frontiers | Frontiers in Sustainable Food Systems

TYPE Systematic Review
PUBLISHED 05 August 2024
DOI 10.3389/fsufs.2024.1336395

OPEN ACCESS

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RECEIVED 10 November 2023
ACCEPTED 22 July 2024
PUBLISHED 05 August 2024

CITATION
Milestad R, de Jong A, Bustamante MJ, Molin E, Martin M and Malone Friedman C (2024) Sustainability assessments of commercial urban agriculture – a scoping review.
Front. Sustain. Food Syst. 8:1336395.
doi: 10.3389/fsufs.2024.1336395

Sustainability assessments of commercial urban agriculture – a scoping review

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The field of urban agriculture has seen an increase in development and attention in recent years, with a large share of literature addressing whether urban agriculture may pose a solution for food insecurity and combat environmental impacts. However, few studies have examined the many sustainability claims of urban agriculture systems, especially for urban farms intended for larger output and commercial ends. In this study, we analyze sustainability assessments of urban agriculture for commercial implementation. We do this by exploring the methods employed for conducting sustainability analyses, outlining the different urban agriculture cultivation systems, analyzing which sustainability aspects are considered, looking into what the sustainability analyses conclude, and studying how authors anticipate the knowledge gained from their sustainability assessments can be used. Environmental aspects of sustainability were more often assessed than other sustainability aspects, and LCA research practice was used for the majority of environmental assessments. Some studies compared the environmental benefits of different types of urban agriculture systems, but this was not conclusive overall as to what systems would be more environmentally beneficial. This suggests that urban agriculture's sustainability cannot be universally categorized but should be assessed in relation to specific environmental conditions and urban contexts. Future research should aim to develop more nuanced frameworks for evaluating the environmental, social, economic and governance impacts of urban agriculture.

KEYWORDS

urban agriculture, sustainability assessment, scoping review, commercial urban agriculture, urban food provisioning

1 Introduction

Food provisioning in urban environments has increasingly become the focus of attention from researchers, policymakers, and citizens, as urbanization continues to increase, and agricultural land connected to cities becomes scarce (e.g., Kalantari et al., 2017; Yan et al., 2022). Thus, solutions for more resilient food systems in urban environments, such as shortening supply chains and promoting local consumption have gained prominence in the literature (Benke and Tomkins, 2017; O'Sullivan et al., 2020; Pinheiro et al., 2020; Pulighe and Luipa, 2020). The COVID-19 pandemic heightened the importance of urban self-sufficiency as supply chains were disrupted and food supply chains experienced significant stress in several countries (Pulighe and Luipa, 2020; Langemeyer et al., 2021). Consequently, interest

in urban agriculture has increased in recent years as an approach to mitigate environmental impacts and enhance food security by producing food in and around urban areas (Eigenbrod and Gruda, 2015; Buehler and Junge, 2016; Di Giustino et al., 2022).

Urban agriculture is often seen as a multifunctional and beneficial activity, providing education, community development, recreation, climate change mitigation, urban biodiversity improvements, and organic waste recycling (Despommier, 2013; Weidner et al., 2019; Orsini et al., 2020; Siegner et al., 2020). It encompasses a number of agricultural practices for the cultivation of food for consumption and decorative purposes, with both commercial and non-commercial aims (de Oliveira Alves et al., 2024). However, as urban agriculture gains momentum, the need to articulate the sustainability and viability of these systems is of utmost importance (Dorr et al., 2021). It is argued that for a system to be considered sustainable, sustainability should be seen holistically, encompassing social, environmental and economic aspects (Giddings et al., 2002). At the same time, while this conceptualization of sustainability aims to simplify analysis, these categories are complex and susceptible to the opinions and experiences of a number of different stakeholders, including governments, business and citizens (Giddings et al., 2002). The literature presents diverse perspectives on the sustainability of urban agriculture (Weidner et al., 2019; Bunge et al., 2022). Yet, few studies have examined whether urban agriculture can progress from a niche production system to a feasible and viable solution for food provisioning. While in recent years an increasing number of studies analyzing the sustainability of urban agriculture worldwide have emerged (Weidner et al., 2019; Milestad et al., 2020; Dorr et al., 2021; Martin et al., 2023), it is important to identify the commonalities and differences in the methods and findings to determine whether urban agriculture can be considered a sustainable and scalable practice. In this study we focus on commercial urban farming, i.e., farms that seek to generate income, due to an interest in understanding how sustainability assessments incorporate all aspects of sustainability and with the assumption that for scalability of systems, economic viability is a key factor.

Sustainability assessments as a method can be described as the "process of identifying, measuring and evaluating the potential impacts of a wide range of relevant initiatives and their alternatives on sustainable development" (Devuyst, 2000 p. 68). Previous assessments have been conducted under different contexts and may employ different considerations, methods, and focus on different sustainability pillars, e.g., environmental, social, and economic factors (Kulak et al., 2013; Goldstein et al., 2016; Dorr et al., 2021, 2023). Furthermore, analysing the target groups of assessments, such as policymakers, urban planners, and consumers, is important since many times these methods are used as information for decision-making processes and to foster legitimacy for urban agriculture initiatives (Al-Kodmany, 2018; Toboso-Chavero et al., 2018; Sarker et al., 2019; Fanfani et al., 2021). It is important to recognize the motivations behind these sustainability analyses, such as communicating the benefits to customers, comparing different urban agriculture practices, and guiding further research (Orsini et al., 2020; Langemeyer et al., 2021; Martin and Bustamante, 2021). Thus, the aim of this paper is to better understand how, why, and for whom sustainability assessments of commercial urban agriculture practices are being conducted. This is a vital step to improve research and policy for the further development of sustainable urban agriculture for food provisioning.

To achieve this aim, we conduct a scoping review of literature that conducts sustainability assessments of commercial urban agriculture alternatives in order to provide an overview of the field (Munn et al., 2018). We analyze how assessments of sustainability are done, which sustainability aspects are considered, what the sustainability analyses conclude, and how authors anticipate the knowledge gained from their sustainability assessments can be used by different targeted stakeholder groups. The study shows that the use of sustainability assessments is increasing as various stakeholders in urban agriculture seek to understand the role of cities in the future food system. Yet, as an emerging field of research, indicators and evaluation methods are scattered, with few taking into consideration indicators that assess the contributions of commercial urban agriculture to environmental, social and economic goals. By synthesizing the findings of these sustainability assessments and understanding their implications, this study contributes to the ongoing discussion on the potential of commercial urban agriculture as a sustainable solution for food production in an increasingly urbanized world.

The paper continues as follows. In section 2, we outline the method employed for the scoping review, followed by a presentation of the key findings from the analyzed articles in Section 3. Section 4 discusses the main gaps and opportunities identified for improving sustainability assessments for commercial urban agriculture, including a discussion on the limitations of the study. The paper ends with a concluding section about sustainability assessments as a tool for connecting commercial urban agriculture to a sustainable food system.

2 Method

A scoping review was selected as an approach due to its effectiveness in identifying relevant materials that may encompass a wide range of disciplines in order to identify potential research gaps (Arksey and O'malley, 2005; Munn et al., 2018). We used the five-stage framework for scoping reviews developed by Arksey and O'malley (2005) as a guide. These stages included: (1) identifying the initial research questions, (2) identifying relevant studies, (3) study selection, (4) charting the data, and (5) collating, summarizing and reporting the results (Arksey and O'malley, 2005).

2.1 Initial scope and research questions

Urban agriculture encompasses several agricultural practices from indoor and outdoor farms, high-tech and low-tech methods, and includes both crop cultivation and the raising of animals (de Oliveira Alves et al., 2024). These activities can serve commercial purposes and/or social and recreational purposes, and, in general, urban agriculture can be divided into two main categories, urban agriculture which is profit-driven and urban gardening, which typically takes on non-profit forms (Pölling et al., 2016; de Oliveira Alves et al., 2024). The focus of this study is on urban

TABLE 1 Search string.

Search string
(TITLE-ABS-KEY ("urban farming" OR "urban agriculture" OR "vertical farming" OR "vertical agriculture" OR aquaponic OR hydroponic OR "city framing" OR "city agriculture" OR aeroponic OR "zfarm" OR "zero acre farming"))*
AND
(TITLE-ABS-KEY (food OR eat OR meal OR vegetable* OR crop* OR seedling* OR sprout* OR herb* OR vegetable* OR seedling OR sprout OR fruit OR crop OR "micro green*" OR "leafy green*" OR "food supply*" OR "food planning" OR "food distribution"))*
AND
(TITLE-ABS-KEY (urban OR periurban OR "peri urban" OR peri-urban OR city* OR town OR metropoli* OR suburb* OR roof OR "roof top*" OR allotment))*
AND (LIMIT-TO (DOCTYPE, "ar")) AND (LIMIT-TO (LANGUAGE, "English"))

TABLE 2 Inclusion and exclusion criteria for review of abstracts.

Criterion	Inclusion	Exclusion
Time period	Published before 11 March 2022	Studies outside these dates
Language	English	Non-english
Type of article	Original research, published in peer-reviewed journals	Article that were not peer-reviewed or orginaial research
Study focus	Commerical urban agriculture defined as for-profit urban and peri-urban farms Forms of urban agriculture with the potential or expectation to become commercial	Non-commerical urban agriculture such as community gardens, subsistence farming, allotments, home gardening
Literature focus	Articles where the overall theme relates to understanding the possibilities and viability of commercial urban farm operations	Highly technical articles that were not connected to broader commercial considerations

agriculture, meaning urban or peri-urban farms that include commercially driven activities. While we recognize the multi-functional role of urban agriculture, this narrowed scope was chosen due to the research objective to understand the potential of urban agriculture as a scalable food production method.

This study was part of a larger research project focused on urban agriculture thus the initial research questions were broad in nature:

1 What is the perceived role of commercial urban agriculture in food provisioning?
2 What considerations are there pertaining to the viability of urban agriculture?
3 Who are the main stakeholders for the development of urban agriculture?

2.2 Identifying relevant studies

The search string was organized into three blocks, each containing terms related to urban farming practices, types of produce, and urban location. Additionally, the search was limited to journal articles written in English. A university librarian helped in the development and application of the search string. The search string incorporated exclusion criteria, following similar methods previously employed to examine the research fields of urban agriculture (Cohen and Reynolds, 2015; Grewal and Grewal, 2021).

The final search string (see Table 1) was applied on 11 March 2022. The databases utilized for this search were the well-established search engines Scopus[1] and Web of Science,[2] both of which feature extensive coverage from numerous scholars and journals across various disciplines.

2.3 Study selection

Using the search string, a total of 1877 articles were obtained from the two search engines. To further guide article selection, the Preferred Reporting of Items of Systematic Reviews and Meta-Analyses (PRISMA) checklist was used (Page et al., 2021). A total of 502 records were removed at this point due to two main reasons. First all duplicate articles were removed ($n = 244$) and second, another 258 articles were excluded because of lack of accessibility due to university-level access agreements. After the removal of duplicates and inaccessible articles, 1,375 abstracts were screened. The abstracts were screened based on the outlined inclusion and exclusion criteria (see Table 2).

Another 1,145 articles were excluded because of not fulfilling the inclusion criteria. A large factor in excluding articles at this stage was a lack of focus on commercial forms of urban agriculture. For example, many articles focused on community farming, allotment gardens, home gardens, or urban agriculture for self-sufficiency (e.g., Dobson et al., 2020; Siebert, 2020; Zasada et al., 2020). Articles that were highly technical without consideration of a broader context were also excluded, for example studies with a purely technical focus or articles

1 www.scopus.com
2 www.webofknowledge.com

that dealt with soil contamination or specific pollutants or nutrients (e.g., Paltseva et al., 2020; Perera et al., 2020; Sharifan et al., 2020).

The next step in article selection included reading the remaining 231 articles in full. During this step, an additional inclusion/exclusion criterion was added. Due to evolving objectives of the overall research project, it was decided to further narrow the scoping study to sustainability assessment of commercial urban agriculture, with the following research question:

4 How is sustainability of commercial urban agriculture assessed, e.g., methods, factors? And what outcomes were articulated?

Articles that applied sustainability aspects were included if they assessed sustainability in some way, i.e., economic, social, governance, and/or environmental aspects of commercial farms. The researchers subjectively assessed the "sustainability analysis" criterion, i.e., the authors of the articles did not have to claim to have done a sustainability analysis for the article to be qualified as such. In addition, during this step, review articles were also excluded unless they also included a case study or application of a real-world context. Figure 1 illustrates the article selection process.

2.4 Charting selected articles

The final 83 articles were analyzed in-depth. The list of articles assessed can be found in Supplementary material. Following the recommendation to "chart key data" in scoping studies (Arksey and O'malley, 2005), we developed a communal excel sheet with items to pinpoint from each article. This included type of assessment method, country and year of study, crops studied, urban agriculture system studied, sustainability aspects addressed, main conclusions, and target group of results (as assessed by researcher based on discussion and conclusions if not clearly stated). The articles were divided among four researchers. As we reviewed the literature, we constantly questioned how the findings could contribute to fulfilling the research aims and whether any additional data or perspectives were needed to provide a comprehensive answer. This iterative approach allowed us to refine the research aims as we gained a deeper understanding of the literature and identified gaps in knowledge. Findings and analysis were calibrated and refined during reoccurring workshops. The results are presented in the following section.

3 Results

3.1 Geographical scope

Most articles reported studies carried out in a specific context, e.g., a named city or region. A few of the articles were more general in nature, talking about the Global North or not specifying geography at all (e.g., Thomaier et al., 2015). In terms of geographical scope, most articles were based on studies fully or partially carried out in Europe ($n = 53$, 64%). When specific countries were named, 17 articles (20%) were from Spain, 8 articles (10%) were from Germany, and 7 articles (8%) were studies from Italy and the UK, respectively. Other articles included studies from Denmark, the Netherlands, Sweden, Portugal, and France. In the Spanish group of articles, the majority originated from studies based in Barcelona ($n = 13$, 16%). For example,

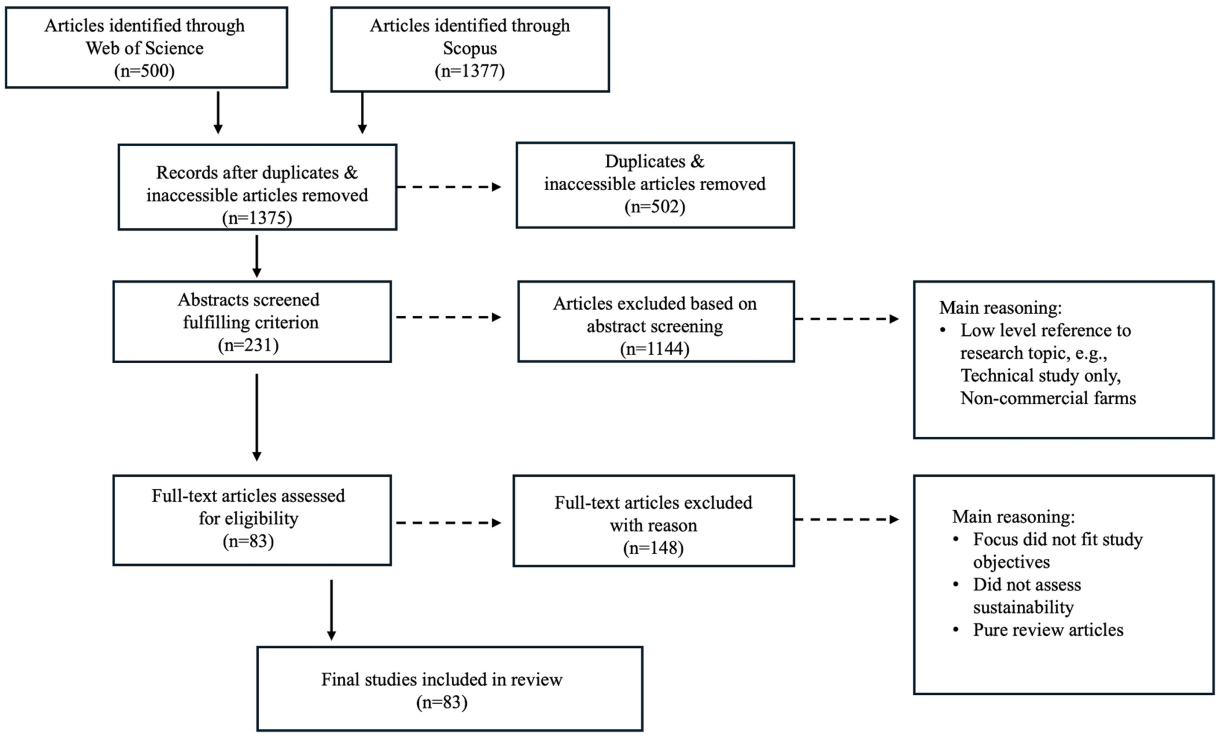

FIGURE 1
PRISMA diagram for article selection.

Sanyé-Mengual et al. (2016) and several other studies explored the sustainability of rooftop greenhouse systems in Mediterranean urban environments, analyzing a case study in Barcelona. In the Italian case, Bologna was a city well represented in the material: 4 articles (5%) reported studies were carried out there. For example, Pennisi et al. (2019) modelled the environmental burden of indoor grown vegetables and herbs in relation to lightning.

The second largest group of articles were based on studies from North America (n = 17, 20%), where the articles from the US were most common (n = 13, 16%), but without any city or state being mentioned more often than others. The articles originating from Asia and Australia were 15 in total (18%), and most often covered Australia (n = 5, 6%), but also studies from Singapore, Japan, India, China, Taiwan, South Korea, and New Zealand. There were also three (4%) articles covering Latin America and two (2%) that studied Sub-Saharan Africa. If an article based its findings on multiple geographical places, each place was counted.

3.2 Production system by year

The different types of urban agriculture production systems were summarized into three categories: indoor, outdoor, and greenhouse. If the articles analyzed vertical farms, aquaponics or controlled environment agriculture, they were tagged as indoor. Analyses of urban agriculture, peri-urban agriculture on fields, and outdoor forms of rooftop gardens were put in the outdoor category. Rooftop greenhouses and conventional greenhouses were put together in the greenhouse category. Some articles analyzed more than one type of production, in which case more than one system was counted. In total, 48 (59%) of the articles analyzed outdoor forms of urban agriculture, 41 (49%) talked about greenhouses, and 28 (34%) indoor farms. Since the articles focusing on production on rooftops were split between the main categories, we also calculated these specifically. There were 30 (36%) articles referring to some type of rooftop production. Studies investigating rooftop systems often assessed different techniques, symbioses with the building or rainwater harvesting (see Sanyé-Mengual et al., 2015a, 2015b; Toboso-Chavero et al., 2018; Rufí-Salís et al., 2020c). A common theme for studies looking into multiple practices was to investigate the most suitable option for a specific place or a larger area, e.g., a city (Barker-Reid et al., 2010; Schmutz et al., 2017; Battisti, 2019), or comparing different systems, e.g., fields on the ground, indoor farming, soil-based and non-soil-based (Goldstein et al., 2016; Samangooei et al., 2016).

The bulk of the articles included in this analysis originate from 2018, 2019 and 2021 (n = 16, 19%; n = 16, 19%, and n = 14, 17% respectively). Together these articles total 46 (n = 55%). There were few articles per year up to 2014, when in 2015 they started to increase (see Figure 2). For unknown reasons the number dropped during 2020, but the general trend is increasing articles for articles on indoor, outdoor and greenhouse systems from 2014 until 2019. After 2019 the number of articles on indoor systems has decreased. The number of articles on outdoor and greenhouse systems have been relatively stable from 2015 but increased again after 2020.

3.3 Crops studied

In the articles where a certain crop, or several crops was/were specified, the most common crop was tomato (n = 23, 28%) as well as the general category "vegetables" (n = 23, 28%). The second most common crop when specified was lettuce (n = 16, 19%), very commonly in combination with tomatoes (n = 10, 12%). Nine articles studied fruits (11%) in isolation or in combination with other crops. Fish, leafy greens and herbs were included in 7 articles (8%) respectively. Fish was mentioned when the articles analyzed an aquaponic system. For example, Love et al. (2015) investigated commercial aquaponics production and profitability, highlighting the integration of fish with leafy greens and tomatoes. Leafy greens, herbs, lettuce and tomato were often mentioned for indoor production systems, such as vertical farms or greenhouses on rooftops. Examples

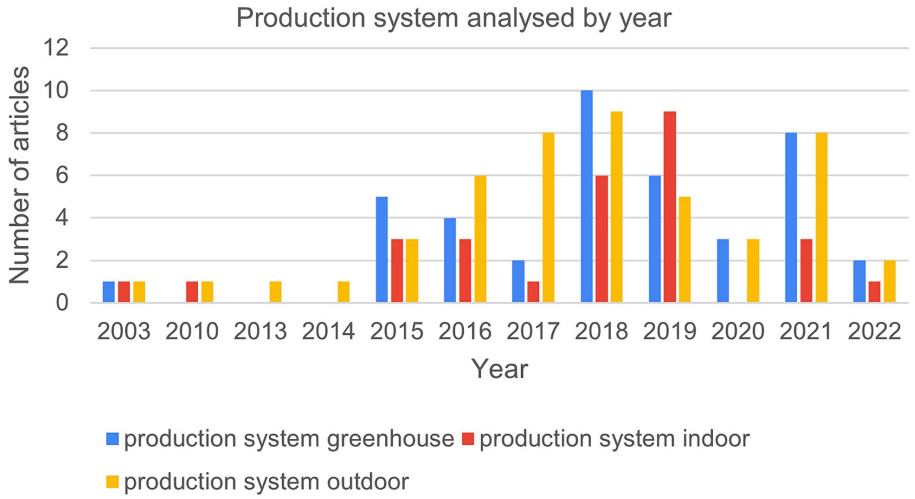

FIGURE 2
The type of production systems greenhouse, outdoor, and/or indoor, as described in the articles analyzed by year and number of articles. Articles were sometimes counted multiple times across categories.

include Sanyé-Mengual et al. (2018b) for rooftop greenhouses and Martin et al. (2019) for vertical, indoor farms. Articles studying outdoor urban farms more often covered a longer list of specified crops, such as the article by Perez-Neira and Grollmus-Venegas (2018). These authors studied peri-urban horticulture in Spain, covering chard, tomatoes, broccoli, onions, herbs, squash, leek, peppers and more.

3.4 Methods used to assess sustainability aspects

The methods used in the articles were sorted into four categories. In the qualitative category all articles using interviews, descriptive case studies, consultation exercises, qualitative criteria evaluation, discourse analysis, SWOT analysis, document/policy analysis, mind-mapping exercises, observations, participatory appraisals or using the Sustainability Assessment of Food and Agriculture (SAFA) framework (FAO, 2014), or similar were allocated. All LCA studies were put in a category of their own, encompassing all full or partial LCAs, as well as comparative LCAs. Other quantitative studies were allocated to the "quantitative other" category, including, e.g., surveys, cost benefit analyses, eco-efficiency assessments, use of different quantitative indicator sets, different types of modelling, LCI, LCC, spatial dataset analysis, quantitative risk assessments, economic feasibility studies, GIS, or different types of measurements (e.g., ecosystem services). A fourth category for review articles was used for articles that were presented as reviews but also included at least one type of application and/or case study. For all methods, one article could be allocated to more than one category.

The content of the sustainability assessments in the articles was categorized as either environmental, economic, social or governance, or a combination of these. Articles were assigned to the governance theme if handling general urban planning and development issues related to urban agriculture. Social aspects were, e.g., health and well-being, consumer preferences, educational effects, social equity issues, labor, cultural identity, community building. The economic dimension was used when articles made conclusions about the costs/revenues of urban agriculture, affordability of products, job opportunities, investments and viability. The environmental dimension was used when articles made conclusions about greenhouse gas emissions/carbon footprints, water use, energy use, biodiversity or other environmentally related issues.

The most frequently used method (Figure 3) identified for sustainability assessments was life cycle assessments (LCA; n = 48, 59%). Most of these articles (n = 33, 40%) brought up environmental aspects of sustainability. Qualitative methods were used in 45 of the articles (54%), evenly spread between economic, social and environmental aspects (n = 13, 13, 11; 16, 16, 13% respectively), with 8 (10%) of the articles assigned to the governance aspect of sustainability. Other quantitative methods were covered in 46 (55%) of the articles, where environmental aspects were in the majority (n = 24, 29%). In total, 12 articles (14%) were reviews. These covered the sustainability aspects evenly.

3.5 Content of sustainability assessments

When looking closer at the content of the sustainability assessments, several different topics were identified in the articles (Figure 4). For environmental sustainability, the main topics were GHG emissions (n = 51, 61%), water use (n = 36, 43%), natural resource and waste management (n = 26, 31%), and land use (n = 21, 25%). These were followed by topics such as energy use or demand (n = 20, 24%), other LCA impact categories (toxicity, eutrophication, acidification; n = 18, 22%), biodiversity issues (n = 15, 18%), and nutrient recovery (n = 4, 5%). 15 articles (18%) included assessments about topics not in the main categories. Examples of these were mentions of pollution (Rufí-Salís et al., 2020b), soil health (Nicholls et al., 2020), or food miles reduction (Lee et al., 2015). Overall, 70 (84%) articles were categorized as addressing environmental sustainability (solely or in combination with other aspects). Articles

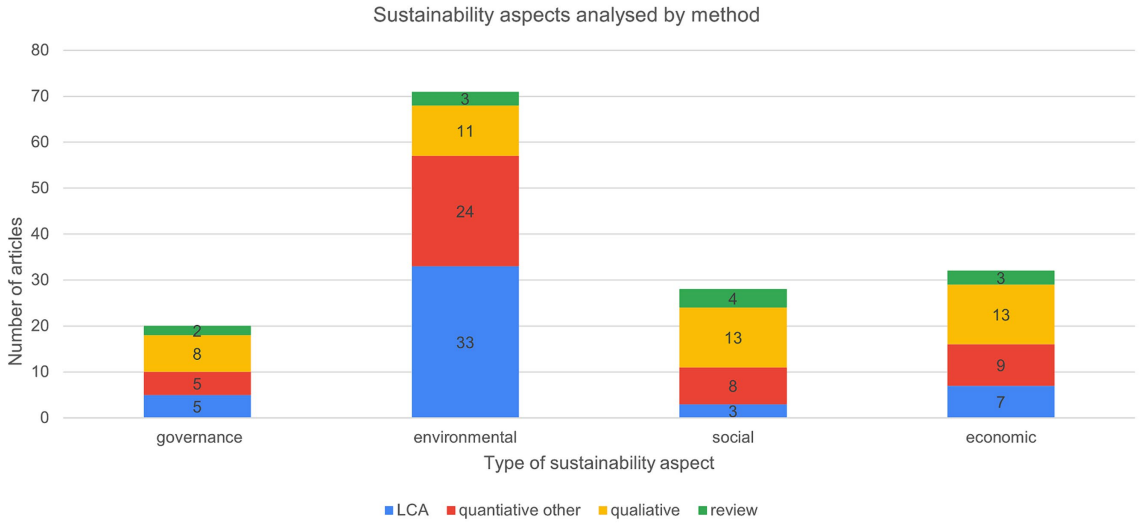

FIGURE 3
Analytic methods used in the articles reviewed to analyze sustainability aspects, expressed in absolute numbers, as addressed in the articles.

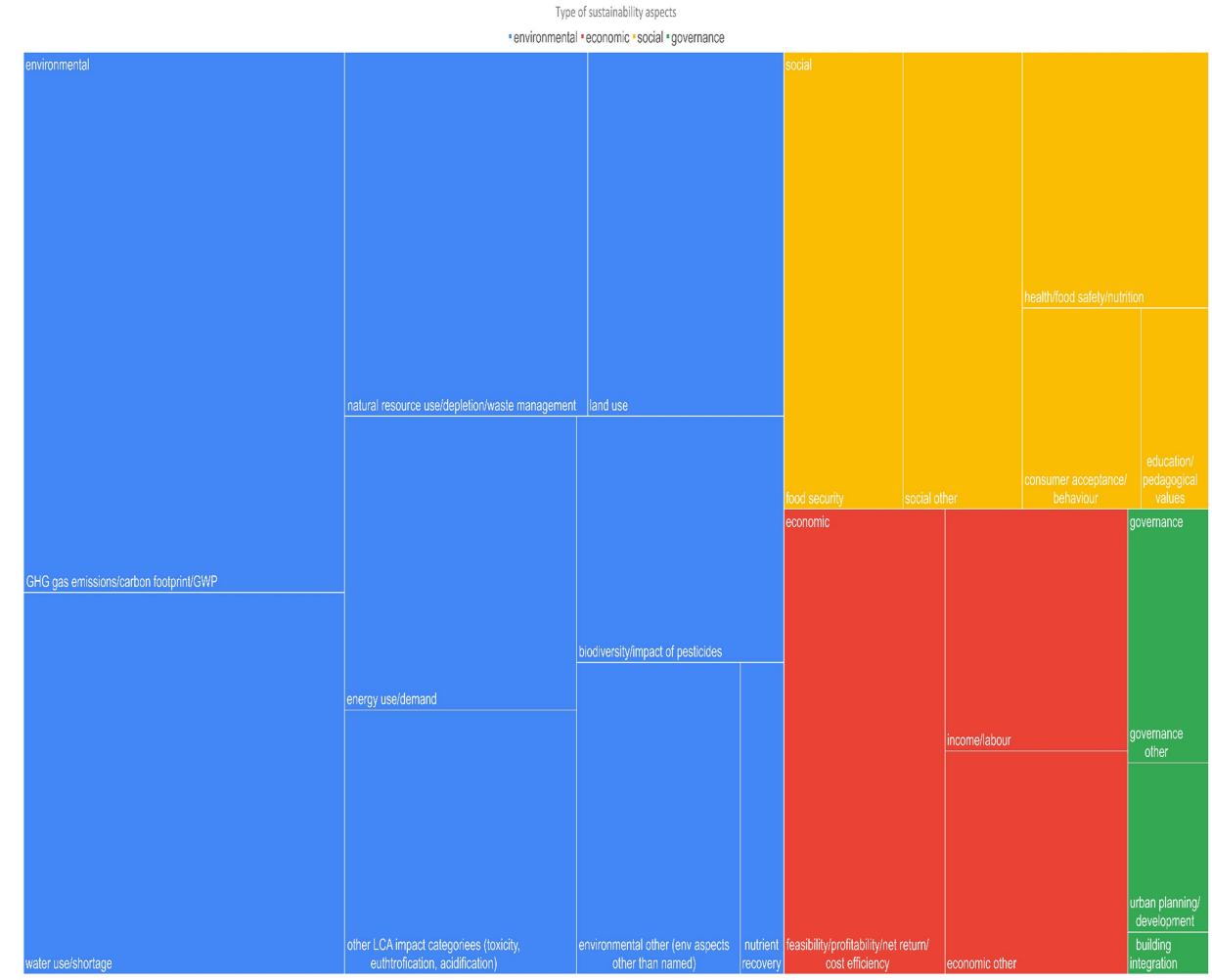

FIGURE 4
The type of sustainability aspects categorized as environmental, economic, social and governance and depicted relative in size as to the number of articles that address them. Several aspects may be addressed in one article.

could cover multiple topics allocated to environmental aspects of sustainability.

For social aspects of sustainability, the most important topic was food security (n = 16, 19%), followed by health-food safety-nutrition (n = 14, 17%), and consumer behavior and acceptance (n = 7, 8%). Four articles (5%) focused on educational and pedagogical aspects of urban agriculture. In 16 (19%) of the articles social aspects only mentioned once or a few times were put together. These included for example corporate social responsibility (Yoshida and Yagi, 2021), food system resilience (Toth et al., 2016), or social cohesion (Säumel et al., 2019). In total, 37 (45%) of the articles dealt with social aspects of sustainability. Articles could cover multiple topics allocated to social aspects of sustainability.

As for economic aspects of sustainability, in total 36 articles (43%) articles dealt with such aspects (solely or in combination with other aspects). The main categories were profitability or economic feasibility of commercial urban agriculture (n = 22, 26%), income or labor costs (n = 13, 16%). 12 (14%) articles concerned issues only mentioned once. For example, Poulsen et al. (2017) discussed affordability of urban agriculture foods, Nicholls et al. (2020) talked about economic growth, and Benis and Ferrao (2018) about investment costs. Articles could cover multiple topics allocated to economic aspects of sustainability.

Governance aspects of sustainability were the least common in the material. These were assessed in 7 (8%) of the articles. Four articles (5%) discussed urban planning or urban development, while one (1%) article analyzed building integration of urban agricultural systems (Jenkins et al., 2015). The rest of the mentions of governance issues (n = 6, 7%) covered other aspects, such as improvement of public space (Poulsen et al., 2017), urbanization (Opitz et al., 2016), or quality aspects of governance (Cánovas-Molina et al., 2021). Articles could cover multiple aspects allocated to governance aspects of sustainability.

Thus, the most common focus was on the environmental sustainability aspects of urban agriculture, followed by social, economic, and governance aspects. Most articles (n = 43, 52%) made assessments on two or more sustainability pillars. Of these, 41 articles (49%) assessed environmental issues and one, two, or three more aspects of sustainability. For articles focusing on one sustainability aspect, environmental assessments were the most

common (n = 30, 36%). For example, Sanyé-Mengual et al. (2015a) focused primarily on the environmental aspects of rooftop greenhouse systems in Mediterranean urban environments, analyzing a case study in Barcelona. In contrast, Dieleman (2017) looked at economic and social aspects of urban agriculture in Mexico City, and Goldstein et al. (2017) assessed the social, economic, and environmental impacts of urban agriculture in the United States, providing a comprehensive overview of three pillars of sustainability.

3.6 Examples of results and conclusions in the articles

Some articles compared two or more urban agriculture systems from environmental points of view (e.g., Goldstein et al., 2016; Samangooei et al., 2016; Schmutz et al., 2017; Al-Kodmany, 2018; Romeo et al., 2018; Hu et al., 2019; Nicholls et al., 2020; Song et al., 2022). For example, in an assessment of six different urban agriculture systems, Goldstein et al. (2016) found that low input urban agriculture systems (with lower yields) were also the ones performing best from an environmental point of view. Samangooei et al. (2016) compared soil-based and soil-less systems and found the soil-based systems to be more environmentally beneficial. Romeo et al. (2018) compared a vertical hydroponic farm with conventional heated greenhouses and found the vertical farm to outcompete the other urban agriculture systems.

Other articles made assessments of specific urban cultivation systems and made conclusions as to their environmental sustainability effects. For example, Toboso-Chavero et al. (2018) found that integrating food production, water harvesting and photovoltaic systems on rooftop farms could significantly reduce emissions. Another study of rooftop gardens concluded that increased diversity of crops led to better environmental performance (Rufí-Salís et al., 2020a). Pennisi et al. (2019) found that electricity use was the main contributor to environmental impacts in an indoor farm. Similarly, Dorr et al. (2021) found that on-farm energy use was the main contributor to environmental impacts across all life cycle assessment categories (except land use) for an urban mushroom farm. For a rooftop farm, however, it was shown that the most impactful component was material use for garden infrastructure and substrate production for potting soil systems (Dorr et al., 2017). Similarly, an analysis of vertical farms suggested that growing media had the largest environmental impact (Martin et al., 2019). Analyzing controlled environment agriculture, Körner et al. (2021) argued that vegetable production in Northern Europe could surpass imported ones in environmental performance. Kulak et al. (2013) found that urban agriculture systems could produce larger reductions in greenhouse gas emissions than parks and urban forests, and Benis et al. (2018a) concluded that high-yielding greenhouses had the potential to reduce global warming potential by 9%, while another study found that urban agriculture generated meagre food-related carbon footprint reductions (Goldstein et al., 2017).

An important social outcome of urban agriculture that was mentioned in the articles was the educational effect urban agriculture can have (Goldstein et al., 2017; Poulsen et al., 2017; Specht et al., 2019; Zambrano-Prado et al., 2021). Some authors found that urban agriculture contributed to social sustainability in broad terms, e.g., by combatting urban food deserts (Goldstein et al., 2017), by being a dynamic and viable livelihood strategy (Drechsel and Dongus, 2010), by benefitting human health and wellbeing (Säumel et al., 2019), or by cultivation of social skills and capabilities that contributes to sustainable urban living (Martin et al., 2016).

One study found that the main barrier to expansion of urban agriculture (in Sydney) was available labor resources (Mcdougall et al., 2020). When comparing growing media for rooftop gardens in a life cycle assessment, Toboso-Chavero et al. (2021a) found that peat had the best social performance, compared to coir-based growing media. This was mainly due to the fact that coir, as a by-product from coconut trees, did not perform well in terms of human rights and community infrastructure in the Social Hotspots Database. While most conclusions about social sustainability referred to outdoor urban agriculture systems, Jürkenbeck et al. (2019) concluded that perceived sustainability was the main driver for acceptance in a study on consumer acceptance of produce from vertical farms.

Economic sustainability was most often assessed in aquaponics, building-integrated agriculture, and vertical farming. Investment costs were mentioned as one limiting factor for economic sustainability for building-integrated agriculture (Specht et al., 2019), along the general conclusion that integrating agriculture in buildings is not necessarily cost effective (Jenkins et al., 2015). Another study concluded that rooftop gardens could give a financial return and provide jobs, especially if solar energy was used and if the energy system of the cultivation was integrated with the building on which it was established (Benis et al., 2018b). While labor costs were mentioned to be high in aquaponics (Asciuto et al., 2019), electricity costs were mentioned as being high in indoor farming systems (e.g., Pennisi et al., 2019). At the same time, two studies concluded that aquaponics could be profitable (Asciuto et al., 2019; El-Essawy et al., 2019). In the assessment of soil-less and soil-based urban agriculture systems, Samangooei et al. (2016) concluded that produce from soil-based urban agriculture systems would be more affordable for consumers. Nogeire-Mcrae et al. (2018) could not find any clear economic or nutritional benefits in urban agriculture.

As for results connected to governance issues, Battisti (2019) concluded that the aim to create modern urban spaces can be obtained with urban agriculture through local food system networks and urban scale markets. In an assessment of Manchester, UK, Jenkins et al. (2015) concluded that 33% of the city would be capable of growing food and that roofs and/or facades would be good spots for food production. Another example is Cánovas-Molina et al. (2021), who found that the main weaknesses for developing urban agriculture in a Spanish region were urban sprawl and poor territorial governance.

3.7 Targeted stakeholders and use of knowledge in the articles

Based on the discussion and conclusion sections of the articles we looked for statements from the authors about the recipients and use of their findings, i.e., who they targeted and how authors thought their produced knowledge could be used. Not all authors stated clearly how their results could be used, and what actors in the food system were the recipients of the knowledge developed in the papers. The authors that did state this primarily focused on four major groups:

policy makers, city planners, urban agriculture practitioners and academia.

Policy makers were targeted to use the results as decision support in order to realize the potential of urban agriculture in general (e.g., Drechsel and Dongus, 2010; Liang et al., 2019; Rufí-Salís et al., 2020b; Lucertini and Di Giustino, 2021; Liu et al., 2022), more specifically by becoming aware of legal barriers to the development of urban agriculture (Specht et al., 2019), or by ensuring that investments take place (El-Essawy et al., 2019). City planners were targeted to be able to focus on suitable types of urban agriculture (Goldstein et al., 2016, 2017), to find new ways of working with urban agriculture to regenerate urban areas (Battisti, 2019) or to use the results from the studies as guides or frameworks for implementing urban agriculture in different ways (e.g., Sanyé-Mengual et al., 2015b, 2018a). A few of the articles specifically aimed to help city planners implement urban agriculture in or on buildings (e.g., Munoz-Liesa et al., 2021). Practitioners, i.e., the actors who do the actual growing and start up different urban agriculture enterprises, were targeted in different ways in the articles. Some authors wanted to help practitioners improve farm processes (Al-Chalabi, 2015; Martin and Molin, 2019; Song et al., 2022) or to find and implement sustainable solutions (Sanyé-Mengual et al., 2015c; Small et al., 2019). Others wanted to help practitioners communicate with consumers (Specht et al., 2019), or to inspire further urban production (Nicholls et al., 2020).

Many authors called for more research and thus targeted academia for further studies on their topics. For example, Buehler and Junge (2016) called for more research to show the future directions of rooftop gardens. Pennisi et al. (2019) argued for more research to assess commercial-scale indoor farms, while Martin et al. (2016) suggested that more research would be needed to understand how social interaction and inclusion could be promoted through urban agriculture. Other authors called for more research on different sustainability aspects, such as achieving sustainability goals with aquaponics (Baganz et al., 2021), or quantifying environmental impacts and benefits of rooftop gardens (Sanyé-Mengual et al., 2015b).

4 Discussion

The aim of this scoping review was to explore how, why, and for whom sustainability assessments of urban agriculture practices are being conducted in order to understand the potential role of urban agriculture for food provisioning. Overall, the study found that commercial urban agriculture and its perceived role in food provisioning, while still in its infancy, has come a long way from conceptual feasibility studies of urban agriculture (e.g., Despommier, 2013), with most of the studies included presenting analyses of real cases, showing real impacts and benefits. At the same time, the diversity of findings across different types of systems and methods makes it difficult to completely ascertain the sustainability of commercial urban agriculture, which appears to be very context dependent.

An increase in the number of studies since 2018 points to the possible rise of the acknowledgment of urban agriculture's importance. This is not surprising considering that the Covid-19 pandemic, inflation and geopolitical tensions have caused countries across the world to reexamine their food systems. Within this context, urban agriculture has also gained prominence as urban populations increase, giving rise to issues including food security, and nutritional issues (e.g., Schmutz et al., 2017; Zambrano-Prado et al., 2021). While the review showed a decrease from 2019 in the number of articles on indoor systems, this does not seem to align with the overall discussions on urban agriculture, which increasingly acknowledge the need for a mix of production systems (Yan et al., 2022). This decrease may also be due to the exclusion of purely technical articles focused on elements such as technological development, lighting and automation, as well as pure review articles (e.g., Heng, 2020; Lakhiar et al., 2020; Modu et al., 2020). When looking at how sustainability is assessed, 84% of articles included an environmental focus, far surpassing the assessment of economic factors (43% of articles), social factors (45%) and governance issues (8%). This shows that sustainability for commercial urban agriculture is currently evaluated heavily through an environmental lens, but as an emerging field of study, it also points to a number of areas for future research.

First, how sustainability was assessed differed based on the intended purpose. When the purpose was conducting an environmental sustainability assessment, the method was most often LCA (e.g., Perez-Neira and Grollmus-Venegas, 2018; Romeo et al., 2018; Pennisi et al., 2019) while assessments focusing more on urban development most often used qualitative assessment methods (e.g., Martin et al., 2016; Dieleman, 2017). The outcomes of the environmental sustainability assessments found in the analyzed articles did not give a clear answer as to the sustainability of urban agriculture overall. For example, while Romeo et al. (2018) found that vertical farms were more environmentally beneficial than conventional greenhouses, and Körner et al. (2021) that Controlled Environment Agriculture performs better than conventionally grown imported produce, Samangooei et al. (2016) and Goldstein et al. (2016) found that soil-based, and low-input system were more environmentally sustainable than other systems. Energy use clearly seems to be a major issue for Controlled Environment Agriculture (Dorr et al., 2017), as does the choice of growing media (Martin et al., 2019). Thus, it is easier to state how urban agriculture farms could be improved, than to make conclusions on their overall environmental performance on a systemic level. Many of these studies compare different food production systems, but this may also be misleading as urban systems are inherently different. Thus, commercial forms of urban agriculture may be better viewed as complementary systems to current systems, and future research could move towards environmental sustainability assessments that look at the potential contributions of urban agriculture to overall functioning of a city and how to evaluate potential trade-offs between those benefits and other forms of agricultural production. For example, integrating commercial urban agriculture with organic waste flows may give synergies not yet captured (Weidner and Yang, 2020).

Second, though social sustainability factors were assessed in 45% of the articles, only nine articles focused solely on social aspects (e.g., Säumel et al., 2019; Yoshida and Yagi, 2021; Zambrano-Prado et al., 2021), which shows that there is an opportunity to expand research in this area. Topics most cited included food security, health, safety and nutrition, and consumer behavior and acceptance. Additionally, the educational aspect of urban agriculture was mentioned often as a social sustainability benefit (e.g., Poulsen et al., 2017; Specht et al., 2019) and was coupled with outdoor production systems. While there were articles dealing with corporate social responsibility (Yoshida and Yagi, 2021), community culture (Sanyé-Mengual et al., 2018a), youth

engagement (Poulsen et al., 2017), and other social aspects these were occasional and often focusing on many different social aspects at the same time. Thus, there is room for more in-depth knowledge on social aspects of sustainability in commercially oriented urban agriculture.

Third, though our study focused on commercial forms of urban agriculture, just under half of the studies (43%) assessed economic sustainability in some way. Of these studies, many of the assessments determined profitability was difficult unless a long-term view was taken (e.g., Benis et al., 2018b; El-Essawy et al., 2019), plants with increased added value were cultivated (Liaros et al., 2016) or farms diversified beyond products to include services and experiences (Love et al., 2015). Investment and labor costs are high, especially for high-tech growing systems such as different forms of Controlled Environment Agriculture (Specht et al., 2019). Relating this to a discussion on viability, indoor forms of agriculture and greenhouses are of interest due to potential year-round harvesting yet come with large investment and operating costs. To be competitive requires a long-term perspective to achieve profitability which implies a trade-off in the short term. The difficulty in overcoming the mental barriers related to upfront costs, as well as novel systems was evident in the study by Toboso-Chavero et al. (2021b), where residents of a building did not prefer to use their rooftop for vegetable production in a greenhouse, even though it ranked high on sustainability, largely due to upfront investment costs and the lack of other such systems in place. Incorporating this external perspective is an important area for future research as many of the articles in this review focused on the business case from an individual farm perspective. Another exception was the study by Poulsen et al. (2017) that looked at consumer affordability. This need to focus on the demand side was also pointed out by Laidlaw and Magee (2016).

The social aspects and governance aspects were related in some studies, such as when discussing building integrations (Jenkins et al., 2015) and the improvement of public spaces (Poulsen et al., 2017). Yet, at the same time urban agriculture is often vying for land use with more economically competitive options preferred by municipal governments (Goldstein et al., 2017), indicating a greater need for governance and policy integrations across national, regional and local levels. To arrive at such recommendations will require more holistic studies looking at the three pillars of sustainability plus governance in order to better balance environmental, social and economic considerations. Goldstein et al. (2017) provide one method for such a comprehensive view of the three pillars of sustainability. Additionally, the paper by Small et al. (2019) presents interesting insights into evaluating the trade-offs among different metrics of sustainability and could inform future studies.

Research published since the conclusion of this scoping study in March 2022, shows a movement towards updated methods and considerations with an aim to provide a more detailed view of urban agriculture for better decision-making among stakeholders. For example, using a life cycle cost (LCC) analysis, Pena et al. (2022) include labor and greenhouse structure costs to assess greenhouse rooftop tomato production. They note that prior LCC studies tend to omit these costs, which are important for a more integrated economic analysis of such production methods, and also provides an important complement to LCA findings, which produce limited insights for decision-makers without complete economic data (*ibid*). Arguing that more qualitative studies are important for the development of commercial urban agriculture, Campbell et al. (2023) point to governance factors like the lack of an industry organization that focuses specifically on the operations and needs of urban agriculture, as well as barriers such as conflicts due to urban residents not used to living next to a farm, legal and regulatory hurdles and the need for some formerly rural farms to transition to peri-urban operations due to urban sprawl. Lastly, research from de Oliveira Alves et al. (2024), provides important perspectives from the Global South. For example, economic resilience is bolstered by urban agriculture in Porto Alegre, Brazil, with a large contribution coming from women, leading to greater equality in leadership positions (*ibid*). These studies show the growing opportunity to create a more in-depth and nuanced view of the role of commercial urban agriculture in sustainable food provisioning.

5 Limitations

This scoping review is not without limitations. First, restrictions in the search methodology and search string design may have resulted in relevant articles being missed or excluded from the study, e.g., broad search terms and/or lack of access to some publications. This is a common limitation of scoping studies which strive to balance breadth and depth of analysis within a timely manner (Pham et al., 2014). Additionally, since the intent was to examine commercial urban agriculture, it excluded urban agriculture that appeared to be geared toward self-sufficiency, which ruled out several studies that originally came up that took place within the context of, e.g., West Africa. Articles captured in this study heavily skewed towards Europe and North America (83% of articles), and this context dependency limits the conclusions that can be drawn from this study. Learnings cannot necessarily be applied across different geographic and economic contexts. Finally, in the time that has elapsed since relevant literature was identified, more studies may have been published that could have been valuable assets to the review. We provide a brief look at some of these articles above, and overall believe this study provides a first step in understanding the potential of commercial urban agriculture in food provisioning systems and indicates a number of avenues for future research studies and systematic literature reviews that could help advance the viability and scalability of commercial urban agriculture.

6 Conclusion

The findings of this scoping review highlight the growing field of sustainability assessments of commercial urban agriculture. The increase of articles on the subject since 2018 shows increasing recognition of its importance, likely driven by recent global crises such as the COVID-19 pandemic and geopolitical tensions which have prompted a reassessment of food systems worldwide. This context has further emphasized urban agriculture's relevance as a potential solution to challenges including food security, health and nutrition. Overall, while this review provides some insights into the potential of commercial urban agriculture, it also highlights several areas for

further research in order to understand the true potential to scale commercial urban agriculture.

The study shows that environmental sustainability is the main focus when assessing the sustainability of commercial urban agriculture. Of the articles reviewed, 84% concentrated on environmental factors, often employing life cycle assessment (LCA) as a method. However, the environmental sustainability of urban agriculture remains complex. While some studies highlighted the environmental benefits of urban agriculture systems such as vertical farms and controlled environment agriculture over conventional systems, others pointed to the advantages of soil-based and low-input systems. The diversity in findings suggests that urban agriculture's sustainability cannot be universally categorized but should be assessed in relation to specific environmental conditions and urban contexts. Future research should aim to develop more nuanced frameworks for evaluating the environmental impacts of urban agriculture.

The study also identifies gaps in research on the social and economic dimensions of urban agriculture. While 45% of the reviewed articles addressed social sustainability, it was often done in an indirect manner. Topics such as food security, health, education and community engagement are mentioned, but there is a lack of in-depth studies that thoroughly explore these social benefits. This indicates a need for more detailed research into how commercial urban agriculture can contribute to social well-being, which is vital for developing policies that support it as an integrated part of urban planning. Though the study focused on commercial urban agriculture, only 43% of the articles addressed economic aspects. The reviewed studies indicate that commercial urban agriculture can be economically viable, particularly with a long-term perspective and through diversification into high-value crops and services. However, high upfront costs and operational expenses, particularly for high-tech systems, are barriers to development. The reluctance of stakeholders to invest in novel systems underscores the need for more research into business models that can support the scalability of urban agriculture. Policies that mitigate financial risks and support investment in urban agriculture could enhance its economic viability and attractiveness to investors and urban planners.

Lastly, governance and policy integration emerged as critical factors for the successful implementation of urban agriculture. The competition for land use with more lucrative economic activities highlights the need for governance frameworks that recognize and support urban agriculture as a valuable component of urban systems. Comprehensive studies that evaluate the interplay between governance, environmental, social, and economic factors are needed to help create regulatory environments that support and enable commercial urban agriculture to scale and realize positive impacts for urban food provisioning.

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.

Author contributions

RM: Writing – original draft. AdJ: Writing – original draft. MB: Data curation, Methodology, Validation, Writing – review & editing. EM: Writing – original draft. MM: Writing – original draft. CM: Writing – original draft.

Funding

The author(s) declare that financial support was received for the research, authorship, and/or publication of this article. The research was funded through a grant from the Swedish Innovation Agency (Vinnova) in the project Urban farming for resilient and sustainable food production in urban areas, Grant 2019-03178.

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.

The author(s) declared that they were an editorial board member of Frontiers, at the time of submission. This had no impact on the peer review process and the final decision.

Publisher's note

Supplementary material

The Supplementary material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fsufs.2024.1336395/full#supplementary-material

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