	Latin name	Conventional yield (kg/m ²)	Organic yield ^b (kg/m ²)
Basil ^a	<i>Ocimum basilicum</i>	360 leaves per plant	219 leaves per plant
Bell pepper	<i>Capsicum annuum</i>	22.5	15.3
Cucumber	<i>Cucumis sativus</i>	27.5	18.7
Egg plant	<i>Solanum melongena</i>	23.7	16.6
Lettuce	<i>Lactuca sativa</i>	22.6	15.4
Onion	<i>Allium cepa</i>	31.3	21.3
Pumpkin	<i>Cucurbita maxima</i>	35.6	24.2
Squash	<i>Cucurbita</i>	29.1	19.8
Tomato	<i>Solanum lycopersicum</i>	33	22.4
Zucchini	<i>Cucurbita pepo</i>	29.5	20

Conventional yield data based on MAPA (2022). These yields correspond to open field production, i.e., no physical structure protecting against pests.

^aBased on Sifola and Barbieri (2006). Plants in this experiment were irrigated every three days.

^bOrganic yields were obtained from Lesur-Dumoulin et al. (2017) who found that organic horticulture yields are on average 10 to 32% lower than those of conventional horticulture. The value of −32% yield was taken to compare a 'worst case' scenario for organic yields compared with average conventional yields.

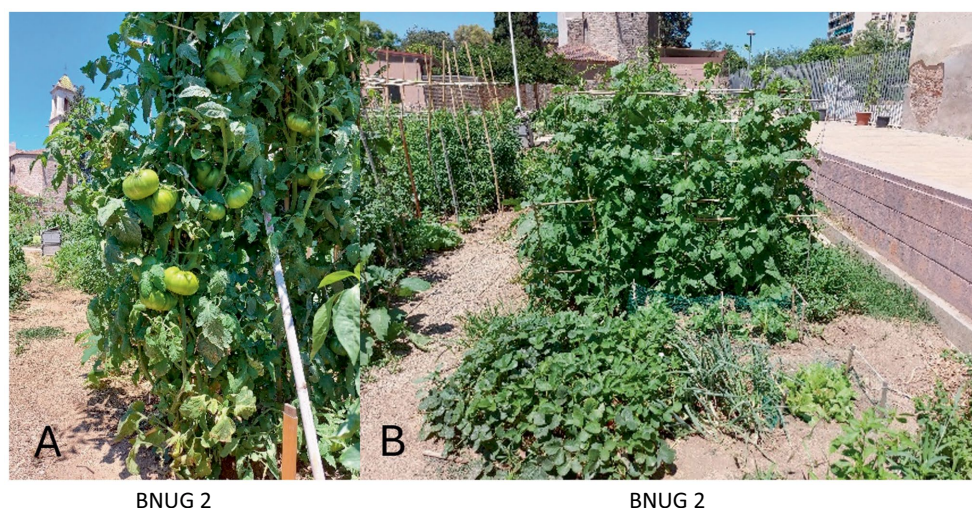


FIGURE 1

Poly culture in Barcelona's community gardens. (A) Tomato plant is growing organically. (B) The polyculture on the same individual plot is shown.

with no novel crops introduced. The primary reasons cited for selecting specific crops included: (i) ease of cultivation, (ii) alignment with crops grown by other CG members, and (iii) personal preference for consuming those crops. Members sourced seeds from a variety of sources, including rural farmers, purchased seeds, and seeds salvaged from vegetables purchased at local supermarkets.

In the BNUG gardens, the use of synthetic inputs is prohibited. Similarly, members of all other visited CGs voluntarily reported practicing UH without synthetic inputs. Among the three visited squatter gardens, members from one garden (S3 in Table 1) explicitly stated that synthetic inputs were not used, while information on fertilizer use in the other two squatter gardens remains unknown. All CGs reported the use of compost as fertilizer. In most BNUG gardens (7 of 9), horse manure was also applied as a natural fertilizer. However, exact quantities and application frequencies could not be determined due to a lack of record-keeping by garden members. The manure was either purchased or obtained as a donation.

Members across all CGs expressed a belief that their gardens were managed sustainably. Interestingly, the majority (10 out of 12 respondents) reported growing the same crops in their plots without practicing crop rotation. Visual inspections of the crops revealed no significant signs of disease or major insect damage in any of the visited CGs, including the squatter gardens. However, members reported mice, rats, and the common city pigeon (*Columba livia domestica*) as the primary pests affecting their crops. Efforts to mitigate pest damage, particularly from pigeons, through methods such as protective nets or scarecrows were deemed largely ineffective (Figure 2).

3.5 Water management in Barcelona's community gardens

In all the CGs visited, irrigation water is sourced from the municipal water supply. CG members are not charged for their water usage and have unrestricted access to this resource, using it as needed



FIGURE 2

Nets are utilized to protect crops from potential damage caused by pigeons and rats. In the image on the left (CIV1), nets are installed on tables to protect crops from pigeons. The central image (BNUG 8) shows nets placed on the ground, providing protection against both mice and pigeons. In contrast, the image on the right (BNUG 4) features a scarecrow used as a deterrent to prevent pigeons from disturbing recently planted crops.

without any monitoring or awareness of the quantities consumed. Manual irrigation using hoses is the standard practice across all observed gardens. Notably, all the CGs rely on potable water for irrigation, with the exception of BNUG3, which utilizes water from its own well for gardening activities. This unregulated water use is particularly significant given Barcelona's increasing vulnerability to droughts, a challenge that is intensifying in both frequency and severity due to climate change (Wilson, 2023). Despite these conditions, none of the visited CGs monitor their water consumption. Furthermore, all water used in these gardens ultimately drains untreated into the municipal sewer system, highlighting a potential area for improving water management practices in UA.

3.6 Physical characteristics of Barcelona's CGs

All of the CGs visited during the study are located on sites that previously housed buildings. In the BNUG network, all gardens except BNUG3⁴ have undergone topsoil replacement to eliminate the risk of soil contaminants being translocated into vegetables and fruits consumed by garden members. Notably, a significant portion of the surface area in each CG was covered by cement or structural remnants, which restricted the feasibility of on-ground UH. In an extreme example, the CIV1 garden was entirely situated on a cement floor, as it was located on the roof of a community center. In cases where on-ground UH is physically unviable, members have adapted by cultivating crops in elevated beds or on raised tables (Figure 3).

4 Discussion

An agronomic and organizational assessment of 18 CGs across Barcelona reveals that 10 of the 22 most consumed vegetables in Catalonia are cultivated within these spaces (MAPA, 2024). This

indicates a notable level of agrobiodiversity in the city's CGs. If the yields achieved in these gardens were scaled up to a city-wide level, they could contribute partially to meeting Barcelona's overall vegetable consumption needs. Garden members have demonstrated adaptability by tailoring their production techniques to the unique conditions of their respective spaces. Crops are cultivated directly in the ground where feasible, while raised tables are utilized in areas where on-ground horticulture is not possible. Despite these innovations, it is important to recognize that all CG activities are carried out on a voluntary basis. Consequently, relying solely on volunteer efforts to achieve Barcelona's food self-sufficiency goals is not a sustainable long-term strategy for enhancing the resilience of the city's food system.

In terms of infrastructure, the BNUG community gardens are particularly well-suited to contribute to the productive component of Barcelona's urban food system, especially for vegetable cultivation. Several factors support this assessment. While UH in Barcelona's CGs is primarily practiced as a hobby, a therapeutic activity, or a means of social interaction, and the BNUG gardens are no exception, these gardens stand out for their superior management. Moreover, the BNUG gardens possess key infrastructure features that could be repurposed for urban vegetable production, including reliable water access and adequate space. Another significant advantage of the BNUG is its sustained municipal support, which ensures its continued operation. In contrast, the future of CGs outside this network, with the exception of COM1, remains uncertain. This is particularly true for squatter gardens and those established under the Pla BUTS scheme, where long-term viability is not guaranteed. Consequently, it is impractical to base a new urban food system on CGs with an uncertain future.

A notable challenge facing CGs in Barcelona, particularly the COM1–3 gardens, is the lack of sustained member participation. This phenomenon is not unique to Barcelona and has been documented in CGs globally (Feinberg et al., 2021a; Feinberg et al., 2021b; Feinberg et al., 2021c). Broadstone and Brannstrom (2017) similarly identify the difficulty of securing committed participants as the primary, and often sole, challenge for CGs in Houston, USA. In the case of Barcelona, the limited engagement of members is understandable, as these gardens are predominantly used as recreational spaces by retirees or as therapeutic environments for individuals with special needs.

⁴ This garden is located near the Collserola mountain range and retains its original soil.



FIGURE 3

In the left panel (A), African refugees cultivate their crops in ground-level wooden beds. In contrast, the right panel (B) depicts individuals engaging in UH as a form of therapy, utilizing elevated tables designed for accessibility, particularly for individuals who use wheelchairs and for whom ground-level beds are unsuitable. Notably, some of these elevated tables are constructed from metal, which, due to their intense red coloration and exposure to direct sunlight, retain high temperatures throughout much of the day. This sustained heat could have significant implications for crop irrigation, potentially increasing water requirements to offset heightened evaporation and water loss caused by the elevated temperatures.

4.1 Urban horticulture productivity and food self-sufficiency potential in Barcelona's community gardens

UH practices in Barcelona's CGs reflect a partial adaptation of rural agricultural systems to the urban context. This is evident in the focus on field crop cultivation. However, unlike the monoculture commonly practiced in rural agricultural systems, CG members in Barcelona universally employ polyculture. As shown in Table 2, the productivity of UH in Barcelona is 10 to 32% lower than conventional agriculture under optimal conditions, such as direct ground cultivation, absence of pests or diseases, and intensive use of agricultural inputs.

Given the maximum of 0.8 km² (80 hectares) of land available for UA in the city, scaling up the current UH practices could only meet a significant proportion of Barcelona's vegetable demand if monoculture under ideal conditions were adopted. For instance, in 2022, Barcelona's citizens consumed 28,416 tons of tomatoes (MAPA, 2024).⁵ Using the organic tomato yield projections from Table 2 and assuming full utilization of the available area for tomato cultivation over a single growing cycle (~7 months), a theoretical production of 17,920 tons could be achieved, equating to 63% of the city's annual tomato consumption. However, this projection is based on several improbable assumptions: that all available UA land is used exclusively for tomatoes, CG members universally agree to cultivate a single crop (contrary to the prevailing polyculture practices), no pests or diseases affect yields, and the municipal authorities ensure a sufficient water supply for cultivation. Given these constraints, this scenario remains a theoretical exercise. Nevertheless, it underscores the potential production capacity of UH in CGs. If systematically and strategically

implemented, UH could make meaningful contributions to Barcelona's food self-sufficiency, albeit primarily for specific crops consumed fresh, such as tomatoes.

4.2 Potential contamination of UH products in Barcelona

Crops produced within Barcelona's urban environment may not be entirely free of contamination. Rodríguez-Bocanegra et al. (2018) highlight the growing interest in locally and sustainably produced food, emphasizing the importance of monitoring potentially toxic element concentrations in urban soils. Their study focused on soil in an empty urban space in the Sants district, located in southeastern Barcelona, a former industrial area previously occupied by a metal smelting industry. The results revealed that tomato plants cultivated in this neighborhood contained elevated levels of copper (Cu), lead (Pb), and zinc (Zn) in their shoots. Additionally, drainage water from the CG where these crops were grown showed high concentrations of Pb, exceeding 10 µg L⁻¹. Lead, in particular, is of significant concern for UA due to its extreme toxicity and prevalence in urban soils (Finster et al., 2004).

Even efforts to remediate soil contamination in urban gardens often yield mixed results, with no guarantee of effectively neutralizing heavy metal pollutants (Paltseva et al., 2020; Una et al., 2022). Beyond soil contamination, urban crops are also vulnerable to airborne pollution. For instance, Antisari et al. (2015) note that heavy metals can be deposited on crop surfaces through air pollution. Ercilla-Montserrat et al. (2018) found that lettuce grown in urban settings accumulated heavy metals from the air, although at concentrations well below the European Union's maximum allowable levels.

Given that most of Barcelona's CGs are situated at ground level, further research is necessary to assess whether crops grown in these spaces are similarly affected by airborne heavy metal contamination. Such studies are essential for understanding the full scope of potential risks associated with UH in CGs in Barcelona.

⁵ The Ministry of Agriculture of Spain (MAPA) reports per capita data for Catalonia consumption. This data for 2022 was aggregated and assumed to be representative of the citizens of Barcelona. According to idescat (2024), in 2024 Barcelona had a total population of 1,686,208 residents.

4.3 Enhancing UH in Barcelona: the need for municipal coordination and professionalization

Barcelona's CGs hold potential to contribute meaningfully to the city's vegetable supply through UH. However, achieving significant production levels would require the adoption of monoculture practices for specific crops currently cultivated in these gardens. Realizing this goal necessitates greater involvement and coordination by municipal authorities to streamline production efforts. Such an approach would enhance the efficiency and impact of UH in meeting Barcelona's vegetable demand, contrasting with rural food production systems, where farmers base their decisions on factors such as expertise and market prices. Given the fundamental differences between urban and rural agricultural contexts, and considering Barcelona's longstanding commitment to expanding UA through various agreements and legal instruments, the economic motivations for UH expansion could be redefined. For example, the municipality could provide urban farmers with access to garden areas under its administration without charging fees for vegetable production. Additionally, ensuring a free water supply for CGs could further incentivize UH and remove barriers to its expansion. These policy adjustments would encourage a more productive integration of UH within the city's CGs. Such a shift, however, would also require a transformation in the profile of the urban farmer. If UH is to significantly contribute to Barcelona's food supply, it cannot continue to rely solely on volunteer efforts. Instead, it must evolve into a professionalized activity. Mcdougall et al. (2020) underscore this point, noting that "amateur" labor, as observed in their study of urban agriculture in Sydney, is insufficient to sustain a productive urban food system. Further research is needed to explore the extent to which Barcelona's municipal authorities are willing and able to coordinate the productive capacities of this emerging urban food system. Additionally, understanding the ideal profile of an urban farmer in Barcelona's CGs is crucial for designing policies that can support the transition to a more professionalized and impactful urban agriculture model.

Data availability statement

Requests to access the datasets should be directed to the corresponding author.

Author contributions

DM: Conceptualization, Formal analysis, Investigation, Writing – original draft, Writing – review & editing, Methodology. XD:

Conceptualization, Funding acquisition, Project administration, Supervision, Writing – original draft, Writing – review & editing, Methodology. SV-T: Conceptualization, Funding acquisition, Project administration, Supervision, Writing – original draft, Writing – review & editing, Methodology.

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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.

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Supplementary material

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References

- Adamczewska-Sowińska, K., and Sowiński, J. (2020). Polyculture management: A crucial system for sustainable agriculture development. *Soil Health Restor. Manag.*, 279–319. doi: 10.1007/978-981-13-8570-4_8
- Ajuntament de Barcelona. (2019). Estratègia d'agricultura urbana a la ciutat de barcelona. Available online at: https://bcnroc.ajuntament.barcelona.cat/jspui/bitstream/11703/116590/3/EstrategiaAgriculturaUrbana_Abril2019_def.pdf
- Ajuntament de Barcelona. (2024). Paisatge Urbà: Àrea de Urbanismo, Transició Ecològica, Servicios Urbanos y Vivienda. Available online at: <https://ajuntament.barcelona.cat/paisatgeurba/es/usos-del-paisaje>
- Antisari, L. V., Orsini, F., Marchetti, L., Vianello, G., and Gianquinto, G. (2015). Heavy metal accumulation in vegetables grown in urban gardens. *Agron. Sustain. Dev.* 35, 1139–1147. doi: 10.1007/s13593-015-0308-z
- Badami, M. G., and Ramankutty, N. (2015). Urban agriculture and food security: a critique based on an assessment of urban land constraints. *Glob. Food Sec.* 4, 8–15. doi: 10.1016/j.gfs.2014.10.003
- Barthel, S., Parker, J., and Ernstson, H. (2015). Food and green space in cities: a resilience lens on gardens and urban environmental movements. *Urban Stud.* 52, 1321–1338. doi: 10.1177/0042098012472744

- Bassett, T. J. (1981). Reaping on the margins: a century of community gardening in America. *Landscape* 25, 1–8.
- Bell, S., Fox-Kämper, R., Keshavarz, N., Benson, M., Caputo, S., Noori, S., et al. (2016). *Urban allotment gardens in Europe*: Routledge. Available at: https://www.researchgate.net/profile/Matthias-Drilling/publication/334358744_The_idea_of_allotment_gardens_and_the_role_of_spatial_and_urban_planning/links/5fa6efa8a6fdcc06241d648a/The-idea-of-allotment-gardens-and-the-role-of-spatial-and-urban-planning.pdf
- Besthorn, F. H. (2013). Vertical farming: social work and sustainable urban agriculture in an age of global food crises. *Aust. Soc. Work.* 66, 187–203. doi: 10.1080/0312407X.2012.716448
- Broadstone, S., and Brannstrom, C. (2017). Growing food is work: the labour challenges of urban agriculture in Houston, Texas. *Global Urban Agric.*, 66–78. doi: 10.1079/9781780647326.0066
- Camps-Calvet, M., Langemeyer, J., Calvet-Mir, L., and Gómez-Baggethun, E. (2016). Ecosystem services provided by urban gardens in Barcelona, Spain: insights for policy and planning. *Environ. Sci. Pol.* 62, 14–23. doi: 10.1016/j.envsci.2016.01.007
- Castañeda-Navarrete, J. (2021). Homegarden diversity and food security in southern Mexico. *Food Secur.* 13, 669–683. Available at: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7881320/pdf/12571_2021_Article_1148.pdf
- Davidson, D. J. (2017). Is urban agriculture a game changer or window dressing? A critical analysis of its potential to disrupt conventional Agri-food systems. *Int. J. Sociol. Agric. Food* 23, 63–76. doi: 10.48416/ijfs.v23i2.123
- Deelstra, T., and Girardet, H. (2000). Urban agriculture and sustainable cities. N. Bakker, M. Dubbeling, S. Gündel and U. Sabel-Koshella, Zeeuw De. *Growing cities, growing food. Urban agriculture on the policy agenda*. Feldafing, Germany: Zentralstelle für Ernährung und Landwirtschaft (ZEL), 43, 66.
- Diehl, J. A., Sweeney, E., Wong, B., Sia, C. S., Yao, H., and Prabhudesai, M. (2020). Feeding cities: Singapore's approach to land use planning for urban agriculture. *Glob. Food Sec.* 26:100377. doi: 10.1016/j.gfs.2020.100377
- Diekmann, L. O., Gray, L. C., and Baker, G. A. (2020). Growing 'good food': urban gardens, culturally acceptable produce and food security. *Renew. Agric. Food Syst.* 35, 169–181. doi: 10.1017/S1742170518000388
- Domene, E., and Sauri, D. (2007). Urbanization and class-produced natures: vegetable gardens in the Barcelona metropolitan region. *Geoforum* 38, 287–298. doi: 10.1016/j.geoforum.2006.03.004
- Drottberger, A., Zhang, Y., Yong, J. W. H., and Dubois, M.-C. (2023). Urban farming with rooftop greenhouses: a systematic literature review. *Renew. Sust. Energ. Rev.* 188:113884. doi: 10.1016/j.rser.2023.113884
- Edmondson, J. L., Cunningham, H., Densley Tingley, D. O., Dobson, M. C., Grafius, D. R., Leake, J. R., et al. (2020). The hidden potential of urban horticulture. *Nat. Food* 1, 155–159. doi: 10.1038/s43016-020-0045-6
- Ercilla-Montserrat, M., Muñoz, P., Montero, J. I., Gabarrell, X., and Rieradevall, J. (2018). A study on air quality and heavy metals content of urban food produced in a Mediterranean city (Barcelona). *J. Clean. Prod.* 195, 385–395. doi: 10.1016/j.jclepro.2018.05.183
- Eriksen-Hamel, N., and Danso, G. (2011). Agronomic considerations for urban agriculture in southern cities. *Urban Agric.*, 86–93. doi: 10.4324/9781849774857
- Fantini, A. (2023). Urban and peri-urban agriculture as a strategy for creating more sustainable and resilient urban food systems and facing socio-environmental emergencies. *Agroecol. Sustain. Food Syst.* 47, 47–71. doi: 10.1080/21683565.2022.2127044
- Feinberg, A., Ghorbani, A., and Herder, P. (2021a). Diversity and challenges of the urban commons: a comprehensive review. *Int. J. Commons* 15. doi: 10.5334/ijc.1033
- Feinberg, A., Ghorbani, A., and Herder, P. M. (2021b). Commoning toward urban resilience: the role of trust, social cohesion, and involvement in a simulated urban commons setting. *J. Urban Aff.*, 1–26. Available at: <https://jasss.soc.surrey.ac.uk/24/3/3.html>
- Feinberg, A., Hooijschuur, E., Rogge, N., Ghorbani, A., and Herder, P. (2021c). Sustaining collective action in urban community gardens. *J. Artif. Soc. Soc. Simul.* 24. doi: 10.18564/jasss.4506
- Finster, M. E., Gray, K. A., and Binns, H. J. (2004). Lead levels of edibles grown in contaminated residential soils: a field survey. *Sci. Total Environ.* 320, 245–257. doi: 10.1016/j.scitotenv.2003.08.009
- Furness, W. W., and Gallaher, C. M. (2018). Food access, food security and community gardens in Rockford, IL. *Local Environ.* 23, 414–430. doi: 10.1080/13549839.2018.1426561
- Gerència d'Àrea d'Ecologia Urbana et al. (2021). Barcelona Nature Plan 2030. Available online at: <https://bcnroc.ajuntament.barcelona.cat/jspui/handle/11703/123630>
- Godoi, F. C., Bhandari, B., Prakash, S., and Zhang, M. (2018). *Fundamentals of 3D food printing and applications*: Academic press.
- Goodman, L. A. (1961). Snowball sampling. *Ann. Math. Stat.* 32, 148–170. doi: 10.1214/aoms/1177705148
- Grewal, S. S., and Grewal, P. S. (2012). Can cities become self-reliant in food? *Cities* 29, 1–11. doi: 10.1016/j.cities.2011.06.003
- Guitart, D., Pickering, C., and Byrne, J. (2012). Past results and future directions in urban community gardens research. *Urban For. Urban Green.* 11, 364–373. doi: 10.1016/j.ufug.2012.06.007
- idescat. (2025). The municipality in figures Barcelona (Barcelonès). Available online at: https://www.idescat.cat/emex/?id=080193&lang=en&utm_campaign=home&utm_medium=cercador&utm_source=territori
- Langemeyer, J., Madrid-Lopez, C., Beltran, A. M., and Mendez, G. V. (2021). Urban agriculture—a necessary pathway towards urban resilience and global sustainability? *Landsc. Urban Plan.* 210:104055. doi: 10.1016/j.landurbplan.2021.104055
- Lesur-Dumoulin, C., Malézieux, E., Ben-Ari, T., Langlais, C., and Makowski, D. (2017). Lower average yields but similar yield variability in organic versus conventional horticulture. A meta-analysis. *Agronomy for Sustainable Development*, 37, 1–12. doi: 10.1007/s13593-017-0455-5
- Mareshwari, B., Purohit, R., Malano, H., Singh, V. P., and Amerasinghe, P. (2014). The security of water, food, energy and liveability of cities. *Water Sci. Technol.* 71. doi: 10.1007/978-94-017-8878-6
- MAPA. (2024). Ministerio de Agricultura, Pesca y Alimentación. Available online at: <https://www.mapa.gob.es/es/default.aspx>
- McDonald, R. I., Marcotullio, P. J., and Güneralp, B. (2013). Urbanization and global trends in biodiversity and ecosystem services. *Urbaniz. Biodiv. Ecosyst. Serv.*, 31–52. doi: 10.1007/978-94-007-7088-1_3
- Mcdougall, R., Rader, R., and Kristiansen, P. (2020). Urban agriculture could provide 15% of food supply to Sydney, Australia, under expanded land use scenarios. *Land Use Policy* 94:104554. doi: 10.1016/j.landusepol.2020.104554
- Menconi, M., Borghi, P., and Grohmann, D. (2020). Urban agriculture, cui prodest? Seattle's Picardo farm as seen by its gardeners. Innovative Biosystems engineering for sustainable agriculture, forestry and food production: International mid-term conference 2019 of the Italian Association of Agricultural Engineering (AIIA),
- Morán, N. (2008). Huertos y jardines comunitarios. Available online at: <http://habitat.aq.upm.es/boletin/n40/anmor.html>
- MUFPP. (2015). Milan Urban Food Policy Pact. Available online at: https://www.milanurbanfoodpolicypact.org/wp-content/uploads/2020/12/MUFPP-15-October_press-release.pdf
- Oh, S., and Lu, C. (2023). Vertical farming-smart urban agriculture for enhancing resilience and sustainability in food security. *J. Hortic. Sci. Biotechnol.* 98, 133–140. doi: 10.1080/14620316.2022.2141666
- Opitz, I., Berges, R., Piorr, A., and Krikser, T. (2016). Contributing to food security in urban areas: differences between urban agriculture and peri-urban agriculture in the global north. *Agric. Hum. Values* 33, 341–358. doi: 10.1007/s10460-015-9610-2
- Paltseva, A. A., Cheng, Z., Egendorf, S. P., and Groffman, P. M. (2020). Remediation of an urban garden with elevated levels of soil contamination. *Sci. Total Environ.* 722:137965. doi: 10.1016/j.scitotenv.2020.137965
- Raneng, J., Howes, M., and Pickering, C. M. (2023). Current and future directions in research on community gardens. *Urban For. Urban Green.* 79:127814. doi: 10.1016/j.ufug.2022.127814
- Rodríguez-Bocanegra, J., Roca, N., Febrero, A., and Bort, J. (2018). Assessment of heavy metal tolerance in two plant species growing in experimental disturbed polluted urban soil. *J. Soils Sediments* 18, 2305–2317. doi: 10.1007/s11368-017-1666-8
- Schmelzkopf, K. (1995). Urban community gardens as contested space. *Geogr. Rev.* 85, 364–381. doi: 10.2307/215279
- Siegner, A., Sowerwine, J., and Acey, C. (2018). Does urban agriculture improve food security? Examining the nexus of food access and distribution of urban produced foods in the United States: a systematic review. *Sustain. For.* 10:2988. doi: 10.3390/su10092988
- Sifola, M. I., and Barbieri, G. (2006). Growth, yield and essential oil content of three cultivars of basil grown under different levels of nitrogen in the field, Scientia Horticulturae, *J. Soils Sediments* 108, 408–413.
- Specht, K., Siebert, R., Hartmann, I., Freisinger, U. B., Sawicka, M., Werner, A., et al. (2014). Urban agriculture of the future: an overview of sustainability aspects of food production in and on buildings. *Agric. Hum. Values* 31, 33–51. doi: 10.1007/s10460-013-9448-4
- Thornton, A. (2018). *Space and food in the city: Cultivating social justice and urban governance through urban agriculture*: Springer.
- Una, T., Hernandez, J., Beebe, A., and Brown, S. (2022). How does your garden grow? Impact of residuals-based amendments on urban soil health, vegetable yield and nutritional density. *Urban For. Urban Green.* 77:127742. doi: 10.1016/j.ufug.2022.127742
- Weidner, T., Yang, A., and Hamm, M. W. (2021). Energy optimisation of plant factories and greenhouses for different climatic conditions. *Energy Convers. Manag.* 243:114336. doi: 10.1016/j.enconman.2021.114336
- Wilson, J. (2023). Barcelona may need water shipped in during a record drought in Northeast Spain, authorities say. The Associated Press. Available online at: <https://apnews.com/article/spain-drought-catalonia-barcelona-climate-4f747b5cee19b77fb098b05d697a585f>
- WinklerPrins, A. M. (2017). *Global urban agriculture*: CABI. Available at: https://www.researchgate.net/profile/Tammy-Parece/publication/317237328_A_survey_of_urban_community_gardeners_in_the_United_States/https://www.researchgate.net/profile/Tammy-Parece/publication/317237328_A_survey_of_urban_community_gardeners_in_the_United_States_of_America/links/5e0e09f7299bf10bc38c099b/A-survey-of-urban-community-gardeners-in-the-United-States-of-America.pdf#page=83
- Zeunert, J., and Waterman, T. (2018). *Routledge handbook of landscape and food*: Routledge London.
- Zimmerer, K. S., Bell, M. G., Chirisa, I., Duvall, C. S., Egerer, M., Hung, P.-Y., et al. (2021). Grand challenges in urban agriculture: ecological and social approaches to transformative sustainability. *Front. Sustain. Food Syst.* 5:668561. doi: 10.3389/fsufs.2021.668561



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Sustainable transitions in food systems: a case study of an urban agriculture farming training program in Washington, United States

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A transition toward more sustainable and just food system is necessary to address global greenhouse gas emissions and inequitable food access. Alternative food networks have emerged as a solution to counteract the adverse impacts of conventional food systems. Urban agriculture is a type of alternative food network that strives to provide local access to food through the development of community gardens or community-supported agriculture. Farmer training programs are uniquely positioned to build the capacity of those who are interested in engaging in urban agriculture, yet little is known about whether these programs—and their graduates—contribute to sustainability transitions within the food system. We build on previous scholarship that establishes the importance of farmer training programs and use a training program in Washington, United States to understand how these programs support and encourage sustainability transitions. The multi-level perspective breaks down systems into landscape, regime, and niche levels. It provides a framework for understanding the system under which urban agriculture operates and the different actors and institutions that stabilize the existing food regime. Social practice theory emphasizes the importance of focusing on how change occurs at the local level. We use a combination of the multi-level perspective framework and social practice theory to explicate how multi-scalar dynamics of food systems pose barriers and allows for opportunities for actors at a local level to exert change on the larger system. Our results show that training programs allow a space for social learning and changes the collective practices and narratives among its graduates. We also find that the potential for graduates to exert larger change on the regime is curtailed due to the training program's limited capacity to exert vertical pressure on the systems. For regime change to occur, state and local government need to intentionally support policies that recognize the importance of urban agriculture in their sustainability agendas.

KEYWORDS

sustainable transitions, urban agriculture, social practice theory, multi-level perspective, niche innovations, alternative food networks

1 Introduction

The conventional food system has negative environmental and human impacts, including increased atmospheric greenhouse gasses and increased rates of chronic disease (Girip et al., 2020; Lane and Davis, 2022). Alternative food networks (AFNs) emerged to counteract both the environmental and social issues embedded in the conventional food system; they vary from organic food to biodynamic farming systems to small scale urban and rural agriculture.

Urban agriculture is an example of an alternative food network that focuses on the cultivation, processing, and distribution of agricultural products in urban and suburban areas (United States Department of Agriculture, 2023). Urban agriculture initiatives range from community gardens and small acre farms to dispersed farms in urban or peri-urban areas. These initiatives also include selling products through community-supported agriculture or farmers' markets. In the United States, urban agriculture was promoted to increase food security during World War II (e.g., "Victory Gardens") (Mok et al., 2014). Even though cities have been involved in food production for decades, there has been a rise in the interest of urban agriculture due to its potential to address environmental issues such as the mitigation of greenhouse gas emissions related to food transportation and high-intensity agricultural practices, as well as local environmental issues such as increases in green spaces and improvement of local air quality (Mok et al., 2014). In addition, urban agriculture has the potential to address inequities in the existing food system, foster an enhanced sense of place for individuals, and build community capacity (López-García et al., 2024; Mendes et al., 2008; Mert-Cakal and Miele, 2020; Siegner et al., 2018; Zoll et al., 2018).

The potential of urban agriculture to promote social equity in addition to environmental sustainability has led many non-profit organizations to include urban agriculture programs as part of their organizations' mission. While many recognize the importance of people and the environment as beneficiaries of urban agriculture, few have developed training programs to serve those who are interested in becoming more involved in urban agriculture. Yet, building the capacity of the individuals to undertake urban agricultural practices is a necessary for urban agriculture practices to take root. For example, those who are interested in urban agriculture often need to learn technical farming skills. Those who wish to make a living from urban agriculture will need appropriate networks and venues (e.g., farmers' markets) to sell their produce and learn managerial skills on how to run a business.

While there is increasingly more research conducted on food systems and how they can contribute to sustainable transition pathways, most of the current research focuses on initiatives in Western Europe [see, for example, the study on Wales by Mert-Cakal and Miele (2020), study in Spain by López-García et al. (2024), study in Germany by Wittenberg et al. (2022), and study in Italy by Belletti et al. (2024)]. Studies in the United States have focused on existing farmers and veteran programs (Crivits et al., 2018; Donoghue et al., 2014). These studies have not focused on farm training programs specific to urban agriculture, even though farm training programs are necessary for providing interested participants with technical skills necessary to adopt specific farming techniques and the financial skills required to successfully run a small-scale agricultural business (Olabisi et al., 2020). Lastly, little research has focused the extent to which learned knowledge of urban agriculture transfers into actual practice.

Our study aims to fill these gaps. We focus specifically on an urban farmer training program to understand how graduates of the training program contribute to sustainability transitions. We also provide recommendations for how the non-profit organization that developed the program can better position itself to support graduates. Due to the unique and context-specific nature of farmer training programs, we took a qualitative approach and interviewed graduates of a training program run by Farm Foundations, an environmental non-profit organization in Pierce County, Washington, United States.

We also interviewed city and county level officials and examined how interactions among different actors and institutions foster or hinder the opportunities for sustainable transitions.

2 Sustainable transitions and food systems

Sustainable transitions examine the ways societies can change; it focuses on transitions that center "clean" and "green" technologies and practices that contribute to sustainability (Hinrichs, 2014; Keller et al., 2022). The concept of "sustainable transitions" has primarily been applied to the energy and transportation sector, though more recently it has also been applied to food studies as people recognize the multiple benefits of transitioning to more sustainable food systems given how food systems are intertwined with ecological objectives (e.g., more resilient ecosystems) as well as social objectives (e.g., health benefits, more equitable access to food) (Ingram, 2011; Wittenberg et al., 2022). However, the process through which we can transition toward more sustainable food systems is not straightforward due to the multiple actors and multiple scales embedded in food systems.

2.1 Multi-level perspective and urban agriculture

Urban agriculture is made of a complex set of actors and institutions at multiple levels (Campbell and Rampold, 2021; Chiffolleau, 2009). Research on food systems has emphasized the importance of multi-level policies that align with local economics and allow for adaptive governance (Belletti et al., 2024; Vaarst et al., 2018). The multi-level perspective (MLP) framework is particularly suited for understanding the potential of urban agriculture to foster sustainable transitions due to its focus on multiple scales within a system. The MLP framework focuses on larger scale societal systems, stratifying society into three levels of analysis: sociotechnical landscapes, sociotechnical regimes, and niches (Geels and Schot, 2007). Food systems reflect these three stratifications. Factors such as economic recession or growth, pandemics, and climate change affect the food system at a landscape level. Regimes are shared cognitive routines as well as institutions and associated rules that stabilize the system. The food system regime includes the production, distribution, and consumption of food based in large-scale monocrops grown with pesticides/herbicides, long distance transport of food to urban centers, and purchases made in supermarkets (Girip et al., 2020; Bonfert, 2022). Research on regime shifts can occur through top-down change, bottom-up change, and internally induced change (El Bilali and Probst, 2018).

Niches, the "lowest" level of analysis, are the level at which radical novelties and innovations emerge; niches are relatively protected from landscape and regime pressures, making them ideal for experimentation. AFNs, ranging from farmers markets to homesteading for personal consumption, are examples of grassroots innovations and alternative technologies that develop at the niche level and hold promise for re-shaping the food system. Actors at the niche have the ability to shift regimes, which is necessary for sustainable transitions to take hold. Thus, examining how change can and cannot occur at the niche level (e.g., the level at which actors are

directly involved in urban agriculture activities such as the planting and dissemination of food, etc.) is a necessary component of transitioning to more sustainable food systems.

2.2 Social practice theory and niche innovations

Social practice theory (SPT) is useful for understanding how transformation at the radical niche level can take hold. Niches are where rules and practices “in the making” exist (van Poeck and Östman, 2021, pg. 161). The SPT framework emphasizes the *social* part of sociotechnical transitions and examines the horizontal links among the elements of a practice; the framework allows for an analysis of the links that are made, maintained, or broken during a process (Hargreaves et al., 2013). Practices are broken down into two main types: practices-as-entities (idealized and abstract forms) and practices-as-performances (grounded enactment of practices conducted amid everyday conditions) (Hargreaves et al., 2013). For example, the food system is made up of a collection of practices-as-performances: most people buy and consume food everyday multiple times a day. In urban agriculture, the “elements of a practice” encompass growing food, shopping and preparing food, and the consumption of food. At the same time, practices-as-entities reveal themselves in consumers’ images of fresh or healthy food and how they view themselves (or want to view themselves) as actors who support urban agriculture and participants in a larger community.

Embedded in the idea of social practices is how one’s identity is tied to one’s practices. As the concept of individual and collective agency becomes more prominent in discussions on the broader structures of governance in food systems, recognizing the role of individuals and their beliefs as well as connections with others will allow us to better understand how to create and sustain niche innovations that are necessary for regime and landscape level changes.

The different foci of the MLP and SPT are both necessary to properly understand sustainable transitions, especially within food systems. The MLP framework allows one to examine change at the systems scale; SPT investigates change at a more local level through looking at practices and examining the horizontal linkages at the niche level. Food systems are affected by both technology and practices; changes are reinforced both vertically and horizontally. Combining MLP and SPT frameworks to analyze urban agriculture allows us to identify and highlight points of intersection that further our understanding of how urban farmer training programs can activate pathways toward sustainable transitions.

3 Methods

We adopted a case study approach because the research question is contemporary and requires an in-depth understanding of the context surrounding the phenomena (Yin, 2003). Given that the impact of training programs on the local food system and the graduates’ role in sustainability transitions are relatively unknown, we determined that a qualitative approach was most suited for this study. We applied the MLP framework to our case study and show the actors, opportunities, and challenges at the landscape, regime, and niche level in [Supplementary material Table 1](#).

3.1 Case study context

Pierce County is the second most populous county in Washington, home to 925,708 residents (United States Census Bureau, 2023). Pierce County has urban centers, such as Tacoma and Puyallup, peri-urban areas surrounding these two cities, and mountainous regions such as Mt. Rainier National Park and National Forest land (see [Figure 1](#)). In 2021, Pierce County passed Sustainability 2030, a sustainability plan with the goal “to reduce our greenhouse gas emissions (45% by 2030) and improve the health of Pierce County residents and our environment” (Pierce County, 2023a). The plan is broken down into five focus areas: transportation, waste management, energy and built environment, carbon sequestration, and education and outreach (Pierce County, 2023a). Even though none of these focus areas reference agriculture specifically, over 80 new community gardens have been formed within the county since 2008 (Harvest Pierce County, 2023).

In 2012, the Pierce County Conservation District adopted a preexisting program that was established in 2008: Harvest Pierce County (H-Pierce County). H-Pierce County’s mission is to help everyone in Pierce County have access to healthy, affordable, and culturally appropriate fruits and vegetables. One of H-Pierce County’s programs is Farm Foundations, a free farm training program that focuses on promoting urban agriculture. The current Farm Foundations program, launched in 2018, emerged after a series of meetings with community members who perceived problems with food security and access.

The training program is a free 9-month farm training program that combines classroom learning with field days. The program teaches no till organic farm practices that are applicable in urban and peri-urban settings, and has three specific goals:

- 1 To grow the next generation of farmers that is different than the current white and aging generation.
- 2 To address historical inequities in farming systems so that people who have historically not had access to farming opportunities – to address racism in farming.
- 3 To put environmental conservation at the heart of farming in order to promote healthy ecosystems as well as farming (personal interview H-Pierce County director).

While there are other farm training programs in the US, many are through a college or university and cost at least a few hundred dollars in tuition (e.g., Future Harvest, Rogue Farm Corps, and Rodale Institute). The Farm Foundations program recognizes that often those who are interested in urban agriculture may not have access to the resources to adopt urban agriculture practices. Yet, these are the people who often stand to benefit most from increased access to healthier food. Thus, Farm Foundations secured funding from the local government to create free training programs.

From 2018 (the program’s inception) to 2023, four cohorts, totaling 78 people, have completed the training and graduated from the program (there was no new cohort in 2021 due to COVID-19 pandemic). In alignment with Farm Foundation’s first goal, the program aims to have participants from groups that have traditionally been excluded from agriculture in the United States: people of color,

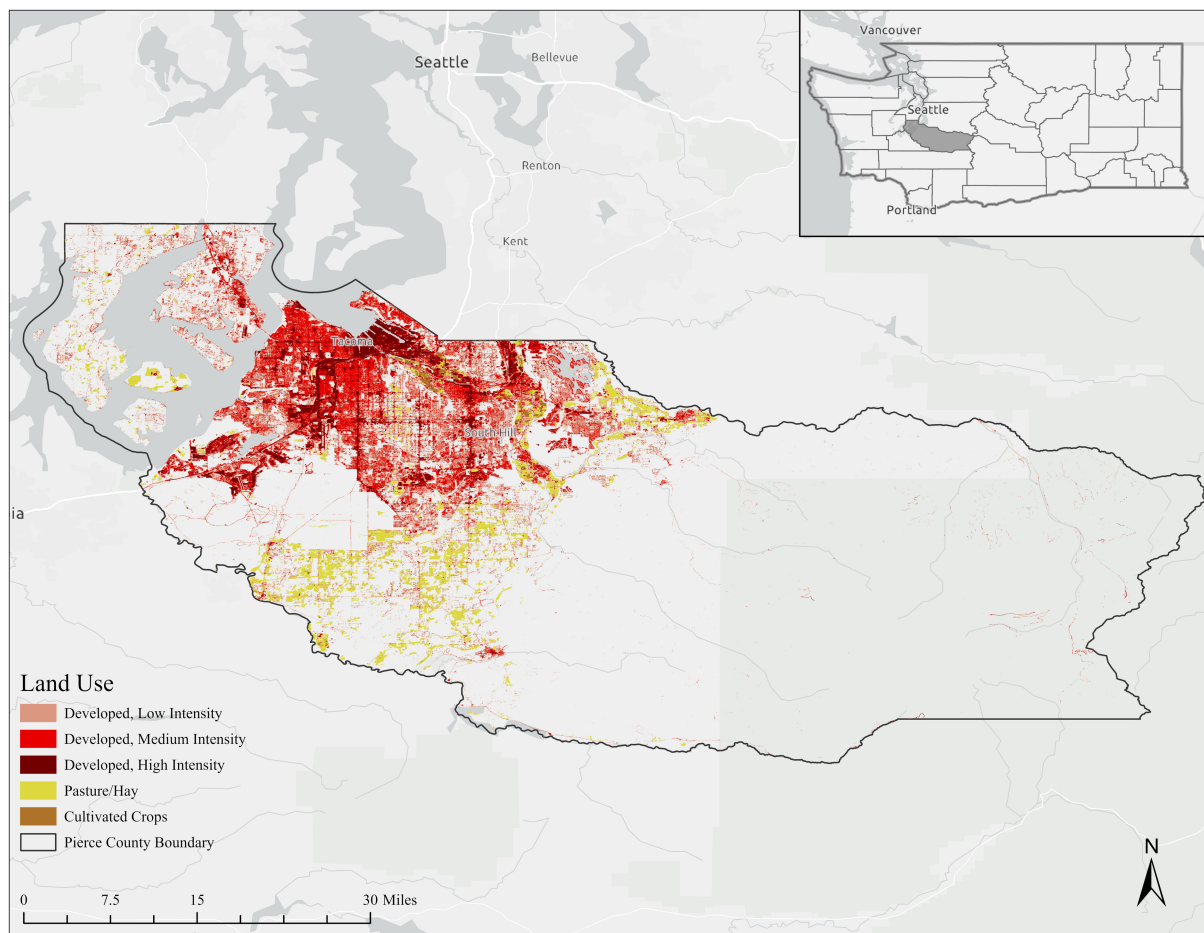


FIGURE 1

Map of Pierce County showing the developed land and agricultural land (Data Source: [National Land Cover Database, 2023](#)). The eastern side of the map is blank as much of that area is federally owned land and cannot be developed for any purpose. The map visually shows the limited land availability in Pierce County.

LGBTQIA+ individuals, and women. In the 2023 cohort, 88% of participants personally identified as belonging to one of those groups.

3.2 Data collection

We chose to conduct semi-structured interviews with participants in the program, county officials, and the program director. We determined the interview questions based on first-hand observations, site visits, document review of program activities and mission, and existing literature on the barriers in scaling up urban agriculture initiatives. Our interview questions were guided by a desire to learn about whether small-scale training programs could lead to larger scale change, as well as how the training program affected participants' understanding and perception of their interactions with the food system. We conducted two rounds of semi-structured interviews with participants of the program. The two rounds of semi-structured interviews were useful for (a) yielding deeper conversations and richer detail on the emerging themes (e.g., connections among graduates, barriers to adopting urban agriculture) and (b) understanding how these themes matter in the context of the MLP and SPT frameworks. We also conducted one round of

interviews with the program director and county officials who were involved in urban planning. Lastly, we conducted a document review of information related to the program as well as city sustainability plans to better understand the role of niche innovations and their interactions with the regime.

We reached out to all 78 individuals who had completed the Farm Foundations program from 2018 to 2020 and from 2022 to 2023; 15 graduates agreed to participate in the research (~20% response rate). Each interview lasted approximately 30 min and was recorded with the Voice Memo app and transcribed using Otter.ai. Questions ranged from why they wanted to join the Farm Foundations program to what they have done with the knowledge they gained during trainings. Any projects or initiatives that Farm Foundations alumni started were coded as innovations developing at the niche level. We examined each innovation – for example the community supported agriculture program one graduate started – individually and identified the regime and landscape actors to draw conclusions about the efficacy of urban agriculture training programs for broader sustainable transitions in the food system.

We also reached out to all seven members of both the County Council and the Planning Commission. The County Council is the highest governing body in Pierce County; the Planning Commission

is the group that makes recommendations to the County Council regarding zoning and land use. We interviewed two members from each governing body. The questions in these interviews were structured to understand decisions related to zoning and land use at the county level. We wrote down their answers to these targeted questions and these interviews lasted 30 min. We also collected county-wide data regarding housing prices to triangulate existing data. Interview questions are listed in [Appendix 1](#).

3.3 Data analysis

We took an inductive approach toward coding and engaged in multiple rounds of interviews and coding. In the first round of coding, we took an exploratory approach and looked for emerging themes in the interviews related to barriers to scaling up urban agriculture. After our initial round of coding, we revisited existing literature on sustainable transitions to identify ways one can analyze the dynamics among actors at the niche level. In the second round of coding, we analyzed how the themes we identified from the coding process fit within the MLP framework (e.g., identifying regime factors, niche innovations, etc.). We also analyzed the interviews through the lens of the SPT framework when we coded participants' reflections about the program; we sought to identify the formation of different types of horizontal linkages. We then grouped the themes that we found (e.g., barriers to implementing urban agriculture, the cultivation of a community that many graduates found valuable) into broader categories so we could better organize, conceptually as well as theoretically, how our results contribute to the MLP and SPT frameworks.

3.4 Study limitations

We tried multiple times to reach out to those who have participated in the urban agriculture training programs and were clear in our communication that interviews would last no more than 30 minutes. While voluntary response bias is still likely, given that those who have a deeper connection with the program might be more willing to respond, the experiences of those who responded to the survey are still valuable for identifying the graduates' roles in contributing to sustainability transitions. In addition, we recognize that our case study is focused on a small geographical area (one county out of the entire state), which limits its scalability. However, the purpose of our study is not to make any type of statistical generalization from our results, but rather to strive for analytic generalization, where we seek to use our case study to support the value of the multi-level perspective and advance our understanding of how social practice theory can be relevant for understanding the value of individual and collective narratives at the niche level.

4 Results and discussion

In the sections below, we share the outcomes of participation in the training program as well as discuss how the training program and its graduates can contribute to sustainable transitions within the food system. We also offer recommendations on how H-Piece County (the

non-profit organization that administers the Farm Foundation's training program) can engage with policymakers and other organizations so graduates have a higher likelihood of developing niche innovations that can destabilize the regime.

4.1 Sustaining nice innovations through social learning

Our interview data shows that participation in the training program leads to niche innovations within the food system. Graduates of Farm Foundations contribute to innovations within the urban agriculture niche. 11 out of the 15 interviewees are involved in a viable form of urban agriculture. Interviewees were involved in a variety of initiatives at the niche level, including starting their own farm, working on a farm, homesteading their own land, and starting a non-profit organization that redistributes food. Responses include "[I] started working on an organic farm in Tacoma, continuing to build up skills" (respondent 12) and "[I] homestead my own property - growing enough food to support me and my husband 9 months out of the year" (respondent 5). Graduates of the program have continued to practice urban agriculture for personal consumption or develop income-producing enterprises. These changes, indicative of a grassroots pathway of change, can lead to collective action against the dominant system in question, thereby creating the necessary vertical pressure to change the system ([Gernert et al., 2018](#)). In addition, these responses show that multiple innovations develop simultaneously within a niche and hold potential for larger system change. While some innovations may never make it past the niche level, this process of testing new ideas is key ([Geels and Schot, 2007](#); [Lachman, 2013](#)).

Respondents discussed the value of learning alongside others. 11 interviewees highlighted the important aspect of community to their experience during and after Farm Foundations, where graduates shared how they valued the connections and how "there's gonna be days where I'm gonna have to reach out to people to come help us out. [It is] always nice to have a group of individuals willing to come help" (respondent 7). Previous studies on food systems have articulated the importance of social learning and its transitional potential within the MLP framework ([van Poeck and Östman, 2021](#)). The interview results shows that the training program fostered social learning among participants. The power of the social learning process lies not in its direct ability to change the current system but in what it represents. In our case study, learning takes place at both an individual level when they first learn about how to practice urban agriculture; double-loop learning arises when the participants identify new challenges and connect with each other to understand how to solve the problems they encounter.

The horizontal connection and increased social capital among the graduates introduces a relational element as an outcome of the training program; this focus on relationships is a critical for food system transformations ([López-García et al., 2024](#)). Strong horizontal ties where ideas are spread and reinforced are pivotal for niche innovations to be sustained over time. Practitioners of urban agriculture can drive change by altering or overthrowing everyday practices if enough practitioners make the same change; this pathway of change occurs when ideas shared horizontally gain enough momentum to have vertical disruption as well ([Gram-Hanssen, 2011](#); [Keller et al., 2022](#); [Shove and Walker, 2010](#)).

4.2 Cultivating shared narratives to foster collective action

10 out of the 15 interviewees noted that the training they received through Farm Foundations had an impact on practices such as food shopping and preparation. They now include more vegetables and organic foods, as indicated in responses such as “[Farm Foundations] made me more conscious of what our family eats, not just what we grow but from the grocery store” (respondent 7) and “I am all organic now. And I really pay attention to what we get and what we bring in” (respondent 3). In addition, participation in the training program led people to see food as part of a larger system, where one respondent shared that “I see nutrition as eating food that is grown in a way that is positive for the ecosystem.” (respondent 5). Respondents’ narratives indicated that their participation in the program led to changes in both their perception of sustainable food and concrete changes in individual practices. These material activities that alumni engage in on a day-to-day basis reflect a “change in practice” that is necessary for scaling up grassroots initiatives that lead to widespread change. These collective changes in practice can also lead to collective action and wider change (Shove and Walker, 2010). The shared narratives among the graduates also reveal how they want to take care of the space that they live in, with one respondent (respondent 5) sharing how they wanted to start an urban garden for their community provide students in the school district with healthier food. Fostering place attachment and a deeper sense of commitment could also motivate participants to continue with experimentation (Dickinson, 2013).

Farmer training programs’ potential to transform food systems comes not only from giving individuals the practical skills to adopt urban agriculture but also the building of a shared narrative and understanding around the importance of local food. Our results suggest that changes in practice based simply on personal preference and images of what is healthy is a necessary intermediate step that lays the groundwork for further action. While Farm Foundations has shown itself to be successful in changing consumer practices for some graduates, this change remains confined to a hyper-local context and has yet to penetrate the larger structures supporting the conventional food system.

Communities need to feel more empowered to make change sustainable and resilient (Mert-Cakal and Miele, 2020). To have a larger impact and contribute to sustainable transitions, Farm Foundations graduates need to connect their learned skills and motivations under the specific goal of pressuring the existing system to shift in favor of small-scale urban agriculture. Harnessing their strong community ties and maintaining open lines of communication will increase their likelihood of success.

4.3 Addressing lock-in mechanisms to overcome economic barriers

The responses from the graduates, and data from the county, indicate that larger structural barriers exist and prevent the scaling-up of niche-level innovations and hinders the ability of interested individuals, such as Farm Foundations graduates, to pursue urban agriculture careers in Pierce County. Graduates of the program who wished to adopt urban farming as a full-time profession faced

significant economic barriers. The lack of available and affordable land hinders the ability of interested individuals to pursue urban agriculture careers in Pierce County. Five respondents cited that a barrier to full time careers in urban agriculture was the difficulty in making full-time work in urban agriculture economically sustainable. Graduates echoed the sentiments of respondent 14, who said that “the reality of farming, it’s hard. Really hard to make a living.” Accessing affordable farmland within Pierce County was a significant barrier; respondents cited that “it [farming] is just economically unrealistic with the price of property (respondent 14)” and “we cannot compete with [the] housing market type of price [in Pierce County]” (respondent 9). Competition for scarce land is also high, with one participant who tried to start and urban farm saying that “every time we put an offer on a farm someone would swoop in out of our grasp because they had cash, and we did not have much cash” (respondent 7).

Interview responses from county-level officials confirm the scarcity of land. Officials said that farmland preservation and urban agriculture is not a policy priority for Pierce County. From 2011 to 2021, over 10,000 acres of agricultural land have been lost to housing and commercial development Pierce County (Pierce County, 2023b) and “no one is prioritizing maintaining land and incentivizing sustainable farming enterprises... at a policy level from the county there is nothing the county can do to pump the breaks” (personal interview Planning Commissioner). In addition, “it’s not like Detroit where land is returning to farmland” (personal interview County Councilperson). The lack of direct incentives and subsidies for farmland reflect that policymakers are not prioritizing urban agriculture and its often intangible benefits when constituents advocate for tangible results such as affordable housing and economic growth.

The current land use policies in Pierce County act as lock-in mechanisms that stabilize regimes and constrain actors’ ability to contribute to sustainability transitions (Klitkou et al., 2015). These lock-in mechanisms are not unique to the food system. For example, low prices of fossil fuels and automobile-centric infrastructure keep the energy and transportation regimes, respectively, stable (Gazull et al., 2019; Kanger and Schot, 2016). This issue of economic viability of urban agriculture is made difficult by regime-level policies as well as societal values and cultural norms (Næss and Vogel, 2012). Our results show that economic challenges are due to structural barriers, and even individuals who have the training and desire to pursue urban agriculture are unable to change their practices if they do not have the money needed. Our results reinforce prior research on AFNs, a study in Wales found that AFNs were successful at the hyper-local level but faced the same structural barriers we found in scaling up related to land availability and the low financial reward of farming (Mert-Cakal and Miele, 2020). However, continued experimentation at the niche level – be it success or failure – is necessary for future success and large-scale impact (Turnheim et al., 2020).

4.4 Embracing hybridity to destabilize regimes

Our results show that participation in Farm Foundations leads to the development of new innovations within the urban

agriculture niche, cultivates strong community ties that lead to shared ideas and narratives regarding food, and influences consumer behavior. While Farm Foundations fosters horizontal pathways of change through community building and social learning, it struggles to enact larger scale change within the county due to its lack of access to vertical pathways of change (e.g., working with policymakers at the state level).

Hybridity in both conventional and experimental spaces to cultivate vertical pathways of change necessary for sustainable transitions (Le Velly and Dufeu, 2016; Saul et al., 2022). Evidence of some hybridity already exists: H-Pierce County and the city of Tacoma collaborated to secure an empty city lot for a graduate to start an urban farm. Through this hybridity, a small urban farm – a niche innovation – was possible. This collaboration serves as a powerful example of how H-Pierce County can utilize its unique position within the Pierce County Conservation District. Partnering with other local governmental agencies and creating a conducive environment for graduates to adopt urban agriculture can have positive spillover effects (e.g., more access to healthy food) that incentivize agencies to fund urban agriculture initiatives. These partnerships among different city and county level agencies suggests that niche innovations at the local level interact with regimes at multiple levels. For example, policies at the state or national level may not yet reflect the principles underlying the need for more sustainable food systems, but the county has shown commitment to fund programs such as Farm Foundations. More communication among the county officials, and demonstrated results from participation in the program, can further enhance the potential of the niche innovation to exert change on the regime.

H-Piece County—the non-profit organization that administers the Farm Foundations program—should embrace hybridity by building networks with other non-profits organizations that have similar missions. Partnerships with other organizations and actors can increase the likelihood of activating both horizontal and vertical pathways of change. Aligning themselves with initiatives aimed at protecting farmland (e.g., East Multnomah soil and water conservation district's ongoing farmland easement projects; Northwest Business Agriculture Center programs on improving the economic vitality of agriculture) can be an effective way to craft a collective narrative and empower actors and organizations to advocate for wider policy change on land use (East Multnomah Soil and Water Conservation District 2023; Northwest Agriculture Business Center, 2023). Creating a community across multiple organizations can provide the space for more radical experimentation so innovations can “breakthrough” when the conditions are right and destabilize regimes.

5 Conclusion

The case study of Farm Foundations reinforces the idea that the key to sustainable transitions requires cultivating community buy-in and pressuring both governmental and non-governmental actors to make progress toward sustainable transitions. Many

grassroots initiatives are better equipped to develop strong horizontal ties and spread changes in practices through building a shared sense of community. However, embracing hybridity and cultivating strong partnerships with other non-profit organizations or federal agencies within the regime can increase access to vertical pathways and ensure that ideas and values at the niche level break into regimes at a higher institutional level.

Removing the structural barriers that keep the current regime dominant is key to allowing the changes in individual practice and niche innovations to influence the larger food system. Our results reinforce other research related to AFNs, where removing structural barriers needs to be a priority at the county level if niche innovations such as CSAs or community gardens are to break through and influence or destabilize the regime. Until these barriers are addressed, it is still vital that niche innovations and changes in practice at a local level continue; the iterative process of learning that people engage with when working with each other transform narratives and lead participants to advocate for change from policymakers, which in turn can drive societal changes related to the value of local urban agriculture.

Lastly, our study shows the importance of focusing on the niche level when examining sustainable transitions and the value of combining the SPT and MLP framework when analyzing sustainable transitions. Our results highlight the type of pressure needed to exert change at the micro versus the macro level is different: alliances with other actors are just as important as individual action and leveraging existing networks as well as building new ones can activate pathways of change more effectively.

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 Amanda Udis-Kessler, Institutional Review Board; Colorado College. 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. Written informed consent was obtained from the individual(s) for the publication of any potentially identifiable images or data included in this article.

Author contributions

SK: Conceptualization, Formal analysis, Investigation, Writing – original draft, Writing – review & editing. JL: Funding acquisition, Project administration, Data curation, Investigation, Conceptualization, Methodology, Supervision, Validation, Writing – original draft, Writing – review & editing.

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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.

References

- Belletti, G., Torres Salcido, G., Scarpellini, P., Mengoni, M., and Marescotti, A. (2024). Multilevel governance in farmers' markets: a stakeholder analysis in Tuscany. *Front. Sustain. Food Syst.* 8, 1–19. doi: 10.3389/fsufs.2024.1401488
- Bonfert, B. (2022). "What we'd like is a CSA in every town." Scaling community supported agriculture across the UK. *J. Rural. Stud.* 94, 499–508. doi: 10.1016/j.jrurstud.2022.07.013
- Campbell, C. G., and Rampold, S. D. (2021). Urban agriculture: local government stakeholders' perspectives and informational needs. *Renew. Agric. Food Syst.* 36, 536–548. doi: 10.1017/S1742170521000156
- Chiffolleau, Y. (2009). From politics to co-operation: the dynamics of embeddedness in alternative food supply chains. *Sociol. Rural.* 49, 218–235. doi: 10.1111/j.1467-9523.2009.00491.x
- Crivits, M., De Krom, M. P. M. M., Block, T., and Dessein, J. (2018). Using policy discourses to open up the conceptual space of farm education: inspiration from a Belgian farm education network. *Environ. Educ. Res.* 24, 1320–1339. doi: 10.1080/13504622.2017.1301384
- Dickinson, E. (2013). The misdiagnosis: rethinking "nature-deficit disorder". *Environ. Commun.* 7, 315–335. doi: 10.1080/17524032.2013.802704
- Donoghue, D., Goodwin, H., Mays, A., Spencer, T., O'gorman, M., Jose, S., et al. (2014). Armed to farm: developing training programs for military veterans in agriculture. *J. Rural Soc. Sci.* 29, 82–93.
- East Multnomah Soil and Water Conservation District. (2023). Land conservation. Available online at: (<https://emswcd.org/land-conservation/>).
- El Bilali, H., and Probst, L. (2018). Towards an integrated analytical framework to map sustainability transitions in food systems. *AGROFOR* 2:15T. doi: 10.7251/AGRENG1702015T
- Gazull, L., Gautier, D., and Montagne, P. (2019). Household energy transition in Sahelian cities: an analysis of the failure of 30 years of energy policies in Bamako, Mali. *Energy Policy* 129, 1080–1089. doi: 10.1016/j.enpol.2019.03.017
- Geels, F. W., and Schot, J. (2007). Typology of sociotechnical transition pathways. *Res. Policy* 36, 399–417. doi: 10.1016/j.respol.2007.01.003
- Gernert, M., Bilali, H. E., and Strassner, C. (2018). Grassroots initiatives as sustainability transition pioneers: implications and lessons for urban food systems. *Urban Sci.* 2:23. doi: 10.3390/urbansci2010023
- Girip, M., Mărăcine, D., and Dracea, L. (2020). Environmental impact of conventional agriculture. *Ovidius Univ. Ann. Econom. Sci. Ser.* 20, 372–381.
- Gram-Hanssen, K. (2011). Understanding change and continuity in residential energy consumption. *J. Consum. Cult.* 11, 61–78. doi: 10.1177/1469540510391725
- Hargreaves, T., Longhurst, N., and Seyfang, G. (2013). Up, down, round and round: connecting regimes and practices in innovation for sustainability. *Environ. Plan. A* 45, 402–420. doi: 10.1068/a45124
- Harvest Pierce County. (2023). Pierce Conservation. Available online at: (<https://piercedcd.org/190/Urban-Agriculture>).

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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.2025.1501877/full#supplementary-material>

- Hinrichs, C. (2014). Transitions to sustainability: a change in thinking about food systems change? *Agric. Human Values* 31, 143–155. doi: 10.1007/s10460-014-9479-5
- Ingram, J. (2011). A food systems approach to researching food security and its interactions with global environmental change. *Food Secur.* 3, 417–431. doi: 10.1007/s12571-011-0149-9
- Kanger, L., and Schot, J. (2016). User-made immobilities: a transitions perspective. *Mobilities* 11, 598–613. doi: 10.1080/17450101.2016.1211827
- Keller, M., Sahakian, M., and Hirt, L. F. (2022). Connecting the multi-level-perspective and social practice approach for sustainable transitions. *Environ. Innov. Soc. Trans.* 44, 14–28. doi: 10.1016/j.eist.2022.05.004
- Klitkou, A., Bolwig, S., Hansen, T., and Wessberg, N. (2015). The role of lock-in mechanisms in transition processes: the case of energy for road transport. *Environ. Innov. Soc. Trans.* 16, 22–37. doi: 10.1016/j.eist.2015.07.005
- Lachman, D. A. (2013). A survey and review of approaches to study transitions. *Energy Policy* 58, 269–276. doi: 10.1016/j.enpol.2013.03.013
- Lane, J. M., and Davis, B. A. (2022). Food, physical activity, and health deserts in Alabama: the spatial link between healthy eating, exercise, and socioeconomic factors. *Geojournal* 87, 1–21. doi: 10.1007/s10708-021-10568-2
- Le Velly, R., and Dufeu, I. (2016). Alternative food networks as "market agencements": exploring their multiple hybridities. *J. Rural. Stud.* 43, 173–182. doi: 10.1016/j.jrurstud.2015.11.015
- López-García, D., Cruz-Maceín, J. L., and DiPaula, M. (2024). Agri vs. food? Perceptions of local policymakers on agro-food policies from a multilevel approach. *Front. Sustain. Food Syst.* 8:1399746. doi: 10.3389/fsufs.2024.1399746
- Mendes, W., Balmer, K., Kaethler, T., and Rhoads, A. (2008). Using land inventories to plan for urban agriculture: experiences from Portland and Vancouver. *J. Am. Plan. Assoc.* 74, 435–449. doi: 10.1080/01944360802354923
- Mert-Cakal, T., and Miele, M. (2020). "Workable utopias" for social change through inclusion and empowerment? Community supported agriculture (CSA) in Wales as social innovation. *Agric. Hum. Values* 37, 1241–1260. doi: 10.1007/s10460-020-10141-6
- Mok, H.-F., Williamson, V. G., Grove, J. R., Burry, K., Barker, S. F., and Hamilton, A. J. (2014). Strawberry fields forever? Urban agriculture in developed countries: a review. *Agron. Sustain. Dev.* 34, 21–43. doi: 10.1007/s13593-013-0156-7
- Næss, P., and Vogel, N. (2012). Sustainable urban development and the multi-level transition perspective. *Environ. Innov. Soc. Trans.* 4, 36–50. doi: 10.1016/j.eist.2012.07.001
- National Land Cover Database. (2023). Data. Available online at: (<https://www.mrlc.gov/data?F%5B0%5D=category%3ALand%20Cover&F%5B1%5D=category%3ALand%20cover&F%5B2%5D=region%3ANorth%20america>).
- Northwest Agriculture Business Center. (2023). Bringing the farm to market. Available online at: (<https://www.agbizcenter.org>).
- Olabisi, L. S., Elegbede, O., and Raven, M. (2020). Insights for farmer training programs from system dynamics: a case study from northern Michigan. *Adv. Agri. Dev.* 1, 1–11. doi: 10.37433/aad.v1i2.33

- Pierce County. (2023a). "Sustainability 2030: Pierce County's greenhouse gas reduction plan." Available online at: (<https://www.piercecountywa.gov/2058/Sustainability-2030>).
- Pierce County. (2023b). "Pierce County median home Price." Available online at: (<https://internal.open.piercecountywa.gov/stories/s/Median-Home-Price/kprt-him3/>).
- Saul, D., Newman, S., DePHELPS, C., and Liao, F. (2022). Exploration of values and agency in place-based food systems. *J. Rural. Stud.* 89, 337–347. doi: 10.1016/j.jrurstud.2021.12.010
- Shove, E., and Walker, G. (2010). Governing transitions in the sustainability of everyday life. *Res. Policy* 39, 471–476. doi: 10.1016/j.respol.2010.01.019
- Siegner, A., Sowerwine, J., and Acey, C. (2018). Does urban agriculture improve food security? Examining the Nexus of food access and distribution of urban produced foods in the United States: a systematic review. *Sustain. For.* 10:2988. doi: 10.3390/su10092988
- Turnheim, B., and Sovacool, B. K. (2020). Exploring the role of failure in socio-technical transitions research. *Environ. Innov. Soc. Transit.* 37, 267–289. doi: 10.1016/j.eist.2020.09.005
- United States Census Bureau. (2023). Measuring America's people, places, and economy. Available online at: (<https://www.census.gov/quickfacts/piercecountywashington>).
- United States Department of Agriculture. (2023). Urban agriculture and innovative production. Available online at: (<https://www.usda.gov/topics/urban>).
- Vaarst, M., Escudero, A. G., Chappell, M. J., Brinkley, C., Nijbroek, R., Arraes, N. A. M., et al. (2018). Exploring the concept of agroecological food systems in a city-region context. *Agroecol. Sustain. Food Syst.* 42, 686–711. doi: 10.1080/21683565.2017.1365321
- van Poeck, K., and Östman, L. (2021). Learning to find a way out of non-sustainable systems. *Environ. Innov. Soc. Trans.* 39, 155–172. doi: 10.1016/j.eist.2021.04.001
- Wittenberg, J., Gernert, M., El Bilali, H., and Strassner, C. (2022). Towards sustainable urban food systems: potentials, impacts and challenges of grassroots initiatives in the Foodshed of muenster, Germany. *Sustainability* 14:13595. doi: 10.3390/su142013595
- Yin, R. K. (2003). Case study research: Design and methods. Thousand Oaks: Sage Publications.
- Zoll, F., Specht, K., Opitz, I., Siebert, R., Piore, A., and Zasada, I. (2018). Individual choice or collective action? Exploring consumer motives for participating in alternative food networks. *Int. J. Consum. Stud.* 42, 101–110. doi: 10.1111/ijcs.12405



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Do urban safety net programs affect the financial inclusion and food security of households, primarily women participating in urban agriculture? A triangulative exploration of Ethiopia

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Throughout the world, poverty, income inequality and food insecurity in urban areas have continued to be pressing issues. As a solution, a productive urban safety net program has been launched to provide conditional cash transfers (CTs) to poor households since 2017 in urban areas of Ethiopia. This study examines the impact of CTs made by the program to beneficiary households on the financial inclusion options, participation in urban agriculture and levels of food security among women in Addis Ababa, Ethiopia. Random stratified sampling was used to select 278 women for questionnaire surveys. Mixed research, comparative impact analysis, food security index, Ordinary Least Square (OLS), Logistic, and Ordinal Probit regressions were applied. Results showed that 94% of respondents could have ownership of a bank account and participated in urban agriculture as additional income source only after receiving CTs from the program. This contributed to better access to other financial inclusion components such as saving, credit, mobile banking, advice on finance management, and farm incomes. The study found that 171 (61.5%) women households were food insecure, while 107 (38.5%) were food secure. The minimum, maximum, and mean K/calorie consumed by food-insecure female farmers was 674.6, 2082.1, and 1378 Kcals, respectively, while 2192.5, 5360.4, and 3776.6 Kcals for food-secure ones. Furthermore, mean calorie consumption of women also significantly varies with the type of urban agriculture they are involved in. Accordingly, among the food-secure women, the mean calorie consumption was relatively better in those involved in horticulture relative to animal husbandry. The OLS model indicate the coefficient of bank account ownership, amount saved in the last 1 year, farm income and proportion of credit used for actual collection intention have a significant positive effect on food security index. The logistic regression model also confirmed that among the financial inclusion options, amount saved, advice on finance management, and proportion of credit used were the most significant predictors. The safety net program's CTs have moderately improved financial inclusion for women and slightly increased food-secured women, but their overall contribution to food security remains inadequate, as a significant portion of women's households still experience food insecurity and poor urban agriculture. The study implies urban planning and development policies still need to be more pro-poor, gender-sensitive & responsive & inclusive to bring majority of urban women households out of food insecurity by improving their nutrition calorie consumption & job via urban agriculture. Accordingly, it informs partners to revisit and expand the safety net program scope, consider more financial inclusion options and urban agriculture

facilities, including soft loan provisions, grants, Agri-input, market links, training, incentives, and increasing CTs amount. Besides, business-to-business networking events among financial service providers is essential to create long-term partnerships to improve financial services, access to agricultural technology and income-generating job options including Agri-Micro Small and Medium Enterprises to urban poor, particularly women program beneficiary households. Organization of further research with wider scope is also necessary.

KEYWORDS

urban safety net, financial inclusion, food security, urban agriculture, women households, urban planning and policy

1 Introduction

According to [Louis and Chartier \(2017\)](#), smallholder farmers in developing countries face limited resources and low income, hindering their ability to scale operations and reducing agricultural production. Access to money and challenges, particularly in urban areas, are primary barriers to agricultural growth. Financial institutions, including commercial banks, development banks, credit cooperatives, microfinance institutions, and savings and loans institutions, provide funding for commercial agricultural output ([Amoah et al., 2020](#); [Mhlanga and Denhere, 2020](#)).

Commercial banks, microfinance banks, registered cooperatives, and development banks are essential financial institutions for agricultural services, contributing to financial inclusion, poverty reduction, commercialization, food security, livelihood development, and reducing vulnerability of the low-income people, especially women ([Dar and Ahmed, 2020](#); [Demircig-kunt et al., 2018](#)).

[Masiyandima et al. \(2017\)](#) define financial inclusion as the provision of affordable financial services to low-income and unbanked individuals, requiring skills, knowledge, and confidence to access mainstream financial products. It involves various actors, including individuals, governments, and financial institutions, collaborating to enhance lives through social policies and financial products. This counters financial exclusion, where low-income individuals cannot access or afford essential services, thereby improving the lives of those unable to afford them ([Mhlanga and Denhere, 2020](#)).

According to [World Bank \(2018\)](#) and [Olaniyi \(2017\)](#), financial inclusion has been identified as a way to achieve the Sustainable Development Goals (SDGs) because it is crucial to strengthening people's livelihoods and, consequently, reducing poverty, enhancing the involvement of households in income generating businesses such as urban agriculture and trade, improving food security, and improving food security, provides more evidence in support.

Financial inclusion enhances access to deposit facilities, improves financial intermediary capacity to mobilize savings, and fosters economic growth by enabling women farmers to invest in productive activities ([Gebrehiwot and Makina, 2019](#)). Access to a well-functioning financial system creates equal opportunities for socially and economically excluded people to integrate into the economy and contribute to economic development, ensuring the financial sector fulfills its responsibility for equitable growth, a key issue facing emerging and developing countries ([Prymostka et al., 2020](#); [Kaur and Kapuria, 2020](#)).

When urban women farmers are excluded and marginalized from the financial system, the urban economy as a whole cannot thrive

since they are the true foundation of the economy. Therefore, progress in financial inclusion serves as a unique channel that may be utilized to inform monetary policy and achieve its objectives ([Anthonia, 2016](#); [Riley and Crush, 2022](#); [World Bank, 2018](#); [Badmus, 2020](#)).

Improving women's access to financial services or financial inclusion is a proven strategy for contributing to women's social and economic empowerment, as well as improving the livelihoods, food security, poverty escape and commercialization of their urban investment including the agricultural output in urban settings through improved urban agriculture ([Badmus, 2020](#); [HLPE, 2012](#); [Devereux et al., 2006](#)).

Financial inclusion allows women to access necessary inputs, labor, and equipment for agricultural or off-farm activities. However, urban areas often lack access to financial services, and these services usually do not benefit women. Sociocultural, economic, legal, and educational barriers also limit women's access to these services, affecting sustainable development and hindering their participation in agricultural activities ([Amurtiya et al., 2018](#); [Etim et al., 2017](#)).

According to [Obisesan and Adeyinu \(2018\)](#), food insecurity refers to the inability to obtain wholesome food in socially acceptable ways, affecting many women farmers, particularly those who farm rice and cassava. Developmental agricultural economics aims to find solutions to escape the semi-subsistence poverty trap faced by these farmers. Challenges include limited access to formal financial institutions, lack of financial literacy, cultural and social barriers, and limited economic opportunities. Without access to financial services, these farmers struggle to diversify income sources and improve their financial well-being, making them food insecure ([Khan et al., 2021](#); [Khan et al., 2018](#)).

Poverty, income inequality, and food insecurity have been growing in major urban areas of developing nations due to various reasons, such as rapid urbanization. To address the significant problems such as financial inclusion, food insecurity, income inequality, and poverty in urban areas, the Ethiopian government initiated a safety net program in 2017 in collaboration with international partners, including the World Bank. Urban Productive Safety Net Program (UPSNP) is defined as a social protection system that is being implemented in the primary urban centers of Ethiopia, targeting chronic food-insecure households and providing cash for the beneficiary households primarily "for work" regularly for a 3-year period ([Tareke, 2022a](#); [FAO, WFP, UNICEF, 2019](#); [Borku et al., 2024a](#); [Derso et al., 2021](#)).

The UPSNP, which is the first of its kind in urban areas, is a 5-year (i.e., 2017–2023) phase-by-phase program targeting 11 major cities in Ethiopia, including Addis Ababa. Being the capital city of Ethiopia,

Addis Ababa is one of the most rapidly urbanizing cities in Africa (Tareke, 2022b; Tareke and Ashebir, 2023). This program has benefited from the country's experience in delivering a rural, productive safety net over the past 10 years. The objective of the program or strategy was to alleviate urban food insecurity and address the increasing levels of vulnerability, inequalities, and poverty. This was expected to be achieved over a long-term period through a gradual roll-out plan in different phases, starting with big cities that have a population of over 100,000 people (Borku et al., 2024b; PSNP, 2014).

Cash transfers are an increasingly popular social protection mechanism used by UPSNP in many developing countries to improve food security and the nutritional status of urban beneficiary households from lower socioeconomic groups through enhanced investment in urban productivity, such as the urban agriculture sector. The overall objective of the UPSNP's CT program can, therefore, be seen as preventing the intergenerational transmission of poverty. The primary type of CT program used primarily in developing countries is conditional CT (CCT). The number and size of CTs have increased noticeably in the last 20 years (Gilligan, 2013; Honorati et al., 2015).

To receive assistance, a conditional cash transfer program requires beneficiaries to undertake a specific activity, such as participating in public works or attending training sessions. After the condition is fulfilled, a monthly CTs are given to beneficiary households with no restrictions on how the cash is to be spent and no requirements beyond meeting the eligibility criteria, for example, being a low-income household (Borku et al., 2024c; FAO, WFP, UNICEF, 2019).

Even though the effects of rural safety net program on farmers and women communities' food security and their contribution to enhanced agricultural output are widely studied, there is severe shortage of studies on the status and effects of the recently started safety net program in urban areas on urban agriculture, income, and food security of urban communities, primarily women.

The studies conducted so far on this topic have not addressed the impact of UPSNP and its CTs on financial inclusion, urban agriculture, and household food security in urban areas of Ethiopia and Africa, primarily from the perspective of women households. Thus, the gap in research, literature, and recent knowledge on this particular topic has motivated the author to conduct this study in Addis Ababa, where the problems continue to increase.

Aligned with the several goals of the SDGs, particularly SDGs 1, 2, 5, 8, and 11, this study focused on the multidisciplinary and transdisciplinary issues our contemporary world faces, chiefly from the context of urban areas in the developing region. It linked the safety net program, financial inclusion, food security, urban planning, and agriculture issues, the cross-cutting gender topic, and the SDGs. The specific SDG goals related to no poverty, zero hunger, gender equality, decent work and growth, as well as sustainable and inclusive cities and communities, were used as frameworks for the study.

However, the impact of the urban safety net program, the status of food security and insecurity among urban beneficiary women households has not been assessed since the program's start. This study aimed to address the knowledge that will help urban planners and policymakers evaluate and revisit program approaches in an urban setting, particularly from the context of women households involved in urban agriculture. Therefore, a key goal of this study is to contribute to the scaling up of the UPSNP, thereby helping to improve the food

security status of low-income urban individuals, particularly women, through urban agriculture and other entrepreneurial ventures.

Given the newness and urgency of these issues, the following question is attempted to be addressed by this original study: Does urban safety net programs through cash transfers affect the financial inclusion, participation in urban agriculture, and food security status of low-income households, particularly women in key urban areas of developing economies, such as Addis Ababa, Ethiopia?

The general objective was to assess the effects of cash transfers from the urban safety net program on financial inclusion and food security of low-income households in Addis Ababa, Ethiopia, from the context of women participating in urban agriculture. Accordingly, the specific objectives were to:

- i) Explore the economic effects of the urban safety net program's cash transfers on the financial inclusion of low-income households, primarily women in Addis Ababa, Ethiopia.
- ii) Estimate the effects of cash transfers of the urban safety net program on women's involvement in urban agriculture.
- iii) Evaluate the implications of cash transfers of the urban safety net program on levels of food security among urban women households.
- iv) Identify the financial inclusion factors influencing the food security status of women households.

In general, the remaining sections of this paper are structured into major sections, including literature review, hypothesis, methods and materials, findings, discussions, and conclusions.

2 Review of related literature

2.1 Urban Productive Safety Net Program

Ethiopia's government and social protection programs have made significant efforts to tackle poverty, food insecurity, and income inequalities. The first program, the Productive Safety Net Program (PSNP), was launched in rural areas, focusing on low-income households. Evidence shows that this program has improved food security and dietary diversity in low-income rural areas. PSNP plays a critical role in advancing food and nutrition security and livelihood targets for vulnerable communities, including women, the elderly population, people with disabilities, and children (Borku et al., 2024a; Burchi and Strupat, 2016; FAO, 2017).

Addressing food insecurity and income inequality has been successful; however, these issues remain among the top global problems, particularly in the urban areas of developing countries. In large cities like Addis Ababa, poverty rates are falling but not as rapidly as in rural and smaller urban centers (CSA and ICF International, 2015; World Bank, 2018; Cook et al., 2004).

Ethiopia's government and development partners, including the World Food Programme and World Bank, have expanded the rural PSNP to urban areas to improve food security and stabilize assets for 10 million people. Launched in 2017, the UPSNP is a pilot project designed to help low-income urban households improve their nutritional status and address the underlying causes of food insecurity through aid in kind, such as food and cash (Development Initiatives, 2017; Porter and Goyal, 2016; FDRE, 2016).

According to the 2022 Urban Job Creation and Food Security Agency (UJFSA) of Ethiopia and WB reports, the components of aid were two types. The first type is direct or without precondition aid, such as aid in kind, including food, for low-income beneficiaries who cannot perform physical work due to age, health, or other physical inability reasons. The second component is conditional aid, primarily in cash (which is called a cash transfer), and it targets low-income individuals who can perform physical work or contribute at least 1 day per week and 4 h per day. Since this safety net program is productive, cash transfers (CTs) are conditional and only made when households contribute and participate in selected public works, such as solid waste collection, greenery maintenance, and water and soil conservation practices for at least 4 h per day.

CTs are monthly payments made to beneficiary households based on family size and total working hours. The minimum CT amount is 181 Ethiopian birr (ETB), or about USD 3.30, for a single-family size, which contributes 4 h to public works per day. For a two-family household, the amount is 1,446 ETB, equivalent to approximately USD 26.4. The calculation of monthly CTs is 181 ETB multiplied by the number of working days per month, depending on the family size. For example, a household with 1, 2, 3, and 4 family members is expected to contribute 4 h of public work for 1, 8, 12, and 16 day(s) per month.

The study of Tareke (2022a) found that female and male program beneficiaries received an average monthly cash transfer of 767.75 ETB (approximately USD 17) and 712.72 ETB (approximately USD 15.9), respectively, compared to only 55 ETB (USD 1.2). The study also found that female beneficiaries received a substantial amount of cash transfer or benefit per month, equivalent to that of male beneficiaries, and this amount was provided until they graduated and transitioned into small and microbusiness ownership. The UPSNP program, which lasted from 2017 to early 2023, involved beneficiaries being selected three times annually in three consecutive years. Each round of beneficiaries received CTs for 3 years and were then transferred into a private income-generating business. The program has been replaced by UPSNJP, an urban productive safety net job program, from 2023 to 2027, with additional components and increased targeted urban areas. Approximately 60% of the total beneficiary households are expected to be women.

Despite being established in Ethiopia for a long time and primarily targeting rural areas, the recent implementation of productive safety net programs in urban areas began in 2017. It targets chronically food-insecure households by providing cash or food for work, free, or a combination of both for 5 years (Borku et al., 2024d; Camilla et al., 2011; PSNP, 2014; Shigute et al., 2019). Food insecurity refers to a state in which individuals lack adequate physical, social, or economic access to sufficient, safe, and nutritious food that meets the dietary needs and food preferences for an active and healthy life (Napoli et al., 2011).

Consistent with most of the 17 SDGs of 2030, goals 1, 2, 5, 8, and 11, the strategy aimed to reduce urban food insecurity, hunger, and poverty through a gradual rollout plan in Ethiopia. The urban safety net program, the first of its kind in urban areas, is a 5-year, phase-by-phase government initiative targeting 11 major cities. The program is based on Ethiopia's experience in delivering a rural productive safety net over the past decade, using a program Implementation Manual (PIM). The program aims to address increasing vulnerability, inequalities, and poverty in urban areas (Borku et al., 2024b; PSNP, 2014).

The program aims to streamline program implementation and management by providing guidelines and operating procedures for key institutions like the Ministry of Urban Development and Housing, UJFSA, and Labor and Social Affairs, as well as regional and city administrations and municipalities (Gilligan et al., 2008; Gilligan, 2013). Urban safety net initiatives are being implemented in developing countries, like Ethiopia, to provide income to individuals and households experiencing food insecurity, unemployment, or a decline in purchasing power. These programs include cash transfers, subsidies, and labor-intensive public works projects. They aim to help low-income households generate seed money or initial capital for new businesses and small and microenterprises, promoting sustainable livelihoods and food security [Khan et al., 2023; World Bank, 2018; Government of Ethiopia (GoE), 2016].

According to Borku et al. (2024c), Ministry of Agriculture (MoA) (2014), and Government of Ethiopia (GoE) (2016), Cash transfers (CTs) are the primary intervention in urban poverty reduction programs (PSNP) in Ethiopia, primarily focusing on Addis Ababa city, where two-thirds of the country's low-income households and the majority of the urban population are located (Tareke and Baraki, 2024). CTs are expected to increase income, food access, and consumption, and serve as seed money for small and micro-businesses, including those owned by women, for low-income households in urban areas.

This study examines the impact of urban safety nets, particularly cash transfers, on food security and nutrition in Addis Ababa, Ethiopia, a city with a high rate of female-headed households, amidst debates about the effectiveness of cash transfers compared to in-kind aid.

This research, the first of its kind, examines the performance, impacts, roles, and challenges of the UPSNP, particularly the CTs, in urban women households in Ethiopia since 2017. It examines theoretical pathways that advocate cash transfers as a means to improve household income, access to financial inclusion services, such as savings, and involvement in urban agriculture, which are essential requirements for food purchasing and intake capacity, as well as diet diversity. These indicators are used to determine household food security, including access, availability, and utilization of food.

2.2 The Nexus between cash transfers and food security in urban areas

The Public Works Program (PWP) is a commonly used social protection or safety net instrument that provides support, primarily cash transfers, to working-aged people who are poor, unemployed or underemployed and working in low-productivity jobs (Bastagli et al., 2019; Anna, 2013). Cash transfers (CTs) are a popular social protection mechanism in developing countries aimed at improving food security for lower socioeconomic groups and preventing intergenerational poverty transmission. Conditional CT (CCT) is the major type used in developing countries, with the number and size of CTs increasing significantly in the last 20 years (Gilligan, 2013; Honorati et al., 2015).

Conditional cash transfers (CTs) are assistance programs that require beneficiaries to undertake specific activities, such as public works or training. Once fulfilled, these transfers are given to vulnerable individuals without restrictions on spending or eligibility criteria. These programs focus on human capital development and typically target households with primary or secondary school-aged children (Pega et al., 2015).

CCTs aim to reduce short-term food insecurity by improving the immediate consumption levels and nutritional status of low-income households. Household food security is defined by the availability of resources to purchase adequate food for all family members, particularly cash income. Standard measures of household food security include spending on food, diet diversity, food frequency, consumption behaviors, and experience of food insecurity (Khan et al., 2023; Khan et al., 2021; Smith and Haddad, 2002).

In line with most of the 17 goals of the SDGs of 2030, the PSNP's CT component can enhance food security and consumption by increasing household income. This can lead to increased food availability and access for the lowest-income households, enabling them to purchase food and increase their actual and share of expenditure on food. Additionally, increased income can improve food utilization and nutrition by enhancing the quality and diversity of daily meals (Smith and Haddad, 2002; Arnold and Conway, 2011). Cash transfers, part of a comprehensive intervention package, provide beneficiaries with knowledge, information, safety, and nutritional supplements, thereby addressing malnutrition and intrahousehold inequalities, primarily through women's empowerment (Yoong et al., 2012; Hagen-Zanker et al., 2017).

Recent studies (Haushofer and Shapiro, 2013; IEG, 2014; Bastagli et al., 2019) demonstrate that CTs can significantly influence intrahousehold dynamics, particularly when distributed to female heads of households, enabling them to advocate for their preferences with higher control over resources. In many developing countries, food security has improved due to cash transfers (CTs), as most households allocate their income primarily to food. CTs provide dignity, choice, and flexibility to affected populations, making them more effective in achieving nutrition security for all, thereby improving dietary diversity (Gilligan et al., 2008).

Attanasio et al. (2005) found that increased income enabled households to overcome credit and saving constraints, leading to more profitable investments. They also found that CTs' positive impact on hunger and food security is most evident in low-income countries, where poverty is often harsher. Similarly, the PSNP in Ethiopia has significantly improved the food consumption and security of over 7 million rural people who were previously dependent on relief (Gilligan et al., 2008; Baye et al., 2014). Studies by Khan et al. (2021) and Khan et al. (2018) also demonstrated that the safety net program is capable of enhancing food security, considering various challenges such as sociocultural barriers faced by women.

However, the studies conducted so far on this topic have not addressed the impact and contribution of such kinds of UPSNP and its CTs to household food security and financial inclusion in urban areas of Ethiopia and Africa, particularly from the perspective of women households.

3 Hypotheses of the study

Based on the theoretical and empirical literature, the following hypotheses were formulated and tested in this study:

HO1: Cash transfers of the urban safety net program significantly affect the financial inclusion and involvement in urban agriculture, but not the food security of women households.

HO2: Financial inclusion factors do not significantly influence the food security index of urban women farmers.

HO3: Financial inclusion factors do not significantly influence the food security status of urban women farmers.

HO4: Financial inclusion factors do not significantly influence the food security levels of urban women farmers.

4 Methods and materials

The study was conducted in Addis Ababa, the capital of Ethiopia, with a population of approximately 6 million and 11 subcity administrations. The target population of this study consisted of all low-income urban households in Addis Ababa, Ethiopia, who are beneficiaries of safety net programs, particularly women participating in urban agriculture. The list was obtained from food security and safety net program offices at the city and subcity levels. A sample size was drawn in a three-stage sampling process. The first stage involved the purposive selection of Addis Ababa city because it has the largest number of safety net beneficiaries and the highest proportion of urban farmers with access to higher agricultural credit provisions in the country. The second stage involved the purposive selection of one subcity, namely Yeka subcity, as this study builds upon previously conducted research in 2022 to address its research limitations.

The third stage involved a total of three "wereda" or districts that were randomly and proportionally selected, particularly from the agricultural zones of the safety net program. To increase the representativeness, objectivity, and fairness of the sampling frame and design at the city level, the three weredas/districts were purposefully selected from inner-city, intermediate-city, and outer-city locations within Yeka subcity of the city. As indicated in Table 1, wereda 6, wereda 10, and wereda 13 were chosen from inner city, intermediate, and outer city locations, respectively. Finally, women participating in urban safety net and urban agriculture from the three locations were proportionally selected using stratified sampling from each wereda based on the sampling frame or list. Thus, the sampling design or frame of this study was aligned with the data sources, collection tools, and findings to address potential biases and provide robust evidence to support the conclusions.

Accordingly, the study determined sample sizes of 92, 88, and 86 women farmers using the Yamane (1967) formula at a 95% confidence interval (CI) level, resulting in a total of 266 urban women households. The study employed a mixed-methods research approach, combining quantitative and qualitative data, and used a cross-sectional survey to collect primary data. Well-trained enumerators gathered primary data from the selected sample of women households using a semi-structured questionnaire, and through strict control and care, they reduced the potential selection biases. Descriptive and inferential statistics were used to analyze data, including OLS multiple regression, binary logistics regression, and ordinal probit Regression to examine the financial inclusion factors influencing food insecurity among urban women farmers. Principal component analysis was used to achieve the last objective. Additionally, content analysis was employed to analyze the qualitative data, facilitating the triangulation of results.

4.1 Food security index

Food security research primarily uses two assessment techniques: estimating the annual output and consumption of women farmers'

TABLE 1 Food security status of urban women farmers.

Food security status (kcal)	Frequency	Percentage	Mean
674–1000.0	20	7.5	
1001.0–2000.0	193	72.6	
2001.0–3000.0	47	17.7	
3000.0–4000.0	5	1.9	
4001.0–5360.0	1	0.4	
Total (N)	266	100.0	

Food insecurity parameters	Food secure	Food insecure	Pooled
Calorie requirement	2100.0	2100.0	2100.0
Minimum	2192.5	674.6	674.6
Maximum	5360.4	2082.1	5360.4
Mean calorie consumption (MCC)	3776.5	1378.4	3017.5
Standard deviation	1459.9	842.5	1124.4
-	Incidence of FS	58.3	

Head count ratio (Nfi/P) (%)	(%)	-
Food insecurity gap (TCRi – TCCi/TCRi) (%)	Depth of FS (%)	33.0
Squared food insecurity gap	Severity of FS (%)	Mean FSI = 1.68
MCC (kcal); <i>t</i> -value = 3.39 (<i>p</i> < 0.05)	Horticulture = 2504.4	animal-husbandry = 2391.3

TCRi, Total calorie requirement for the *i*th food-insecure household; TCCi, Total calorie consumption by the *i*th food-insecure household.

families, and assessing the increase or depletion of food supplies. It assumes that any food that enters households and is not accounted for has been consumed. The alternative technique involves conducting a food consumption recall for each family member or the entire household, and then calculating the calorie content of each food type reported (Maxwell, 1996).

This study used a seven-day recall strategy. The recommended daily calorie intake of 2,100 kcal per person was utilized as the food security line. The women farmers' consumption provided the calories needed by the households. The data were used to determine how much of each food item was consumed over 7 days by women farmers' households. Using the nutritional composition table of regularly consumed foods in Ethiopia, the amounts were translated to kilograms, and the calories were calculated. By dividing the projected total calorie consumption for the home by the number of occupants, per capita calorie intake was obtained.

The household's daily per capita calorie consumption was calculated by dividing the household's total calorie intake by the number of people in the household. Families were considered to be food secure if their daily per capita calorie intake did not fall below 2,100 kcal, and food insecure if it did. The food security situation was binary, with 0 denoting food-insecure families and 1 denoting food-secure households. The study followed the model employed by Babatunde et al. (2007). Accordingly, it is expressed in Equation 1 as follows:

$$Z_i = Y_i / R \quad (1)$$

where,

Z_i = food security status of the *i*th household, which takes values 1 for food-secure households or 0 for food-insecure households;

Y_i = daily per capita calorie of the *i*th household;

R = recommended calorie intake by the number of people in the household (2,100 kcal);

$Z_i = 1$ for $Y_i \geq R$; and

$Z_i = 0$ for $Y_i < R$, all other indices.

Head count method was used to measure food security status of the entire area under study and is expressed in Equation 2 (Babatunde et al. 2007) as:

$$FII = (FIH / TH) \times 100 \quad (2)$$

where,

FII = food insecurity index;

FIH = number of food-insecure households; and

TH = total households under study.

Food insecurity gap measures the depth of food insecurity and is expressed in Equation 3 (Babatunde et al. 2007) as:

$$FIG_i = (TCR_i - TCC_i) / TCR_i \times 100 / 1 \quad (3)$$

where,

FIG_{*i*} = Food Insecurity Gap of the *i*th food-insecure household;

TCR_{*i*} = Total Calorie Requirement for the *i*th food-insecure household;

TCC_{*i*} = Total Calorie Consumption by the *i*th food-insecure household.

Hence, the total food insecurity gap is expressed in Equation 4 (Babatunde et al. 2007) as:

$$TFIG = \sum \{ (TCR_i - TCC_i) / TCR_i \} / FIH \quad (4)$$

Squared food insecurity gap, which indicates the severity of food insecurity among the food-insecure households is given in Equation 5 (Babatunde et al. 2007) as:

$$\text{SFIG} = \sum (\text{FIG}_i)^2 / \text{FIH} \quad (5)$$

4.2 Ordinary least squares multiple regression

The ordinary least squares (OLS) multiple regression model was used to analyze the first and fourth objectives. It estimated the impacts of CTs of UPSNP on financial inclusion options and also the effects of various socioeconomic and institutional factors on food security index of women farmers in the study area, this is in accordance with a study done by Atagher (2013). The generalized form of the model is given as in Equation 6:

$$Y = \alpha + \sum \beta X + e \quad (6)$$

where,

Y = food security index;

α = intercept of equation;

Σ = summation sign;

β = coefficients of the explanatory variables;

X = the vector of explanatory variables in the model; and

e = error term.

4.3 The functional forms of the model

Three functional forms of the OLS model were fitted including linear, semi-log, and double-log. The equation of best fit was selected based on the magnitude of R^2 and the statistical significance of the explanatory variables. The explicit forms of the functions are as follows:

where,

Y = food security index;

X1 = frequency of bank mobile application usage (continuous variable: number of times bank mobile application is used for a transaction);

X2 = ownership of account with commercial banks (continuous variable: number of accounts with commercial banks);

X3 = amount saved in the past 12 months (continuous variable in ETB);

X4 = means of saving (discrete variables: bank, home, and group of friends);

X5 = farm income (continuous variable in ETB);

X6 = professional advice on finance management (continuous variable: number of times received professional advice on finance management);

X7 = transport cost to financial institutions in a month (continuous variable);

X8 = level of savings with bank in the last 12 months (continuous variable);

X9 = proportion of credit utilized (measured in percentages);

X10 = access to insurance policy (dummy variable; Yes = 1, No = 0); and

e = error term.

4.4 Binary logistic regression model

The logistic regression was used to analyze objective (iv) (estimate the determinants of commercialization/food security status among urban women farmers in the study area). The model is specified in Equation 7 (Atagher 2013) as follows:

$$Y = \beta X_i + \epsilon_i \quad (7)$$

where,

ϵ - N (0, 1). Then Y can be observed as an indicator for whether this latent variable is positive;

Y = (Commercialized = 1, Not commercialized = 0);

X = vector of explanatory variables;

β = coefficients; and

ϵ_i = random error.

The model is specified explicitly in Equation 8 (Atagher 2013) as follows:

$$11+11+11+11+11+\dots+ \quad (8)$$

The explanatory variables for women farmers are as follows:

X1 = frequency of bank mobile application usage (continuous variable: number of times the bank mobile application is used for a transaction);

X2 = ownership of account with commercial banks (continuous variable: number of accounts with commercial banks);

X3 = amount saved in the past 12 months (continuous variable: ETB);

X4 = means of saving (discrete variables: bank, home, and group of friends);

X5 = farm income (continuous variable: ETB);

X6 = professional advice on finance management (continuous variable: number of times received professional advice on finance management);

X7 = transport cost to financial institutions in a month (continuous variable: ETB);

X8 = level of savings with bank in the last 12 months (continuous variable: ETB);

X9 = proportion of credit utilized (measured in percentages); and

X10 = access to insurance policy (dummy variable; Yes = 1, No = 0).

4.5 Food security status

Y = food security status (food secure = 1, food insecure = 0);

X = vector of explanatory variables;

β = coefficients; and

ϵ_i = random error.

The model is specified explicitly in Equation 9 (Atagher 2013) as follows:

$$11+11+11+11+11+\dots+ \quad (9)$$

The explanatory variables for women farmers are as follows:

X1 = frequency of bank mobile application usage (continuous variable: number of times the bank mobile application is used for transaction);

X2 = ownership of account with commercial banks (continuous variable: number of accounts with commercial banks);

X3 = amount saved in the past 12 months (continuous variable: ETB);

X4 = means of saving (discrete variables: bank, home, and group of friends);

X5 = farm income (continuous variable: ETB);

X6 = professional advice on finance management (continuous variable: number of times received professional advice on finance management);

X7 = transport cost to financial institutions in a month (continuous variable: ETB);

X8 = level of savings with bank in the last 12 months (continuous variable: ETB);

X9 = proportion of credit utilized (measured in percentages); and

X10 = access to insurance policy (dummy variable; Yes = 1, No = 0).

5 Findings and discussions

5.1 Food security status and financial inclusion factors influencing the food security status of women farmers

5.1.1 Perception toward the contribution of cash transfers of UPSNP for the involvement in urban agriculture as a means of livelihood

As indicated in [Table 2](#), the study achieved a 100% response rate, and out of the 265 study participants, approximately 119 and 100 showed a positive perception or agreement regarding the actual contribution of the cash transfer of safety net program to the involvement of women program beneficiaries in urban agriculture in the study area. This means that for the majority of women participants (about 83%), the urban safety net program, through its financial transfers, could play crucial roles for urban women households in increasing their monthly income as well as to participate in different kinds of urban agriculture such as horticulture and animal-husbandry, as their means of livelihood and generating income. The findings are almost similar among the three study sites. Most of the key informant interviews (KIIs) also confirmed that the financial transfers provided by the urban safety net program are helping beneficiary households, including women, by increasing their monthly income and enhancing their capacity to participate in income-generating activities such as urban agriculture in the city.

Similarly, a study by [Tareke \(2022b\)](#) demonstrated that the financial transfers made by the urban safety net program to low-income households in Addis Ababa city helped increase their income, food expenditure, and intake capacity. Thus, it is easy to understand that the recently started urban safety net program in Addis Ababa city, Ethiopia, through its financial transfers, could play crucial roles not only in increasing the monthly income of urban women households but also the financial ability to participate in different kinds of urban agriculture such as horticulture and animal-husbandry, as their means of livelihood and generating income.

5.1.2 Food security status of urban women households

[Table 1](#) presents the food security index for urban women farmers in the research area. The parameters for the two groups of homes under study are shown in the table along with their corresponding indicators. According to the [USDA \(U.S. Department of Agriculture\) \(2000\)](#) methodology, there were two categories in terms of food security: those who had access to enough food and those who did not. The food-secure groups consume 2,100 kcals or more per person per day, whereas the food-insecure groups, which are further divided into marginally, moderately, and severely food-insecure groups, consume 2,099 kcals or less per person per day, ranging from 1,800 kcals to 1,500 kcals, respectively.

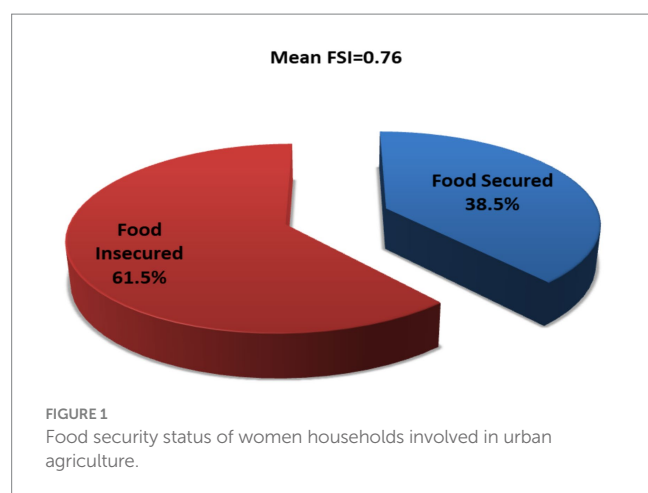
Based on the food security groupings, the frequencies and percentages of women farmers were displayed. The lowest and maximum caloric intake of the women farmers' food-secure and food-insecure groups were displayed ([Table 1](#)). The food insecurity gap was shown, demonstrating the prevalence, depth, and severity of food insecurity in percentages, as well as the average number of calories consumed and the food security score for each group.

5.1.3 Food security status and levels of women households involved in urban agriculture

To enhance the strength of the analysis tests, based on the statistical analysis, any variable with a p -value < 0.05 at 95% CI was declared significantly associated with food insecurity among women household. Model fitness was also assessed using the Hosmer–Lemeshow test, with a p -value > 0.05. As shown in [Figure 1](#), the study assessed the food security status of women farmers in urban agriculture by analyzing food consumption within a 7-day recall period. The data was converted into K/calorie amounts and the number of calories consumed by a single adult equivalent. The required calorie intake for an active and healthy life was determined, with 2,100 kcal a day as a minimum threshold level ([Smith et al., 2017](#)). Therefore, women farmers were classified as having food

TABLE 2 Contribution of cash transfer of the safety net program to the involvement in urban agriculture.

Selected wereda/district	Location in the city	Women farmers (N)	Sample (n)	Levels of agreement with the contribution of the safety net program for women's involvement in urban agriculture					Total
				Strongly agree	Agree	Moderate	Disagree	Strongly disagree	
Wereda 10	Intermediate	745	92	41	33	5	9	4	92
Wereda 13	Outer city	532	88	40	35	4	3	5	87
Wereda 6	Inner city	464	86	38	32	5	5	6	86
Total	-	1,741	266	119	100	14	17	15	265



security if their K/calorie consumption/acquisition was equal to or more than the threshold level, and as having food insecurity otherwise.

As a consequence, out of the 278 urban women households participating in urban agriculture, 107 (38.5%) had access to enough food, which helped them achieve a relatively “food-secure” status. In contrast, 171 (61.5%) did not have access and were classified as being in a “food-insecure” status. The lowest and maximum K/calorie ingested by a single adult woman farmer who was food insecure were 674.6 and 2,082.1, respectively, whereas those of the women farmers who were food secure were 2,192.5 and 5,360.4. As a result, the mean calorie levels for food-secure non-farm families were 3,776.6 Kcal and 1,378 Kcal, respectively. As a consequence, 1,459.9 kcals and 842.5 kcals, respectively, were found to be the standard deviation for households with food insecurity and those with food security. The head count ratio determines the proportion of households with deficits of 2,100 kcal per person per day. The percentage of women farmers who had daily caloric deficits of 2,100 kcal or greater is determined using the head count ratio. According to this finding, the majority (or 61.5%) of women households were food insecure as they were unable to meet their daily energy needs, whereas 38.5% were relatively food secure because they were able to do so on average (see Figure 1).

The food insecurity gap measures the mean depth of food insecurity among food-insecure households. It is the mean proportion by which the food security status of food-insecure households falls below the minimum level of calorie requirement. The results of this study indicated that food-insecure women farmers are 33.0% below the minimum level of calorie requirement, that is, 2,100 kcals.

The squared food insecurity gap measures the severity of food insecurity among food-insecure women farmers. It gives more weight to the average calorie shortfalls of the most food-insecure women farmers. Thus, it measures the squared proportional shortfalls from the minimum level of calorie intake. The drawback of this food insecurity index, according to Shemelis and Daniel (2023), is that it is difficult to understand. However, it can be claimed that in Addis Ababa city, the degree of food insecurity among women farmers is approximately 5.74%. According to the statistical test of significance, urban women involved in urban agriculture, such as horticulture and animal husbandry in the research area, consume substantially different amounts of calories on average (t -value = 3.39; p -value = 0.05).

This result is consistent with that of Ibok et al. (2014), who found that in Cross River State, 52.5% of urban food crop-producing households were food secure, while 47.5% were not. In their study on the impact of urban agriculture on household food insecurity in Ibadan city, Oyo State, Nigeria, Rose et al. (2020) observed that 62.5% of households were food secure while 37.5% were food insecure. Similarly, Idrisa et al. (2008) found that 42.5% of families in the Gwagwalada Area Council of the Federal Capital Territory, Abuja, Nigeria, were food secure, 27.5% were moderately food secure and just 30.0% were non-food secure in their research of the food security status of farmer households.

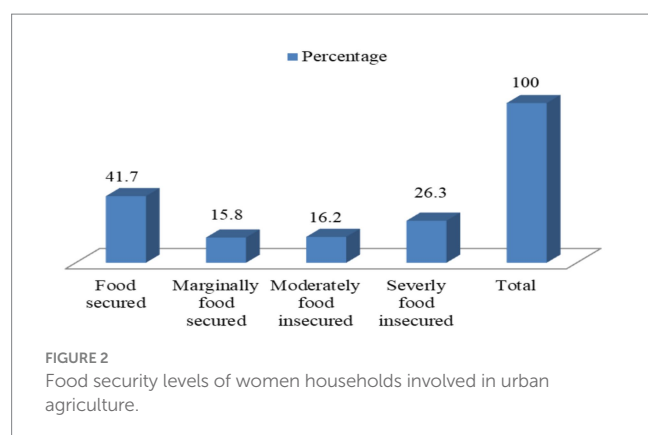
Good household incomes, a high level of education, as well as engagement in activities that diversify sources of revenue are factors that may contribute to the presence of food security among women households. According to FAO (2021), there is a correlation between education level and the likelihood of finding decent work. Thus, it may be inferred that women farmers may have had access to decent occupations, financial services, and various sources of income that would have allowed them to afford the correct kind and amount of food, improving their situation about food security. Adebayo et al. (2012) found a comparable outcome among farmers in both rural and urban areas in Kaduna State, Nigeria.

Figure 2 also illustrates the level of food security experienced by women who are safety net beneficiaries and involved in urban agricultural activities. According to the results, only a small percentage (15.8%) experienced slight food insecurity, 16.2% experienced moderate food insecurity, and 26.3% experienced severe food insecurity. In non-farm homes, the average calorie intake is 3,403.3, compared to 1,690.7 in households where food security is a concern. For women farmers who are either food secure or food insecure, the respective mean food security indices are 1.68 and 0.76. Furthermore, it is worth noting that during the survey, it was also found that the maximum and mean family sizes of women households involved in the safety net program were 3 and 2, respectively, which may have its own implications for the family planning practices and food security status and levels.

5.1.4 Financial inclusion factors influencing the food security index of urban women farmers

The study employed the OLS multiple regression approach to analyze the financial inclusion factors affecting the food security index of women farmers in the study area, as shown in Table 3. The double-log function was chosen due to its high coefficient of multiple determinations, lowest mean squared error, and significant Fisher's statistic value. The coefficient of determination (R^2) showed that 52.4% of the variability in the food security index among women farmers was attributed to the specified explanatory variables, indicating their importance as determinants (Table 3).

The F-statistic value of 20.9 indicates that the data fits the model and that the independent variables are significant explanatory factors for variations in the food security index. The R^2 -value assumes all independent variables affect the model's result, while the adjusted R^2 -value considers only those that significantly affect the model's performance. To balance this, models are compared using different independent variables, as adjusted R^2 . Previous studies (Olayemi, 2012; Adetunji, 2015; Beyene and Muche, 2010) have shown that adjusted R^2 increases as new variables improve the model more than expected by chance.



The Durbin–Watson (DW) statistic is used as a test for checking autocorrelation in the residuals of a statistical regression analysis. If autocorrelation exists, it underestimates the standard error and may lead us to believe that predictors are significant when, in reality, they are not. The value always lies between 0 and 4. If the DW statistic is substantially less than 2, there is evidence of positive serial correlation. As a rough rule of thumb, if DW is less than 1.0, there may be cause for alarm.

The DW statistic in the model was 1.49, indicating positive autocorrelation, which follows Cameron and Trivedi's rule of thumb. The Akaike/Schwartz or Bayesian Information Criterion/Hannan-Quinn information criterion, which considers the lower values of these criteria, suggests that the model is the best to adopt. The Akaike/Schwartz or Bayesian Information Criterion/Hannan-Quinn information criterion values of 0.299297, 0.434015, and 0.353418 (<2) are the lowest among the other functional forms, indicating that this form is most suitable for this case.

The empirical results show that the coefficient of ownership of account with commercial banks (0.150967), amount saved in the past 12 months (0.191881), farm income (0.134985) and proportion of credit utilized for actual collection intention (0.391406) has a significant positive effect at various significant levels on food security index of urban safety net beneficiary women farmers in the study area.

The coefficient of ownership of accounts with commercial banks (0.150967) was positive and significant at a 1.0% alpha level, implying that the probability of women farmers' food security increased with a rise in the level of ownership of accounts with commercial banks by 0.150967. This finding aligns with the prior expectation. Having a bank account provides a secure place to store and manage one's money. Instead of keeping cash at home, which can be susceptible to theft or loss, women farmers can deposit their funds in a bank account. This reduces the risk of financial loss and ensures that the money earmarked for food expenses is protected. Also, bank accounts offer a convenient means for individuals to save money. By regularly depositing a portion of their income, individuals can build up savings over time. This can serve as a financial safety net during emergencies or periods of income fluctuations, ensuring that there are sufficient funds to purchase food even in challenging times. Similar results were obtained by the following studies (Olayemi, 2012; Adetunji, 2015; Beyene and Muche, 2010).

Bank accounts provide access to a range of financial services that can support food security. For example, individuals can use their bank accounts to receive wages, government benefits, or remittances,

ensuring a steady flow of income for purchasing food and maintaining food security. Bank accounts also enable individuals to make convenient and secure payments for groceries and other food-related expenses, reducing the risk of loss or theft associated with carrying cash. According to Carbo et al. (2007), owning a bank account can improve access to credit facilities such as loans or overdrafts. This can be particularly beneficial for small-scale farmers or individuals engaged in food production activities. Access to credit can help them invest in agricultural inputs, equipment, or infrastructure, ultimately increasing their productivity and ensuring a stable food supply. Furthermore, according to Clement (2018) and Cook et al. (2004), bank accounts enable individuals to track their income and expenses, facilitating better financial planning and budgeting. By having a clear understanding of their financial situation, women farmers can allocate funds appropriately for food expenses, ensuring that they prioritize their nutritional needs.

In conformity, ownership of a bank account can contribute to financial empowerment by providing individuals with a sense of control over their finances. This empowerment can positively impact decision-making related to food choices, enabling individuals to make informed decisions about purchasing nutritious and diverse food items (Dereje, 2021).

It is essential to acknowledge that while bank accounts can contribute to enhancing food security, several barriers to access exist, including banking infrastructure, limited financial literacy, and affordability issues. Efforts to promote financial inclusion, enhance financial education, and address these barriers are crucial in ensuring that the benefits of bank account ownership translate into improved food security for women farmers in urban areas.

The coefficient of the amount saved in the past 12 months (0.191881) had a positive sign and was statistically significant at a 1.0% risk level. This result indicates that a unit increase in the amount of money saved by women farmers yearly increases food security by 0.191881. By saving money in banks, women farmers can build emergency funds that can be used during times of financial hardship or unexpected expenses. This can help protect against food insecurity during times of crisis, such as job loss or medical emergencies, by providing a safety net to cover basic needs like food.

According to Béné and Devereux (2023), saving money in banks can provide women farmers with the necessary capital to invest in agricultural activities. These women involved in urban agriculture, for example, can use their savings to purchase seeds, fertilizers, equipment, or livestock, which can increase their agricultural productivity and ultimately improve their food production and income.

This, in turn, can enhance food security not only for themselves but also for the larger community. Maintaining a good savings history and having a bank account can enhance an individual's creditworthiness. This can make it easier for them to access credit from banks or financial institutions, which can be used for agricultural purposes or to start income-generating activities related to food production or processing. Access to credit can provide farmers with the necessary resources to expand their operations, invest in technology, or improve their farming practices, thus increasing their food production capacity. A higher amount saved in the bank can also contribute to overall financial stability. When women farmers have a financial cushion, they are less likely to face sudden financial crises or resort to harmful coping mechanisms, such as selling productive assets or reducing food consumption. By maintaining financial

TABLE 3 OLS multiple regression of financial inclusion factors affecting food security status of women farmers.

Variable	Linear				Semi-log				Double-log+			
	Coefficient	SE t-Statistic		Prob.	Coefficient	SE t-Statistic		Prob.	Coefficient	SE t-Statistic		Prob.
Frequency of bank mobile application usage	-7.735701	11.03944	-0.700733	0.4841	-4.973373	9.585849	-0.518824	0.6043	-0.086610	0.107049	-0.809062	0.4192
Ownership of account with commercial banks	17.20355	5.670745	0.033737	0.0027	6.929444	5.044337	1.373708	0.1707	0.150967***	0.056332	2.679931	0.0078
Amount saved in the past 12 months	6.83E-06	1.63E-05 0.420332		0.6746	7.226349**	2.880535	2.508683	0.0127	0.191881***	0.032168	5.964933	0.0000
Means of saving	2.041455	4.163872	0.490278	0.6244	1.054111	3.731810	0.282466	0.7778	0.044665	0.041675	1.071754	0.2848
Farm income	0.000110	3.81E-05 0.881064		0.0043	3.487740	2.915186	1.196404	0.2326	0.134985***	0.032555	4.146343	0.0000
Professional advice on finance management	24.90749***	7.696566	3.236182	0.0014	-0.460487	7.143914	-0.064459	0.9487	0.093744	0.079779	1.175046	0.2411
Transport cost to financial institutions in a month	4.918240	3.845080	1.279100	0.2020	1.293281	3.367924	0.383999	0.7013	0.019730	0.037611	0.524572	0.6003
Level of savings with bank in the last 12 months	10.08715**	4.219166	2.390791	0.0175	3.793797	3.689859	1.028169	0.3048	0.011513	0.041206	0.279399	0.7802
Proportion of credit utilized	78.63354*	8.765070	0.971239	0.0000	29.08610***	9.325642	3.118938	0.0020	0.391406***	0.104144	3.758335	0.0002
Access to Insurance Policy	-7.399261	7.566773	-0.977862 0.3291		-14.60948**	6.500606	-2.247402 0.0255		0.197159	0.072595	0.715867	0.0071
R-Squared	0.320659	Mean dependent var		64.38489	0.424576	Mean dependent var		64.38489	0.523979	Mean dependent var		1.755146
Adjusted R-squared	0.307088	SD dependent var		25.21347	0.400419	SD dependent var		25.21347	0.467010	SD dependent var		0.253924
S.E. of regression	29.48023	Akaike info criterion		9.642186	25.59408	Akaike info criterion		9.359468	0.285820	Akaike info criterion		0.369963
F-statistic	22.2485.5	Schwarz criterion		9.776904	19.23042	Schwarz criterion		9.494186	20.91348	Schwarz criterion		0.504681
Significance	0.000000	Hannan–Quinn criterion		9.696307	0.000000	Hannan–Quinn criterion 9.413590			0.000000	Hannan–Quinn criterion		0.424084
Log likelihood	-1272.411				-1234.809				-39.20504			
Durbin–Watson stat	1.486287				1.501429				1.493763			

Source: Tareke (2023). SE, standard error; F-statistic, Fisher's statistic; SD, standard deviation; Prob., probability. In the model output of Table 3, star/s (*) next to coefficients indicate the statistical significance of those coefficients. The number of stars corresponds to the level of significance, with more stars indicating higher significance. Typically, coefficients with three stars (***) indicates highest significance level of all coefficients, while coefficients with two stars (**) means higher significance than coefficients with one star (*).

stability, individuals can ensure a consistent and reliable food supply for themselves and their families. This finding aligns with [Fakayode et al. \(2009\)](#), who found that households primarily save to maintain their food security.

The study found a significant positive effect of farm income (with a coefficient of 0.134985) on the food security of women farmers. This finding was consistent with previous expectations, suggesting that increased income, possibly due to higher yields, better credit access, or financial inclusion, can accelerate food security. High farm income can also directly and indirectly contribute to food security, as it encourages women farmers to invest in their agricultural activities.

They can purchase improved seeds, quality fertilizers, modern machinery, and advanced farming techniques. These investments can enhance agricultural productivity, leading to increased food production. With higher farm income, women farmers can also afford to adopt sustainable farming practices and invest in technologies that improve efficiency and reduce post-harvest losses. This, in turn, can contribute to a more secure food supply.

Furthermore, high farm income allows urban women farmers to have better access to crucial agricultural inputs and resources. They can afford to purchase high-quality inputs, such as fertilizers, pesticides, and irrigation systems, which can improve crop yields and overall productivity. Additionally, women households with higher incomes can access credit and financial services more easily, enabling them to invest in necessary resources for their farming operations. Access to inputs and resources can result in increased food production and improved food security.

In the view of [Fayeye and Ola \(2017\)](#), women households have the opportunity to diversify their agricultural activities with a higher income. They can allocate resources to grow a variety of crops or engage in livestock rearing, aquaculture, or other income-generating activities. Diversification can help mitigate the risks associated with crop failures, market fluctuations, and the impacts of climate change. By having multiple sources of income, women farmers can better sustain themselves during challenging times, thereby reducing their vulnerability to food insecurity.

The result conforms with [Feleke et al. \(2019\)](#), who found that higher farm income can lead to improved living standards for farmers and their families. It can enable them to meet their basic needs, including access to nutritious food, healthcare, and education. When women farmers have better access to essential resources, they can provide a more stable and healthier environment for their families.

This, in turn, contributes to improved overall food security within the household. A similar argument was made by [Gebre \(2012\)](#), who believed that increased farm income can stimulate local economies, particularly in urban areas where agriculture is a significant sector. A similar study by [Tareke \(2022a\)](#) also found that increasing the income of urban low-income households can enhance their food purchasing power, savings, and probability of participating in income-generating activities. When women farmers are involved in urban agriculture, they tend to have higher incomes and higher purchasing power, enabling them to buy goods and services from local businesses. This can create a positive economic cycle, leading to job creation, increased incomes for non-agricultural workers, and improved access to food for the local community.

Strong local food systems contribute to food security by reducing dependence on external food sources and promoting self-sufficiency. It is important to note that while high farm income can have positive

impacts on food security, it should be accompanied by equitable distribution of resources, access to markets, and supportive policies to ensure that the benefits reach all stakeholders in the agricultural sector. Similar results have also been obtained by [Gitu \(2020\)](#), [Abdullahi \(2021\)](#), and [Hadebe and Mpofu \(2019\)](#).

The study found that increasing the proportion of credit used for its intended purpose (0.391406) is positive and statistically significant at a 1% probability level, leading to a corresponding increase in the food security of urban farmers by 0.391406. This aligns with *a priori* expectations and can be particularly beneficial for women farmers who obtain credit specifically for agricultural purposes, enabling them to invest in their farming operations.

This can include purchasing quality seeds, fertilizers, machinery, irrigation systems, and other inputs necessary for increasing agricultural productivity. By utilizing credit for its intended purpose, urban women farmers can enhance their production capacity, improve crop yields, and ultimately contribute to a more secure food supply. In the words of [Hanson et al. \(2021\)](#), credit utilized for its intended purpose by farmers can also be used to strengthen the agricultural value chain, which encompasses all the activities involved in bringing agricultural products from the farm to the consumer.

Women farmers can utilize credit to establish or improve post-harvest infrastructure, such as storage facilities, processing units, and transportation systems. By investing in value chain development, farmers can reduce post-harvest losses, improve the quality of their produce, and ensure timely delivery to markets. This can lead to increased income, improved market access, and enhanced food security. Similar results have also been obtained by [Idrisa et al. \(2008\)](#) and [Irohibe and Agwu \(2014\)](#).

5.2 How have CTs of UPSNP improved the food security of low-income urban people, primarily women?

The preceding study ([Tareke, 2022b](#)) confirmed that the food security of households improved primarily after receiving CTs from the urban safety net program, as the majority of households' income is recently spent on food expenditures and intake in many developing countries, including Ethiopia. The key components of household food security, including food access, expenditure, and diet intake capacities of beneficiaries in post-CT years, were significantly improved.

In addition to the monthly CTs from the safety net program in urban areas, supplementary income could be obtained as a result of relatively better saving habits; participation in other income-generating activities, such as urban agriculture; access to financial inclusion options, such as agricultural credit provisions, bank account ownership and farm income; and relatively better family planning practices in this particular city, which contributed to the reducing trend of family size and dependency ratio. In this city, as a result of the financial benefits received from the safety net program, the involvement of women households in urban agriculture, including horticulture and animal husbandry, contributed not only to an additional source of income but also as a source of daily diets for their families.

In line with recent studies such as [Borku et al. \(2024a,b,c,d\)](#), [Tareke \(2022a\)](#), and [Bastagli et al. \(2019\)](#), the statistical and qualitative results of the current study indicated that these factors could

contribute to the improvement in households' food purchasing power, access and daily diet intake, which ultimately resulted in that relatively high proportion of households' food security levels compared to other cities and the scenario or situation before 2024.

Unlike the food insecurity levels indicated by other studies conducted before (for example, 77.1% by [Derso et al., 2021](#), and 75% by [Birhane et al., 2014](#)), the 61.5% food insecurity level (or 38.5% of the food-secure level) found in the current study in 2024 is either relatively higher or similar and consistent with other recent studies and reports. For example, [Gebre \(2012\)](#) showed that the food insecurity level was 58.1% in the city. Moreover, in 2018, the magnitude of food insecurity among populations in Eastern Africa was 62.7%. As a consequence of food insecurity in this region, nearly one-third of the population (30.8%) was undernourished due to a lack of sufficient calories ([FAO, WFP, UNICEF, 2019](#)).

It can be attributed to the government's collaboration with the World Food Program (WFP) and development partners who have worked together to improve food security and stabilize assets for 10 million Ethiopian people through the UPSNP.

It is essential to note that the somewhat enhanced food security levels observed in the current study are specific to Safety Net Program (UPSNP) beneficiary households, excluding non-beneficiary households, and do not reflect the food security level of households in general. In addition, the beneficial households in this study are exclusively women, who have relatively better performance in the proper use of the monthly CTs, participation in income-generating activities such as urban agriculture, saving, food purchasing capacity, and others, compared to men's households ([Tareke, 2022b](#); [Bastagli et al., 2019](#); [Hagen-Zanker et al., 2017](#); [Pega et al., 2015](#)).

According to [Yoong et al. \(2012\)](#), [AIR \(2014\)](#), [IEG \(2014\)](#), and [Rebecca et al. \(2013\)](#), when females receive financial benefits or cash transfers, consumption decisions are often found to be more focused on children and investing in different types of assets compared to males. Providing economic benefits to females makes a difference. It significantly enhances females' empowerment and decision-making power independently and jointly with their husbands in urban areas, which can at long last contribute to the enhancement of food security levels among women's households ([Yoong et al., 2012](#); [Hagen-Zanker et al., 2017](#); [Haushofer and Shapiro, 2013](#); [IEG, 2014](#)).

Being consistent with the evidence forwarded by prior studies ([Borku et al., 2024c](#); [Khan et al., 2021](#); [Prymostka et al., 2020](#); [Badmus, 2020](#)), the findings confirmed that in addition to the monthly financial transfers of UPSNP received by beneficial women, the various financial inclusion options played significant roles in the involvement of women households in income-generating activities such as urban agriculture as well as the reduction of households' food insecurity levels in the last few years, chiefly in Addis Ababa city, Ethiopia.

6 Conclusion

Worldwide, reducing urban poverty and food insecurity through inclusive, effective, and sustainable interventions by governments and actors has been widely advocated. Accordingly, the urban safety net program has been implemented primarily in developing regions to reduce poverty, food insecurity, and income inequality among urban populations, particularly women. The issue of the relevance and contribution of cash transfers of urban safety nets to support income

improvement, financial services, and engagement in private business, such as urban agriculture and food security for women's households, is relatively unexplored in developing economies, including Ethiopia. To inform urban planning and policy, the research aimed to empirically investigate the causal link between cash transfers, financial inclusion options, involvement in urban agriculture, income enhancement, and food security, primarily among women households in Ethiopia. A review of qualitative and quantitative concepts, along with any related analytical models, provided the basis for designing, implementing, and analyzing the empirical part of the inquiry. The research expanded our knowledge of this topic and compared it to findings from the literature based on the outcomes of the qualitative and quantitative surveys, as well as relevant statistical inferential analysis models such as OLS and logistic regression. The key findings of the current study largely confirm the hypotheses and conclusions of the preceding study ([Tareke, 2022a](#)) on this topic. In this subsequent research, it is clearly observed that the recently initiated urban safety net program, through its financial transfers, could play a crucial role for urban women households, not only increasing their monthly income but also enabling them to participate in urban agriculture, such as horticulture and animal husbandry, as a means of livelihood and income generation. However, through its financial transfers, the contribution of the urban safety net program to the food security status and level of its target groups, primarily urban women households, is not satisfactory. According to the food security index, a slightly higher percentage of people than usual experienced food insecurity. In the study area, the mean calorie consumption of women participating in various urban agriculture activities differed substantially.

The study implies that the proportion of credit used for actual collection purposes, the amount saved in the past 12 months, farm income, and the coefficient of account ownership with commercial banks all had significant positive effects on the food security index of women involved in urban agriculture in the study area, while the amount saved in the past 12 months, professional advice on financial management, and the proportion of credit utilized had significant negative effects at various significant levels.

Additionally, having an account with a commercial bank and the frequency with which one uses their mobile banking applications both had a significant impact on one's degree of food security. The study found that the majority of urban farmers were food insecure. There needs to be soft loan provisions, grants, and incentives provided by the government, in addition to the financial inclusion policy, to help urban women involved in urban agriculture out of food insecurity.

The theoretical and practical implications of these findings are profound, particularly for the urban safety net, financial services, job creation, and food security policy in developing economies, using a relevant model. They underscore the urgent need for urban planners, policymakers, and decision-makers to consider the following issues: To reach the majority of food-insecure urban women households in the research region, the government should expand its urban safety net program to include livelihood empowerment and school feeding. The next step is to increase family planning education and awareness, as a larger reliance rate is anticipated to aggravate the food security situation for women farmers. Urban women, particularly those involved in the safety net program and urban agriculture, should be made aware of the need to have as many children as they can easily care for.

The study informs that due to cash transfers of the urban safety net program, women households involved in urban agriculture enjoyed

financial inclusion components, but were still food insecure. The study also suggests that if the government and stakeholders offer work or business opportunities to people, primarily women, they will choose to work because most people are unaware that a business can make more money than a salary. This is because low-income individuals often remain in the low-income bracket, as they lack the training to recognize entrepreneurial opportunities. Entrepreneurial education and training should be prioritized because they help women to work for themselves, generating income and profit, rather than working for a salary or for others. Accordingly, profits can make women a fortune, but wages or salaries can provide a more stable support for women.

Moreover, the study contributes to the existing literature by highlighting the relevance of mixed design, OLS, and binary regression models in better understanding cash transfers of urban safety net programs and financial service options, as well as their implications for the food security of urban people, including women. Thus, the existing urban safety net programs, urban planning, and development policy need to be pro-low-income people, inclusive, gender-sensitive, and responsive through entrepreneurial-oriented approaches rather than direct aid. The study suggests revisiting financial inclusion options and considering soft loan provisions, grants, agricultural inputs, market links, training, incentives, and increasing the CTs amount to bring urban women households out of food insecurity by improving their nutrition and employment opportunities through urban agriculture and other businesses.

Although the sampling design could help select proportional and representative households from inner, intermediate, and outer-city locations or districts, and it is aligned with the robust analysis tools and findings, the study is not without limitations. The limitations of the current study relate to the fact that it focused on women households and was also confined to three districts/weredas of the city, due to financial, time, and other constraints. It would have been, however, better to include a certain number of men beneficiary households for comparative analysis. More importantly, a better generalization would have been possible had the data been collected from a higher number of districts or weredas in the city.

Despite some of the limitations mentioned above, the present study is capable of providing insights and making a contribution to the body of knowledge on the relationship between cash transfers of urban safety net programs, financial service options, and their implications on involvement in urban agriculture and food security in urban settings.

In conclusion, to make the safety net program and urban agriculture goals more effective, it is essential to carry out further research considering the gaps and to organize Business-to-Business Networking events among financial service providers to create long-term partnerships to improve financial services to low-income urban communities, particularly safety net program women households and agricultural micro, small, and medium enterprises. In addition to scaling up & expanding the achievements of this urban safety net program to reach more low-income women households, the provision of health and family planning services as well as and innovative agricultural practices such as Agri-tech, precision, regenerative, sustainable and climate-smart agriculture can make significant difference in the enhancement of urban agriculture and food security. Furthermore, as the safety net program's cash transfer is a short-term solution, in the long run, other reliable privately owned businesses or shares, and access to land for production and product sale, will serve as a catalyst for life expectancy and well-being after or before the retirement of women households. These initiatives will

assist urban women households in achieving the threshold to graduate from the UPSNP. Improved access to financial services plays a crucial role in achieving the goals of UPSNP and SDGs, including food security and sustainable urban development, primarily in developing regions.

Data availability statement

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

Ethics statement

Ethical review and approval was not required for the study on human participants in accordance with the local legislation and institutional requirements. Written informed consent from the [patients/ participants OR patients/participants legal guardian/next of kin] was not required to participate in this study in accordance with the national legislation and the institutional requirements.

Author contributions

KT: Conceptualization, Data curation, Formal analysis, Funding acquisition, Investigation, Methodology, Project administration, Resources, Software, Supervision, Validation, Visualization, Writing – original draft, Writing – review & editing.

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

Generative AI statement

The author declares that no Gen AI was used in the creation of this manuscript.

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References

- Abdullahi, G., (2021). Food insecurity and coping strategies of agro-pastoral household in Awbare Woreda, Somali region, Ethiopia. A M.Sc. Thesis presented to the school of graduate student of Alemaya university. 93p
- Adebayo, C. O., Sanni, S. A., and Baiyegunhi, L. J. S. (2012). Microcredit scheme impact and food security status of beneficiaries in Kaduna state, Nigeria: a propensity score matching approach. *Afric J Agric Res* 37, 5181–5197. doi: 10.5897/AJAR12.475
- Adetunji, M. O. (2015). Analysis of food security status of fruit and vegetable marketers in Ibadan north L. G. Area, Oyo state, Nigeria. *J. Emerg. Trends Econ. Manag. Sci.* 6, 252–257.
- AIR (2014). *American Institutes for Research. Zambia's child Grant program: 36-month impact report*. Washington, DC: American Institutes for Research.
- Amoah, A., Korle, K., and Asiamah, R. K. (2020). Mobile money as a financial inclusion instrument: what are the determinants? *Int. J. Soc. Econ.* 47, 1283–1297. doi: 10.1108/IJSE-05-2020-0271
- Amurtiya, M., Yuniyus, D. G., Mark, P., and Zubaira, E. A. (2018). *Analysis of rural farm households' access to formal agricultural credit in Yola south local government area*. Adamawa State, Nigeria: Acta Universitatis Agriculturae et Silviculturae Mendelianae Brunensis.
- Anna, M. (2013). Social protection and resilient food systems: The role of public works and resilient food systems. London, UK: Annual Report, Overseas Development Institute.
- Anthonia, T. O. (2016). Financial inclusion and inclusive growth in Nigeria. In: *Conference paper*.
- Arnold, C. T., and Conway, G. M. (2011). "Cash transfers: literature review," in Policy division, DFID.
- Atagher, M. M. (2013). *Effects of Benue ADP's cassava production technologies on the productivity and incomes of women farmers in Benue state*. Nigeria: Department of Agricultural Economics, University of Nigeria, 2013.
- Attanasio, O., Battistin, E., Fitzsimons, A., and Mesnard, V.-H. (2005). *How effective are conditional cash transfers? Evidence from Colombia. IFS briefing note*. London, UK: Institute for Fiscal Studies.
- Babatunde, R. O., Omotesho, O. A., and Sholoton, A. (2007). Socio-economic characteristics and food security status of farming households in Kwara state, north Central Nigeria. *Pak. J. Nutr.* 6, 49–58. doi: 10.3923/pjn.2007.49.58
- Badmus, O. (2020). Gender gap and credit use in smallholder agriculture in Nigeria. Available online at: <https://ideas.repec.org/a/bjc/journal/v7y2020i9p355-362.html> (Accessed 25 July, 2024).
- Bastagli, F., Hagen-Zanker, J., Harman, L., Barca, V., Sturge, G., and Schmidt, T. (2019). The impact of cash transfers: a review of the evidence from low- and middle-income countries. *J. Soc. Policy* 48, 569–594. doi: 10.1017/S0047279418000715
- Baye, K., Retta, N., and Abuye, C. (2014). Comparison of the effects of conditional food and cash transfers of the Ethiopian productive safety net program on household food security and dietary diversity in the face of rising food prices: ways forward for a more nutrition-sensitive program. *Food Nutr. Bull.* 35, 289–295. doi: 10.1177/156482651403500301
- Béné, C., and Devereux, S. (2023). "Resilience, food security and food systems: setting the scene" in *Palgrave studies in agricultural economics and food policy*, Eds. C. B. Barrett, Cornell University, Ithaca, NY, USA and palgrave macmillan, Springer Nature Gewerbestrasse, Cham, Switzerland AG. 1–29.
- Beyene, F., and Muche, M. (2010). Determinants of food security among rural households of Central Ethiopia: an empirical analysis. *Zeitschrift Für Ausländische Landwirtschaft* 49, 299–318. doi: 10.22004/ag.econ.155555
- Birhane, T., Shiferaw, S., Hagos, S., and Mohindra, K. S. (2014). Urban food insecurity in the context of high food prices: a community based cross sectional study in Addis Ababa, Ethiopia. *BMC Public Health* 14:680. doi: 10.1186/1471-2458-14-680
- Borku, A. W., Utallo, A. U., and Tora, T. T. (2024a). The level of food insecurity among urban households in southern Ethiopia: a multi-index-based assessment. *J Agriculture Food Res* 15:101019. doi: 10.1016/j.jafr.2024.101019
- Borku, A. W., Utallo, A. U., and Tora, T. T. (2024b). The strategies pursued by urban households to cope with food insecurity: insights from selected towns in southern Ethiopia. *Am. J. Hum. Biol.* 36:e24135. doi: 10.1002/ajhb.24135
- Borku, A. W., Utallo, A. U., and Tora, T. T. (2024c). Determinants of urban household vulnerability to food insecurity in southern Ethiopia. *Discov. Food* 4:110. doi: 10.1007/s44187-024-00110-x
- Borku, A. W., Utallo, A. U., and Tora, T. T. (2024d). Contributions of urban productive safety net program to enhancing food security and livelihood diversification: an in-depth analysis of household-level perceptions among urban populations in Ethiopia. *Comput. Urban Sci.* 4:1497. doi: 10.1007/s43762-024-00149-7
- Burchi, F., and Strupat, C. (2016). The impact of cash transfers on food security in sub-Saharan Africa: evidence, design, and implementation. In: *DIE Briefing Paper*.
- Camilla, A., Alemu, M., and Jesper, S. (2011). Impacts of the productive safety net program in Ethiopia on livestock and tree holdings of rural households. *J. Develop. Econ.* 94, 119–126. doi: 10.1016/j.jdeveco.2009.12.002
- Carbo, S., Gardener, E. P. M., and Molyneux, P. (2007). Financial exclusion in Europe. *Public Money Manage* 27, 21–27. doi: 10.1111/j.1467-9302.2007.00551.x
- Clement, A. C. (2018). *Assessment of food security status among rural farming households in Guma local government area of Benue state*. Economic Policy Research Department Nigerian Institute of Social and Economic Research (NISER): Nigeria.
- Cook, J. T., Frank, D. A., Meyers, A. F., Berkowitz, C., Black, M. M., Casey, P. H., et al. (2004). Food insecurity is associated with adverse health outcomes among human infants and toddlers. *J Nutr.* 134, 1432–1438. doi: 10.1093/jn/134.6.1432
- CSA and ICF International (2015). *Ethiopia demographic and health survey*. Addis Ababa, Ethiopia, and Calverton, MD: Central statistical agency and ICF International, 430.
- Dar, A. B., and Ahmed, F. (2020). Financial inclusion determinants and impediments in India: insights from the global financial inclusion index. *J Fin Econ Policy* 13:391–408. doi: 10.1108/JFEP-11-2019-0227
- Demircuc-kunt, A., Klapper, L., Singer, D., Ansar, S., and Hess, J. (2018). *The global Findex database 2017: Measuring financial inclusion and the Fintech revolution*. Washington DC: World Bank.
- Dereje, F. (2021). Contributions of urban agriculture to household food security: a case study in Kirkus sub city, Addis Ababa, Ethiopia. *Int J Urban Sustain Dev* 13, 125–138.
- Derso, A., Bizuneh, H., Keleb, A., Ademas, A., and Adane, M. (2021). Food insecurity status and determinants among urban productive safety net program beneficiary households in Addis Ababa, Ethiopia. *PLoS One* 16:e0256634. doi: 10.1371/journal.pone.0256634
- Development Initiatives (2017). *Global nutrition report 2017: Nourishing the SDGs*. Bristol, UK: Development Initiatives.
- Devereux, S., Sabates-Wheeler, R., Tefera, M., and Taye, H. (2006). *Ethiopia's productive safety net Programme (PSNP): Trends in PSNP transfers within targeted households*. Sussex, UK and Addis Ababa, Ethiopia: Institute of Development Studies and Indak International Pvt LC.
- Etim, I. J., Eyo, O. E., and Enimu, S. (2017). Analysis of small-scale farmers' access to formal financial services in Cross River state, Nigeria. *Donnish J Agric Res* 4, 009–014.
- Fakayode, S. B., Rahji, M. A. Y., Oni, O. A., and Adeyemi, M. O. (2009). An assessment of food security status of farm households in Nigeria: a USDA approach. *Soc Sci* 4, 24–29.
- FAO (2017). Social protection framework; promoting rural development for all. Rome: food and agriculture Organization of the United Nations 2017. Available online at: <http://www.fao.org/3/i7016e/i7016e.pdf> (Accessed December 26, 2023).
- FAO (2021). *The millennium development goals: The road ahead*. New York, United Nations: FAO.
- FAO, WFP, UNICEF (2019). *The state of food security and nutrition in the world. Safeguarding against economic slowdowns and downturns*. Rome: Food and Agriculture Organization.
- Fayeye, T. R., and Ola, D. J. (2017). Strategies for food security and health Africa. *World J Agric Sci* 3, 808–814.
- FDRE (2016). *Building an integrated safety net system for the Most vulnerable women and children in rural and urban Ethiopia*. Addis Ababa, Ethiopia: FDRE.
- Feleke, S. T., Kilmer, R. L., and Gladwin, C. H. (2019). Determinants of food security in southern Ethiopia at the household level. *Agric. Econ.* 33, 351–363. doi: 10.1111/j.1574-0864.2005.00074.x
- Gebre, G. G. (2012). Determinants of food insecurity among households in Addis Ababa City, Ethiopia. *Interdiscip. Descr. Complex Syst.* 10, 159–173. doi: 10.7906/indecs.10.2.9
- Gebrehiwot, K. G., and Makina, D. (2019). Macroeconomic Determinants of Financial Inclusion: Evidence Using Dynamic Panel Data Analysis In D. Makina (Ed.), *Extending financial inclusion in Africa* (Massachusetts, USA: Academic Press. Elsevier), 167–191. doi: 10.1016/B978-0-12-814164-9.00008-6
- Gilligan, D. O. (2013). Cash vs. food: measuring the effectiveness of food assistance (blog). Available online at: <http://www.foodsecurityportal.org/cash-vs-food-measuring-effectiveness-food-assistance> (Accessed December 12, 2019).
- Gilligan, D. O., Hoddinott, J., and Taffesse, A. S. (2008). *An analysis of Ethiopia's safety net program and its linkages*. Washington, DC: International Food Policy Research Institute.
- Gitu, K. (2020). *Agricultural development and food security in Kenya: Building a case for more support*. Nairobi: FAO.
- Government of Ethiopia (GoE) (2016). Government of Ethiopia. Productive safety net program (PSNP) Phase IV. Program Implementation Manual. Addis Ababa, Ethiopia: Ministry of Agriculture.

- Hadebe, L. B., and Mpofu, J. (2019). Empowering women through improved food security in urban centers. A gender survey in Bulawayo urban agriculture. *Afric Educ Res J.* 1, 18–32. Available at: https://www.netjournals.org/z_AERJ_13_034.html (Accessed June 13, 2024).
- Hagen-Zanker, J., Pellerano, L., Bastagli, F., Harman, L., Barca, V., Sturge, G., et al. (2017). The impact of cash transfers on women and girls. Education 42, Available online at: <http://www.cashlearning.org/downloads/11374-odi.pdf> (Accessed September 18, 2021).
- Hanson, K., Sobal, J., and Frongillo, E. (2021). *Gender and mental status clarify association between food insecurity and body weight*. Ithaca: Division of Nutritional Sciences, Cornell University and Department of Health Promotion Education, and Behaviour, University of South Carolina.
- Haushofer, J., and Shapiro, J. (2013). Household response to income changes: evidence from an unconditional cash transfer program in Kenya. Massachusetts Inst. Technol. 24, 1–57. Available online at: <https://search.issuelab.org/resource/household-response-to-income-changes-evidence-from-anunconditional-cashtransfer-program-in-kenya.html> (Accessed February 17, 2020).
- HLPE (2012). *Social protection for food security: A report by the high-level panel of experts on food security and nutrition of the committee on world food security*. Rome: HLPE.
- Honorati, M., Gentilini, U., and Yemtsov, R. (2015). *The state of social safety nets. Sex to Informe: Proyecto PRAF/BID Fase II: ImpactoIntermedio*. Washington, DC: International Food Policy Research Institute.
- Ibok, O. W., Bassey, N. E., Ataire, E. A., and Obot, O. J. (2014). Food Security Determinants among Urban Food Crop Farming Households in Cross River State, Nigeria. *Asian Journal of Agricultural Extension Economics* \u0026amp; Sociology, 3, 76–90. doi: 10.9734/ajaees/2014/6560
- Idrisa, Y., Gwary, M., and Shehu, H. (2008). *Analysis of food security status among farming households in Jere Local Government of Borno State, Nigeria*. Agro-Science. doi: 10.4314/as.v7i3.45552
- IEG (2014). *Independent evaluation group. Evidence and lessons learned from impact evaluations on social safety nets*. Washington, DC: World Bank.
- Irohabe, I., and Agwu, A. (2014). Assessment of Food Security Situation among Farming Households in Rural Areas of Kano State, Nigeria. *J. Cent. Eur. Agric.*, 13, 94–107. doi: 10.5513/jcea01/15.1.1418
- Kaur, S., and Kapuria, C. (2020). Determinants of financial inclusion in rural India: does gender matter? *Int. J. Soc. Econ.* 47, 747–767. doi: 10.1108/ijse-07-2019-0439
- Khan, Y., Daraz, U., and Bojnec, Š. (2023). Enhancing food security and nutrition through social safety nets: a pathway to sustainable development. *Sustain. For.* 15:14347. doi: 10.3390/su151914347
- Khan, Y., Shah, M., and Asadullah, N. (2021). Exploring household food security through a sociocultural perspective: an associational approach of district Torgar. *Glob Sociol Rev* 6, 59–68. doi: 10.31703/gsr.2021(vi-ii).08
- Khan, Y., Shah, M., Ud-din, F., Ullah, Z., and Rehan, S. (2018). Familial impediments to women political status in Pukhtun society. *Anthropology* 6:208. doi: 10.4172/2332-0915.1000208
- Louis, L., and Chartier, F. (2017). Financial inclusion in South Africa: an integrated framework for financial inclusion of vulnerable communities in South Africa's regulatory system reform. Available at: <https://readingroom.law.gsu.edu/jculp/vol1/iss1/13> (Accessed September 12, 2024).
- Masiyandima, N., Mlambo, K., and Nyarota, S. (2017). Financial inclusion and quality of livelihood in Zimbabwe. In *14th African Finance Journal Conference-Africa Growth Institute*
- Maxwell, J. A. (1996). *Qualitative research design: An interactive approach*. Thousand Oaks, CA: Sage Publications.
- Mhlanga, D., and Denheer, V. (2020). Determinants of financial inclusion in southern Africa. *Stud Univ Babeş Bolyai Econ* 65, 39–52. doi: 10.2478/subboec-2020-0014
- Ministry of Agriculture (MoA) (2014). MoA productive safety net implementation manual; Ethiopia. Enhanced social assessment, and consultation. Available online at: https://www.usaid.gov/sites/default/files/documents/1866/psnp_iv_ (Accessed May 13, 2024).
- Napoli, M., De Muro, P., and Mazziotta, M.. (2011). Towards a food insecurity multidimensional index. Unpublished master thesis Universita Deglistudi.
- Obisesan, A., and Adeyolu, A. (2018). Financial inclusion of arable crop farmers in Nigeria. In: *RePEc: Research Papers in Economics*.
- Olaniyi, E. (2017). Back to the land: The impact of financial inclusion on agriculture in Nigeria. ideas. repec.org. Available at: <https://ideas.repec.org/a/eut/journal/v21y2017i4p885.html> (Accessed September 23, 2023).
- Olayemi, A. O. (2012). Effects of family size on household food security in Osun State, Nigeria. *Asian J. Agric. Rural Dev.* 2, 136–141. doi: 10.22004/ag.econ.197951
- Pega, F., Liu, S., Walter, S., and Lhachimi, S. (2015). Unconditional cash transfers for assistance in humanitarian disasters: effect on the use of health services and health outcomes in low- and middle-income countries. *Cochrane Datab. System. Rev.* 2015:CD011247. doi: 10.1002/14651858.CD011247.pub2
- Porter, C., and Goyal, R. (2016). Social protection for all ages? Impacts of Ethiopia's productive safety net program on child nutrition. *Soc. Sci. Med.* 159, 92–99. doi: 10.1016/j.socscimed.2016.05.001
- Prymstka, L., Krasnova, I., Kulish, G., Nikitin, A., and Shevaldina, V. (2020). Modeling the segment interactions of Ukraine's financial market. *Invest Manage Fin Innov* 17, 101–112. doi: 10.21511/imfi.17(2).2020.09
- PSNP (2014). *Productive safety net program. Designing and implementing a rural safety net in a low-income setting: Lessons learned from Ethiopia's productive safety net program 2005–2009*. Addis Ababa: Government of Ethiopia.
- Rebecca, H., Rachel, S., and Dharini, B. H. (2013). Social protection and resilient food systems.
- Riley, L., and Crush, J. (2022). *Transforming urban food systems in secondary cities in Africa*. Cham, Switzerland AG: Springer.
- Rose, N., Manning, N., Bentall, R., Bhui, K., Burgess, R., Carr, S., et al. (2020). The social underpinnings of mental distress in the time of COVID-19 – time for urgent action. *Wellcome Open Res* 5:166. doi: 10.12688/wellcomeopenres.16123.1
- Shemelis, K. H., and Daniel, T. T. (2023). Determinants of financial inclusion gender gap in Ethiopia: Evidence from decomposition analysis. *Cogent Business \u0026amp; Management*, 10, 2238124. doi: 10.1080/23311975.2023.2238124
- Shigute, Z., Mebratie, A. D., Sparrow, R., Yilma, Z., Alemu, G., and Bedi, A. S. (2019). Uptake of health insurance and the productive safety net program in rural Ethiopia. *Soc. Sci. Med.* 176, 133–141. doi: 10.1016/j.socscimed.2017.01.035
- Smith, L. C., and Haddad, L. (2002). How potent is economic growth in reducing under-nutrition? What are the pathways of impact? New cross-country evidence. *Econ. Develop. Cult. Change* 51, 55–76. doi: 10.1086/345313
- Smith, M. D., Kassa, W., and Winters, P. (2017). Assessing food insecurity in Latin America and the Caribbean using FAO's food insecurity experience scale. *Food Policy* 71, 48–61. doi: 10.1016/j.foodpol.2017.07.005
- Tareke, K. M.. (2023). Field Survey Data. Unpublished raw data.
- Tareke, K. M. (2022a). Impacts of public transit on economic sustainability: a case of Addis Ababa light rail transit Ethiopia. *J Afric Dev Stud* 7, 22–36. doi: 10.56302/jads.v7i2.3108
- Tareke, K. M. (2022b). Impacts of urban safety net on income, food expenditure and intake capacity of poor households in Addis Ababa city, Ethiopia, 2021. *Front Sustain Food Syst* 6:1031213. doi: 10.3389/fsufs.2022.1031213
- Tareke, K. M., and Ashebir, G. M. (2023). Impact of COVID-19 pandemic on the people's choice of urban public transportation modes and mobility in Addis Ababa and Hawassa city, Ethiopia. *Urban Plan Transport Res* 11:233. doi: 10.1080/21650020.2023.2193233
- Tareke, K. M., and Baraki, G. A. (2024). Affordability and accessibility of condominium housing in urban Ethiopia using a combined transportation and housing cost (CHT) index model: implication for sustainable urban infrastructure, policy and development. *Int J Urban Sustain Dev* 16:38–61. doi: 10.1080/19463138.2024.2429393
- USDA (U.S. Department of Agriculture). (2000). Food security in the U.S. - Survey Tools | Economic Research Service. Available at: <https://www.ers.usda.gov/topics/food-nutrition-assistance/food-security-in-the-us/survey-tools> (Accessed 18 December, 2023).
- World Bank. (2018). *The state of social safety nets*. Report overview, Washington, DC. World Bank. p.8.
- Yamane, T. (1967). *Statistics: An introductory analysis. 2nd Edn*. New York: Harper and Row.
- Yoong, J., Rabinovich, L., and Diepeveen, S. (2012). The impact of economic resource transfers to women versus men: A systematic review. Technical Report. London: EPPI-Centre, Social Science Research Unit, Institute of Education, University of London.

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