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# Urban Agriculture: Setting the Agenda on Plant-pollinator Interactions Among Food Plants, Research Funding, and Policy Actions

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**Abstract**
We review published research on plant-pollinator interactions among food plants in urban agriculture worldwide and provide a critical overview of the spatiotemporal distribution of knowledge, urban plant-pollinator profiles, and research funding for urban agriculture and ecosystem services. We also highlight the potential of urban agriculture to create pollinator-friendly spaces that support local pollinator conservation. We conclude that pollination services are a promising nature-based solution to meet Sustainable Development Goals (SDG) targets, delivering several ecosystem services, ensuring food security and sovereignty for urban dwellers, and alleviating malnutrition. By synthesizing evidence on plant-pollinator interactions, we identify major knowledge gaps to guide future research.

**Keywords** Crops · Food security · Food systems · Urban farms · Urban gardens · Pollination

## Introduction

Urban areas continue to grow globally, particularly in low-income countries (FAO, 2019), with over half of the world's population already living in cities. Unfortunately, populations in developing countries are often the most vulnerable, with over two billion people facing moderate to severe food insecurity (FAO et al., 2021). Urban agriculture may alleviate urban livelihood challenges by producing a variety of crops, from cereals to vegetables and fruits, for both local subsistence and sale (Altieri & Nicholls, 2018; FAO, 2022; Silva et al., 2021; Royer et al., 2023). Moreover, urban agriculture is gaining popularity worldwide through initiatives focused on greater sustainability, providing a range of benefits, including greater access to fresh and healthy food, promoting local food production with fewer or no chemicals, reducing food transportation distances, and improving food security, nutrition, and income opportunities (Brito & Borelli, 2020; Nicholls et al., 2020; FAO, 2022; Silva et al., 2021). By providing a wide range of benefits, urban agriculture has been perceived as an instrument to meet the United Nations Sustainable Development Goals (SDGs) related to ending poverty, food security, sustainable cities and communities, life on land, and climate action (United Nations, 2015; France, 2016).

Biotic pollination supports one-third of pollinator-dependent crops globally (Klein et al., 2007). Natural pollinators, including bees, bats, butterflies, and birds, pollinate over 100 crop species, ranging from cereals to vegetables and fruits such as apples, plums, raspberries, cucumbers, and pumpkins (e.g., Klein et al., 2007; Oliveira et al., 2024). Crops cultivated in various forms of urban farming also

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depend heavily on animal pollination for seed set and fruit development (e.g., Potter and LeBuhn, 2015; Foster et al., 2017; Altieri & Nicholls, 2018; Zhao et al., 2019). Plant-pollinator interactions provide a critical ecosystem service responsible for the reproduction of ~88% of all flowering plants (Ollerton et al., 2011) and play a major role in the functioning of food webs (IPBES, 2016). Yet pollinator populations, particularly insects, have declined markedly in recent decades due to drivers such as land-use intensification, habitat loss, pesticides, and climate change (Potts et al., 2010; Vanbergen et al., 2013; IPBES, 2016), posing a critical threat to biodiversity. In fact, at least 40% of all invertebrate pollinator species and 16.5% of all vertebrate pollinators are at risk of extinction due to anthropogenic drivers (IPBES, 2016). Therefore, the loss of pollinators can have several impacts on the conservation of biological and cultural diversity, the maintenance of traditional knowledge, and global food security (Potts et al., 2010; IPBES, 2016).

Urbanization is a major driver of biodiversity declines, alongside habitat loss and fragmentation and climate change, reducing foraging and/or nesting sites for pollinators (Baldock et al., 2015) and thereby undermining pollinator persistence in urban ecosystems (Silva et al., 2021; Silva et al., 2023). Nevertheless, urban planning that incorporates biodiversity conservation practices can be a viable way to maintain biodiversity in urban ecosystems and associated ecosystem services by providing floral resources for pollinators in green spaces, such as parks, woodlots, gardens, and allotments (e.g., Hall et al., 2017; Baldock et al., 2019; Silva et al., 2021; Maruyama et al., 2025). Thus, urban planning and urban agriculture contribute to food security by promoting pollinator-friendly practices, such as habitat protection and diversified floral rewards for animal pollinators (Kennedy et al., 2013; Nicholls et al., 2020; Silva et al., 2021). Urban agriculture likely serves as a pollinator reservoir and/or source area for adjacent rural areas, thereby amplifying its role in the context of the SDGs, which can provide nutrition and food security for households and alleviate urban poverty (Maxwell et al., 1998; Drescher, 2004; Orsini et al., 2013).

Despite the importance of urban environments to humanity and wildlife (Baldock et al., 2015, 2019; Hall et al., 2017; Lin et al., 2015; Nicholls et al., 2020; Silva et al., 2023; Zhang et al., 2022) and the benefits of biodiversity-friendly urban agriculture, pollination in urban farming has received little attention (Matteson & Langellotto, 2009; Silva et al., 2021), hindering strategic planning for urban agriculture. We review published data on plant-pollinator interactions in urban agriculture worldwide, drawing on research available in Web of Science and Google Scholar. First, we examine the spatiotemporal distribution of published data and describe the biological profile of plant-pollinator interactions in urban agriculture. We also compile and map global information on research funding and political initiatives in urban agriculture using the Dimensions Platform. Finally, we synthesize patterns and evidence on the pollination of food plants in urban agriculture and identify existing knowledge gaps. We also propose a roadmap to guide the development of urban agriculture practices that support pollinator diversity, strengthen local food systems, and conserve pollination services.

## Methods

### Scientometrics of Studies on Plant-pollinator Interactions in Urban Agriculture

We used the ISI Web of Science – Science Citation Index Expanded platform (www.webofknowledge.com) and Google Scholar (www.scholar.google.com) to conduct a bibliographic search. In the Web of Science, the search term was "urban agricult* and pollinat*", which had to appear in the title, keywords, and/or abstract. The Google Scholar searches were conducted using an R script developed with the RSelenium package, simulating manual navigation, applying the same search term, and collecting data on titles and abstracts. The results were last accessed on October 19, 2025. Following our search and selection process, we retained publications focused on interactions between food plants and pollinators in urban agriculture (Fig. 1). After a preliminary search that yielded 1385 publications, we included only articles that specifically examined relationships between plants and pollinators in urban agriculture, resulting in 32 articles (Table 1). We excluded studies not directly related to our topic, e.g., those listing potential pollinators/floral visitors, foraging pollinators in urban ecosystems, or articles on pollination of medicinal or ornamental plants in urban areas.

We grouped the data into 12 categories (Table 2) to analyze information from the selected publications. In particular, we used the widely recognized global standard for ranked pollinator dependence (Klein et al., 2007) to categorize the pollinator dependence of the food plants. Based on production reductions, we categorized all crops into five levels of pollinator reliance, following Klein et al. (2007), Roubik (2018), BPBES (2019), and Oliveira et al. (2024): (1) non-dependent: no difference in yields with or without animal-mediated pollination; (2) little dependent [reductions > 0% and ≤ 10%]; (3) modest [> 10% and ≤ 40%]; (4) high [> 40% and ≤ 90%]; and (5) essential [reductions > 90%]. For certain food plants, including coriander, onions, and turnips, human use of the plant component may not be entirely pollinator-dependent,

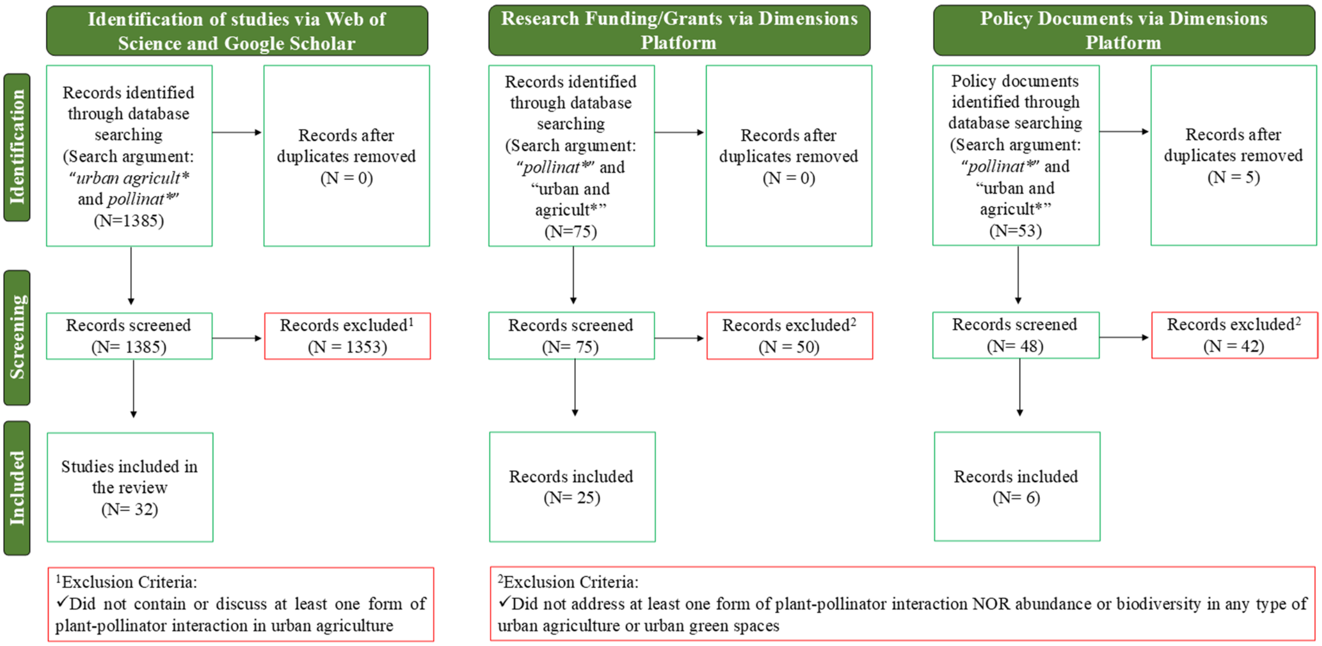


**Fig. 1** Flow diagram representing the body of literature reviewed here on plant-pollinator interactions in urban agriculture (including counts of sources and exclusion criteria used to filter the body of literature into the final dataset). This diagram is based on The PRISMA Statement: Preferred Reporting Items for Systematic Reviews and Meta-Analyses (after Moher et al. 2009; http://www.prisma-statement.org/PRISMAStatement/FlowDiagram)

but seed generation in these plants depends on animal pollinators.

### Research Funding and Policy Documents Related To plant-pollinator Interactions in Urban Agriculture

We used the Dimensions Platform (https://www.dimensions.ai), an online research database that includes a comprehensive collection of research articles and their citations, books, grants awarded, and policy documents, to review government documents and research funding related to the conservation of pollinators and pollination ecosystem services in urban agriculture worldwide. To identify government documents and research funding, we combined the following keywords in our search: "pollinat* and urban agricult*." This search encompassed all government records and funded research projects since 1992, the first year of record. We examined each government document and research funding record separately to eliminate duplicates, and we considered only grants and government papers that focused on pollinators or pollination in urban agriculture as the primary subject of the proposed study or the conservation of pollinators or pollination in urban habitats, respectively (Fig. 1).

Our search returned 122 records on research funding related to pollination in urban agriculture. After removing grant records without monetary values, duplicates, and records that did not meet our exclusion criteria, only 25 were retained for subsequent analysis (Fig. 1). For policy actions, the search returned 53 documents after including our keywords. After further screening and removing duplicates, only six documents were retained (Fig. 1). The Dimensions Platform aggregates a large collection of interconnected global research data and policy outputs. Despite this source, most available data come from institutions and funding agencies in developed countries. Therefore, geographic bias may emerge, potentially underrepresenting grants and policy documents from developing nations.

## Results and Discussion

### Trends and Knowledge Gaps in Plant-pollinator Interactions in Urban Agriculture

The earliest studies on plant-pollinator interactions among food plants in urban agriculture were published in 2009 (Frankie et al., 2009; Ahrne et al., 2009; Matteson & Langellotto, 2009; Table 1). However, 50% of the 32 articles considered here were published between 2020 and 2024, indicating a recent surge in publications on urban agriculture (Fig. 2A). We identified 20 scientific journals that published articles on plant-pollinator interactions in urban agriculture (Table 1). Among them, *Urban Ecosystems* published the most studies (nine of 32), which is not surprising given its exclusive focus on urban green spaces. *Basic and Applied Ecology* published three papers, and *Sustainability*

**Table 1** List of the 32 articles used for the analysis and review of plant-pollinator interactions in urban agriculture

| Year of publication | Authors | | Journal title |
|---|---|---|---|
| 2009 | Frankie, GW; Thorp, RW; Hernandez, J; Rizzardi, M; Ertter, B; Pawelek, JC; Witt, SL; Schindler, M; Coville, R; Wojcik, VA | Native bees are a rich natural resource in urban California gardens | California Agriculture |
| 2009 | Ahrne, K; Bengtsson, J; Elmqvist, T | Bumble Bees (*Bombus* spp.) along a Gradient of Increasing Urbanization | PLoS ONE |
| 2009 | Matteson, KC; Langellotto, GA | Bumble Bee Abundance in New York City Community Gardens: Implications for Urban Agriculture | Cities and the Environment |
| 2013 | Gardiner, MM; Burkman, CE; Prajzner, SP | The Value of Urban Vacant Land to Support Arthropod Biodiversity and Ecosystem Services | Environmental Entomology |
| 2015 | Potter, A; LeBuhn, G | Pollination service to urban agriculture in San Francisco, CA | Urban Ecosystems |
| 2015 | Lin, BB; Philpott, SM; Jha, S | The future of urban agriculture and biodiversity-ecosystem services: Challenges and next steps | Basic and Applied Ecology |
| 2015 | Lowenstein, DM; Matteson, KC; Minor, ES | Diversity of wild bees supports pollination services in an urbanized landscape | Oecologia |
| 2015 | Taylor, JR; Lovell, ST | Urban home gardens in the Global North: A mixed methods study of ethnic and migrant home gardens in Chicago, IL | Renewable Agriculture and Food Systems |
| 2015 | Speak, AF; Mizgajski, A; Borysiak, J | Allotment gardens and parks: Provision of ecosystem services with an emphasis on biodiversity | Urban Forestry and Urban Greening |
| 2016 | Camps-Calvet, M; Langemeyer, J; Calvet-Mir, L; Gomez-Baggethun, E | Ecosystem services provided by urban gardens in Barcelona, Spain: Insights for policy and planning | Environmental Science and Policy |
| 2017 | Foster, G; Bennett, J; Sparks, T | An assessment of bumblebee (*Bombus* spp.) land use and floral preference in UK gardens and allotments cultivated for food | Urban Ecosystems |
| 2018 | Stenchly, K; Hansen, MV; Stein, K; Buerkert, A; Loewenstein, W | Income Vulnerability of West African Farming Households to Losses in Pollination Services: A Case Study from Ouagadougou, Burkina Faso | Sustainability |
| 2018 | Wilhelm, JA; Smith, RG | Ecosystem services and land sparing potential of urban and peri-urban agriculture: A review | Renewable Agriculture and Food Systems |
| 2018 | Siegner, A; Sowerwine, J; Acey, C | 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 | Sustainability |
| 2018 | Clinton, N; Stuhlmacher, M; Miles, A; Aragon, NU; Wagner, M; Georgescu, M; Herwig, C; Gong, P | A Global Geospatial Ecosystem Services Estimate of Urban Agriculture | Earth's Future |
| 2019 | Zhao, C; Sander, H.A.; Hendrix, SD | Wild bees and urban agriculture: assessing pollinator supply and demand across urban landscapes | Urban Ecosystems |
| 2020 | Tasker, P; Reid, CR; Young, AD; Threlfall, C; Latty, T | If you plant it, they will come: quantifying attractiveness of exotic plants for winter-active flower visitors in community gardens | Urban Ecosystems |
| 2020 | Lanner, J; Kratschmer, S; Petrovic, B; Gaulhofer, F; Meimberg, H; Pachinger, B | City dwelling wild bees: how communal gardens promote species richness | Urban Ecosystems |
| 2020 | Helen; Gasparatos, A | Ecosystem Services Provision from Urban Farms in a Secondary City of Myanmar, Pyin Oo Lwin | Agriculture |
| 2020 | Orsini, S; Pennisi, G; Michelon, N; Minelli, A; Bazzocchi, G; Sanyé-Mengual, E; Gianquinto, G | Features and Functions of Multifunctional Urban Agriculture in the Global North: A Review | Frontiers in Sustainable Food Systems |
| 2021 | Cohen, H; Philpott, SM; Liere, H; Lin, BB; Jha, S | The relationship between pollinator community and pollination services is mediated by floral abundance in urban landscapes | Urban Ecosystems |
| 2021 | O'Connell, M; Jordan, Z; McGilvray, E; Cohen, H; Liere, H; Lin, BB; Philpott, SM; Jha, S | Reap what you sow: local plant composition mediates bumblebee foraging patterns within urban garden landscapes | Urban Ecosystems |

**Table 1** (continued)

| Year of publication | Authors | | Journal title |
|---|---|---|---|
| 2021 | Scherr, KD; Jamieson, MA | Abiotic and biotic drivers of strawberry productivity across a rural-urban gradient | Basic and Applied Ecology |
| 2021 | Olsson, RL; Brousil, MR; Clark, RE; Baine, Q; Crowder, DW | Interactions between plants and pollinators across urban and rural farming landscapes | Food Webs |
| 2021 | Langemeyer, J; Madrid-Lopez, C; Beltran, AM; Mendez, GV | Urban agriculture – A necessary pathway towards urban resilience and global sustainability? | Landscape and Urban Planning |
| 2022 | Brom, P; Underhill, LG.; Winter, K | A review of the opportunities to support pollinator populations in South African cities | PeerJ |
| 2022 | McDougall, R; Kristiansen, P; Latty, T; Jones, J; Rader, R | Pollination service delivery is complex: Urban garden crop yields are best explained by local canopy cover and garden-scale plant species richness | Journal of Applied Ecology |
| 2023 | Nicholls, E; Griffiths-Lee, J; Basu, P; Chatterjee, S; Goulson, D | Crop–pollinator interactions in urban and peri-urban farms in the United Kingdom | Plants People Planet |
| 2023 | Nguyen, H; Schmack, JM; Egerer, M | Drivers of cultivated and wild plant pollination in urban agroecosystems | Basic and Applied Ecology |
| 2023 | Blareau, E; Sy, P; Daoud, K; Requier, F | Insect-Mediated Pollination of Strawberries in an Urban Environment | Insects |
| 2024 | Rotondi, BAR; Casanelles-Abella, J; Fontona, S; Moretti, M; Videla, M; Fenoglio, MS | Floral species evenness is the major driver of wild bee communities in urban gardens | Urban Ecosystems |
| 2024 | Ploessl, S; Willden, SA; Ingwell, LL | Invertebrate diversity in peri-urban community gardens and possible mechanisms of community assemblage | Urban Ecosystems |

**Table 2** Information and categories selected for the scientometric analysis. (adapted from Viana et al., 2012)

| Items for analysis | Categories |
|---|---|
| 1. Publication year | - |
| 2. Corresponding author's name | - |
| 3. Corresponding author's country | - |
| 4. Co-author name | - |
| 5. Article title | - |
| 6. Journal title | - |
| 7. Country of the study area | - |
| 8. Ecoregion/Climatic zone where the study was carried out | (1) tropical, (2) subtropical, (3) temperate, (4) Mediterranean, (5) Not applicable |
| 9. Nature of the method | (1) descriptive, (2) review, (3) observational (sampling), (4) experimental, (5) meta-analysis, (6) opinion |
| 10. Type of urban agriculture | - |
| 11. Pollinator dependency | (1) non-dependent, (2) little, (3) modest, (4) great, (5) essential |
| 12. Pollination vector | (1) bees, (2) other insects, (3) bats, (4) birds, (5) several groups of pollinators, (6) not specified |

Articles were surveyed in the ISI Web of Science—Science Citation Index Expanded Platform (www.webofknowledge.com) with the following search argument: "urban agricult* and pollinat*" appearing in the title, keywords, and/or abstract

and *Renewable Agriculture and Food Systems* each published two papers. The remaining journals published only one article on the topic each (Fig. 2B).

We identified seven literature reviews on plant-pollinator interactions in urban agriculture. The first review, published in 2013, examined the role of vacant lands in supporting arthropod diversity and ecosystem services (pollination) in the United Kingdom and continental Europe (Gardiner et al., 2013). The second review, published in 2015, discussed the potential of different types of urban agriculture (allotments, private gardens, rooftop gardens) to maintain plant, insect, and vertebrate biodiversity and support ecosystem services such as pollination, pest control, and climate resilience (Lin et al., 2015). Another review addressed urban pollination knowledge in South Africa, aiming to identify opportunities for pollinator conservation in urban areas and to maintain pollination services in urban agriculture, as some poor communities in South Africa often rely on urban agriculture as part of their livelihood (Brom et al., 2022). The remaining four reviews focused on the potential of urban agriculture to improve food security, multifunctionality, and sustainability. These studies reinforce the importance of urban agriculture as a habitat for pollinators, pollination, and food production (Wilhelm & Smith, 2018; Siegner et al., 2018; Orsini et al., 2020; Langemeyer et al., 2021). We also recorded case studies that investigated the potential of urban agriculture (gardens, urban farms, and allotments) to provide ecosystem services at the local scale (Taylor & Lovell, 2015; Speak et al., 2015; Camps-Calvet et al., 2016; Helen & Gasparatos, 2020). In addition, one case study estimated the value of ecosystem services, including

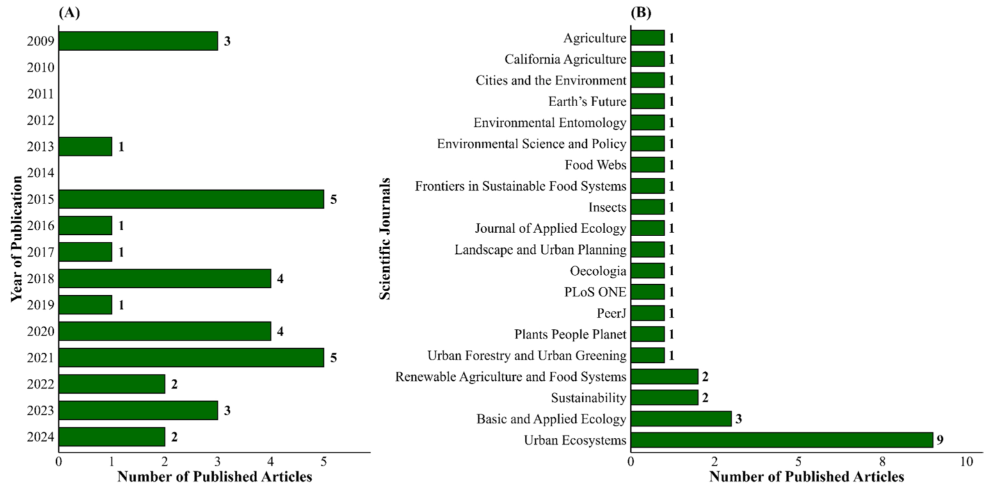


**Fig. 2** Growth of research effort over time on plant-pollinator interactions in urban agriculture (**A**) and the number of publications on this theme (**B**)

pollination, provided by urban agriculture at the global scale (Clinton et al., 2018). Nevertheless, there are few reviews on the topic. In addition to the reviews and case studies, the remaining studies were mostly observational. These studies highlight the significance of urban gardens for food production in urban ecosystems by examining their potential to provide bees with floral and nesting resources, quantifying flower visitation rates, measuring pollinator abundance and richness, or identifying pollinators of urban food plants (Frankie et al., 2009; Matteson & Langellotto, 2009; Foster et al., 2017; Zhao et al., 2019). Some have also observed how habitat variables, flower diversity, and evenness influence bee composition in urban gardens (Rotondi et al., 2024) or examined the composition of the invertebrate community, including pollinators, in peri-urban gardens, considering factors such as size, management, and crop diversity (Ploessl et al., 2024). Moreover, a fraction of papers was experimental, evaluating the reproductive success of jalapeño peppers in urban gardens and employing "mobile gardens," for instance, in residential yards, to investigate the effects of wild bees on fruit and seed set (Lowenstein et al., 2015; Cohen et al., 2020). Additionally, pollinator exclusion experiments in community gardens evaluated the effects of biotic and abiotic factors on pollination services, including fruit and seed mass (Nguyen et al., 2023). Overall, these studies addressed the following issues: (i) how urban agriculture supports pollinator diversity, (ii) the contribution of pollinators to crop yield in urban areas, and (iii) how local context influences pollination services within cities.

Additional studies are thus required to better understand and support the delivery of ecosystem services in urban agriculture at the local, regional, and global scales. In addition, we show a striking concentration (92%) of publications in extra-tropical regions (Fig. 3). Previous reviews also highlighted the lack of studies addressing plant-pollinator interactions in tropical urban ecosystems (Silva et al., 2021; Wenzel et al., 2020), and none of the existing studies focused on pollination in urban agriculture. This observed trend toward extra-tropical regions may reflect not only the current distribution of research effort but also limitations related to language and indexing. Generally, indexing platforms include predominantly English-language papers, meaning that studies published in other languages (e.g., Spanish or Portuguese) are underrepresented in the dataset.

Residential gardens and community gardens were the most targeted habitats, together accounting for 57.2% of the articles in our sample, followed by backyards, allotments, and urban farms, each representing 9.5%. Additionally, 14.3% of the articles covered more than one type of urban agriculture. The studies reveal that urban agriculture can harbor a high diversity of food plants. Across the different types of urban agriculture, a total of 71 crop species from 19 botanical families were recorded. Regarding food plant richness across the 32 studies' urban agriculture types, community gardens, residential gardens, and backyards were the richest areas, with 49, 41, and 20 crop species documented, respectively. In studies of urban farms, only 8 crop species were recorded, and in studies of allotments, only 3. However, because these studies focused on pollinator activity rather than crop inventories, these numbers may underestimate crop richness in these systems. Considering crop pollinator dependence, 73.2% (30) of all recorded food plant species were pollinator-dependent to some extent, including 17 species (56.7%) that were modestly or greatly dependent on pollinators, 30% (9 spp.) that were little dependent on pollinators, and only 13.3% for which pollinators are essential (Table 3). Thus, most of the cultivated food plants in urban agriculture surveyed in the reviewed papers rely on pollinators to some degree. In fact, residential gardens can enhance agrobiodiversity in urban ecosystems by cultivating several food plants for subsistence and small-scale sales, most of which are pollinator-dependent. Examples include apple, canola, cucumber, tomato, pumpkin, melon, broad

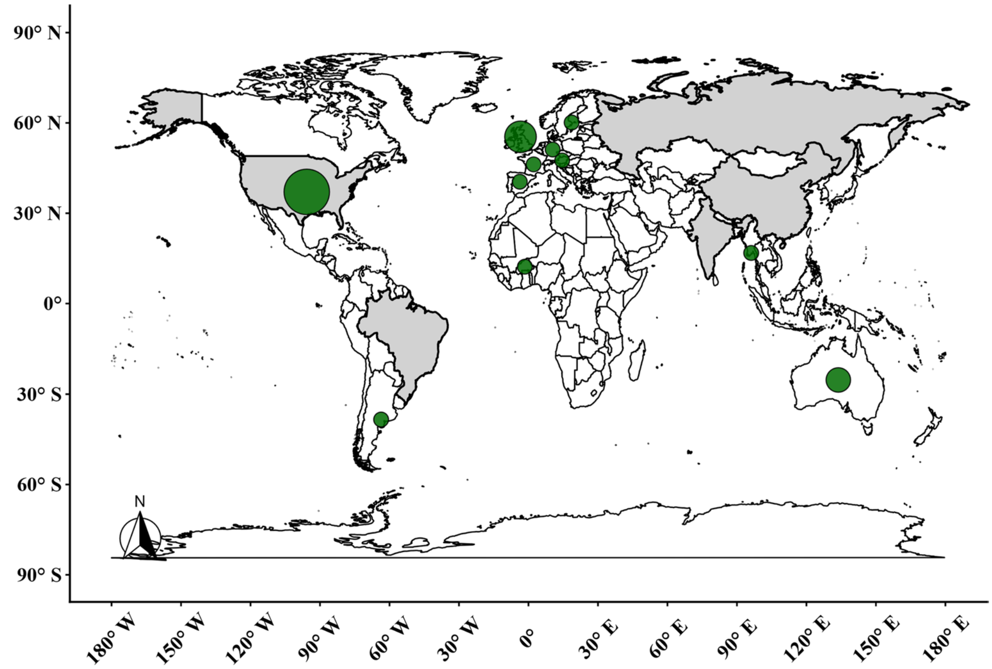


**Fig. 3** Distribution of articles on plant-pollinator interactions in urban agriculture across tropical and extratropical countries. Bubble sizes indicate the number of published articles; the highlighted countries represent the top 5 agricultural producers worldwide: China, USA, Brazil, India, and Russia

beans, and plum (Galluzzi et al., 2010; Altieri & Nicholls, 2018).

Urban agriculture can also harbor a rich diversity of pollinators. We compiled all pollinator taxa reported across studies and types of urban agriculture to provide an overview of the groups and species documented. This synthesis is descriptive because studies vary in spatial scale and sampling effort. In total, 101 pollinator species were recorded across the types of urban agriculture. Insects were by far the dominant pollinators, with Hymenoptera accounting for the majority of taxa reported, followed by Diptera, Lepidoptera, and other minor groups. Hymenoptera contributed 12 families, 43 genera, and 78 species as pollinators, with bumblebees and honeybees being the most frequently recorded species. Surprisingly, vertebrates were neither recorded nor mentioned. Considering the two richest types of urban agriculture in terms of cultivated food plant species, we report descriptively on the diversity of pollinators documented in community and residential gardens, given the heterogeneity across studies. Community gardens have the potential to harbor 63 species from four pollinator groups [Hymenoptera (46 species), Diptera (14), Lepidoptera (two), and Hemiptera (one species)], while residential gardens are home to 50 Hymenoptera species, six Diptera, and one species each of Lepidoptera and Coleoptera, as recorded by studies focusing on pollinators of crops in these systems. These figures are consistent with other reviews that recognize bees as the primary pollination vector in urban ecosystems (Wenzel et al., 2020; Silva et al., 2021; Maruyama et al., 2025). Globally, bees have been reported as the main pollinators of crops (Klein et al., 2007), increasing fruit production (e.g., Gallai and Vaissière, 2009) and quality (Garratt et al., 2014; Klatt et al., 2014). Moreover, some urban settings, such as allotments, residential gardens, and vacant lands, can support the maintenance of species-rich wild bee assemblages (Gardiner et al., 2013; Camps-Calvet et al., 2016; Silva et al., 2021).

## Research Funding and Policy Actions for Urban Agriculture

All funded pollination projects in urban agriculture were from developed nations, while developing nations received no funding. Research funding totaled ~$15 million and was distributed among three countries (Canada, the United Kingdom, and the United States). Grant values ranged from $16,503 in Canada to $6.5 million in the United States. Projects in the United States received the most funding, $14.7 million (98% of all investments), followed by projects in the United Kingdom ($165,961) and Canada ($139,384). Of the six policy documents, four were from the United Kingdom and two from Italy. However, none of these documents were strictly focused on urban agriculture; instead, they addressed the distribution, occurrence, and conservation of pollination services and/or pollinators in urban ecosystems.

The pattern of insufficient investment in research and policy actions for nature conservation in urban areas of developing nations is evident, reflecting the economic disparities that affect scientific production in many

**Table 3** List of families, species, common names, and pollinator dependence (according to Klein et al., 2007; Roubik, 2018; BPBES, 2019; Oliveira et al., 2024) for food plant species cultivated in urban agriculture, as reported in the sampled articles; the list includes 71 food plant species, and published data on pollinator dependence are available for 41 species. Lines with (-) indicate that the pollinator dependence of the food plant is unknown

| Family and crop species | Common name | Pollinator dependence |
|---|---|---|
| Amaranthaceae | | |
| *Beta vulgaris* | Beet | - |
| *Spinacia oleracea* | Spinach | - |
| Amaryllidaceae | | |
| *Allium ampeloprasum* | Leek | - |
| *Allium cepa* | Onion | Great |
| *Allium schoenoprasum* | Chives | - |
| *Allium tuberosum* | Garlic chives | - |
| Apiaceae | | |
| *Anethum graveolens* | Dill | - |
| *Apium graveolens* | Celery | - |
| *Coriadrum sativum* | Coriander | Great |
| *Daucus carota* | Carrot | Non-dependent |
| *Foeniculum vulgare* | Fennel | Great |
| *Pastinaca sativa* | Parsnip | - |
| *Petroselinum crispum* | Parsley | - |
| Asparagaceae | | |
| *Asparagus officinalis* | Asparagus | Non-dependent |
| Asteraceae | | |
| *Cichorium intybus* | Chicory | Non-dependent |
| *Cynara cardunculus* | Globe artichoke | - |
| *Helianthus annus* | Sunflower | Modest |
| *Lactuca sativa* | Lettuce | - |
| *Scorzonera hispanica* | Black salsify | - |
| Brassicaceae | | |
| *Brassica chinensis* | Kale | - |
| *Brassica oleracea* | Cauliflower | Non-dependent |
| *Brassica juncea* | Chinese Mustard | - |
| *Brassica rapa* | Turnip | Great |
| *Brassica* spp. | Cabbage | Non-dependent |
| *Eruca vesicaria* | Arugula | - |
| *Raphanus sativus* | Radish | - |
| *Sinapis alba* | White mustard | Modest |
| Cucurbitaceae | | |
| *Cucurbita maxima* | Pumpkin | Essential |
| *Cucurbita mixta* | Squash | Essential |
| *Cucurbita pepo* | Zucchini | Essential |
| *Cucurbita* spp. | - | - |
| *Cucumis melo* | Cantaloupe | Essential |
| *Cucumis sativus* | Cucumber | Great |
| Ericaceae | | |
| *Arctostaphylos* spp. | Manzanita | - |
| Lamiaceae | | |
| *Calamintha nepeta* | Calamint | - |
| *Mentha* spp. | Mint | - |
| *Ocimum basilicum* | Basil | - |
| *Origanum vulgare* | Oregano | - |
| *Rosmarinus officinalis* | Rosemary | - |
| *Salvia officinalis* | Sage | - |
| *Thymus vulgaris* | Thyme | - |
| Leguminosae | | |
| *Arachis hypogaea* | Groundnut | Little |

**Table 3** (continued)

| Family and crop species | Common name | Pollinator dependence |
|---|---|---|
| *Phaseolus coccineus* | Runner bean | Little |
| *Phaseolus vulgaris* | Bean | Little |
| *Phaseolus* spp. | - | - |
| *Pisum sativum* | Pea | Non-dependent |
| *Vicia faba* | Broad bean | Modest |
| *Vigna unguiculada* | Cowpea | Little |
| *Vigna unguiculada* subsp. *unguiculada* | Black-eyed pea | Little |
| *Vigna* spp. | Beans, green | Little |
| Malvaceae | | |
| *Abelmoschus esculentus* | Okra | Modest |
| Papaveraceae | | |
| *Papaver somniferum* | Poppy | Little |
| Pedaliaceae | | |
| *Sesamum indicum* | Sesame | Modest |
| Piperaceae | | |
| *Piper nigrum* | Pepper | Non-dependent |
| Poaceae | | |
| *Echinocloa frumentacea* | Millet | Non-dependent |
| *Sorghum guineensis* | Sorghum | Non-dependent |
| *Zea mays* | Maize | Non-dependent |
| Polygonaceae | | |
| *Rheum rhabarbarum* | Rhubarb | - |
| Rosaceae | | |
| *Fragraria* x *annassa* | Strawberry | Modest |
| *Malus domestica* | Apple | Great |
| *Prunus domestica* | Plum | Great |
| *Prunus persica* | Peach | Great |
| *Prunus* spp. | - | - |
| *Rubus fruticosus* | Blackberry | Great |
| *Rubus idaeus* | Raspberry | Great |
| Solanaceae | | |
| *Capsicum annuum* | Chillie | Little |
| *Capsicum frutescens* | Bell pepper | - |
| *Physalis ixocarpa* | Tomatillo | - |
| *Solanum lycopersicum* | Tomato | Little |
| *Solanum melongena* | Eggplant | Modest |
| Vitaceae | | |
| *Vitis vinifera* | Grape | Non-dependent |

developing countries in the Global South (Silva et al., 2021). Developed countries generally receive more research funding than developing countries, a disparity that contributes to differences in scientific output and conservation investments (Zhang et al., 2023). Overall, funding for research is one of the main challenges for scientists in developing countries (Parker et al., 2012), compounded by often inadequate infrastructure and restricted access to scientific literature (Agosti, 2006). Here, we note that all research funding for pollination in urban areas occurred in developed countries. This is one of the main issues in scientific production worldwide, creating knowledge barriers that primarily affect developing countries.

## A Roadmap Towards Agriculture-friendly Urban Landscapes

Our results suggest that interactions between food plants in urban agriculture and pollinators are an emerging topic, as evidenced by the accumulation of about half of the publications in the last three years. Overall, we observed that (1) most published articles were restricted to extra-tropical regions, (2) residential and community gardens were the most frequently studied urban agriculture habitats, (3) over 75% of all food plants recorded in the studies were pollinator-dependent, (4) Hymenoptera were the most frequently recorded pollinator group across all publications, (5) all funded projects were from developed nations, and (6) as far as we know, there are no detailed policy documents on pollination in urban agriculture. In this context, our findings reinforce the relevance of urban agriculture in supporting pollinator diversity and enhancing food production in urban ecosystems, while also highlighting a significant knowledge gap and a severe lack of investment in this topic, particularly in low-income tropical countries. In the coming decades, the world's population is projected to become increasingly urbanized, with at least 68% of people living in cities by 2050 (United Nations, 2019). This trend is faster in developing countries, where urbanization is accompanied by the emergence of slums and shanty towns, which house approximately one-third of the current urban population (UN-HABITAT, 2010). As a result, there is growing interest in urban landscapes as suitable areas for supplementary food production (FAO, 2019), which could help address some of the intractable challenges posed by the Sustainable Development Goals, such as ending poverty, zero hunger, and improving quality of life (United Nations, 2015). Urban agriculture has emerged as an important nature-based solution to reduce global food insecurity, malnutrition, and urban poverty (FAO, 2019). The Food and Agriculture Organization (FAO) has developed the Urban Food Agenda to guide discussions with decision-makers on the potential of urban farming and to develop strategies that connect urban dynamics to food production and ecological issues. The aim is to create sustainable food systems in urban areas that ensure freedom from hunger and malnutrition (FAO, 2019).

Given that most biodiversity hotspots worldwide are located in tropical regions (Myers et al., 2000) and that tropical plant diversity is higher and often depends on biotic pollination (Ollerton et al., 2011), the lack of urban biodiversity studies in these regions is concerning (McDonald et al., 2020; Silva et al., 2021). Therefore, it is crucial to prioritize research investments in the tropics to close this knowledge gap (Anderson et al., 2013; Pauchard & Barbosa, 2013). Addressing the socioeconomic challenges of food production and access in urban areas is essential to achieving SDG priorities, such as eradicating poverty and hunger (United Nations, 2019). Hence, there is an urgent need to develop alternative food systems in cities, and pollination studies in urban farming must be a high-priority research area to inform urban planning, public policy strategies, and opportunities to develop sustainable food systems in urban areas. In particular, a radical rethinking of the principles to improve the sufficiency, regeneration, distribution, and care of global agrifood systems is necessary, as agrifood systems account for many of the drivers of climate change, ecological degradation, and rural decline (McGreevy et al., 2022).

Urban agricultural areas host a variety of animal and plant species, including medicinal, ornamental, aromatic, and food plants (vegetables and fruits) (Silva et al., 2021; Maruyama et al., 2025; Royer et al., 2023). However, our focus was on plant-pollinator interactions involving food plant species, aiming to assess the potential of urban agriculture to support pollination processes essential to plant reproduction and, consequently, to food production in cities, and to highlight its potential to harbor pollinator diversity (Silva et al., 2021). Urban agriculture can indirectly sustain plant reproduction by providing floral and nesting resources for pollinators. In addition, maintaining pollinator diversity in cities requires not only the availability of flowers but also suitable nesting sites and connectivity between green spaces (Hall et al., 2017; Baldock et al., 2019; Silva et al., 2021). Furthermore, the diversity of food plants cultivated in urban agriculture may be underestimated due to limited research on this topic. Beyond our limited understanding of pollination in urban agriculture, residential and community gardens can operate as pollinator hotspots, supporting elevated pollinator diversity (Baldock et al., 2019). Cities worldwide can increase green areas to conserve bee and other pollinator diversity through urban green spaces (e.g., gardens, allotments, rooftops, and squares). These sites can provide floral resources year-round, acting as hotspots for delivering pollination services to many food and nonfood plants (Hall et al., 2017; Baldock et al., 2019; Theodorou et al., 2020; Maruyama et al., 2025; Silva et al., 2021). Insects are the main pollinator group, with bees the most dominant (Maruyama et al., 2025; Silva et al., 2021). Overall, bees pollinate several crops (Klein et al., 2007; Giannini et al., 2015; IPBES, 2016; Oliveira et al., 2024). However, despite their importance as pollinators, bee diversity is declining

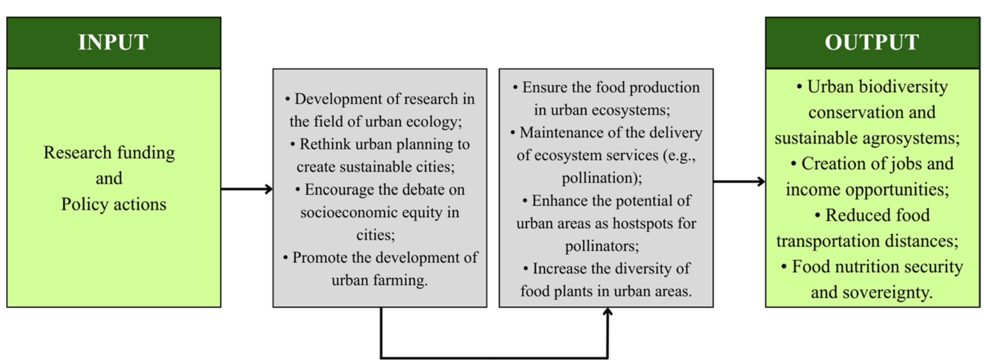


**Fig. 4** Flow diagram illustrating suggested governmental inputs for urban agriculture and its multiple benefits for biodiversity and human well-being

**Table 4** Potential roles of urban agriculture to achieve Sustainable Development Goals. (Adapted from Brito and Borelli, 2020)

| Sustainable Development Goal | Target (sensu SDGs) | The role of urban agriculture (this paper) |
|---|---|---|
| No Poverty | **1.5** Build the resilience of the poor and those in vulnerable situations and reduce their exposure and vulnerability to climate-related extreme events and other economic, social, and environmental shocks and disasters | Urban agriculture can create new employment and is a nature-based solution that is biodiversity-friendly, supporting ecosystem services in urban ecosystems and providing food for the most vulnerable people living in cities. |
| Zero Hunger | **2.1** End hunger and ensure access by all people, in particular the poor and people in vulnerable situations, including infants, to safe, nutritious, and sufficient food all year round.<br>**2.2** End all forms of malnutrition<br>**2.4** Ensure sustainable food production systems and implement resilient agricultural practices that increase productivity and production, that help maintain ecosystems, that strengthen capacity for adaptation to climate change, extreme weather, drought, flooding, and other disasters, and progressively improve land and soil quality. | Urban agriculture can be responsible for food production, such as fruits and vegetables, which could be an alternative to ensuring safe and nutritious food all year round for poor and vulnerable people living in cities, reducing food insecurity and forms of malnutrition. In addition, urban agriculture is recognized as a sustainable system of food production that provides paramount benefits for human well-being and biodiversity. The benefits for biodiversity are particularly important, as urban agriculture creates habitats with abundant resources for pollinators, such as local nesting sites and floral rewards, which can help maintain the plant-pollinator interactions of many pollinator-dependent crops cultivated in urban agriculture, ensuring food production for people. |
| Quality Education | **4.7** Ensure that all learners acquire the knowledge and skills needed to promote sustainable development, including, among others, through education for sustainable development and sustainable lifestyles, human rights, gender equality, promotion of a culture of peace and non-violence, global citizenship, and appreciation of cultural diversity and culture's contribution to sustainable development | Urban agriculture can be found in schools and used as an educational resource to develop sustainable skills in students. Students can learn about several aspects of the ecosystem services provided by urban agriculture, such as pollination. In addition, they could develop a sense of environmental awareness, food waste, and biodiversity conservation. |
| Decent work and economic growth | **8.4** Improve progressively, through 2030, global resource efficiency in consumption and production and endeavor to decouple economic growth from environmental degradation, in accordance with the 10-year framework of programs on sustainable consumption and production, with developed countries taking the lead<br>**8.9** Devise and implement policies to promote sustainable tourism that creates jobs and promotes local culture and products | As mentioned before, urban agriculture can generate employment and promote economic growth for the poor and vulnerable people living in cities. In addition, urban agriculture can be used to maintain and promote cultural aspects by cultivating food and medicinal species. |
| Sustainable cities and communities | **11.3** Enhance inclusive and sustainable urbanization and capacity for participatory, integrated, and sustainable human settlement planning and management in all countries<br>**11.4** Strengthen efforts to protect and safeguard the world's cultural and natural heritage<br>**11.7** Provide universal access to safe, inclusive, and accessible, green and public spaces, in particular for women and children, older persons, and persons with disabilities<br>**11. A** Support positive economic, social, and environmental links between urban, peri-urban, and rural areas by strengthening national and regional development planning | Urban agriculture has the potential to help create sustainable cities. There is a need to include the role of urban agriculture in urban planning, as this type of sustainable agriculture can benefit biodiversity and positively impact human well-being across several spheres, including social, economic, and health. In addition, urban agriculture plays an important role in reducing fossil-fuel use in crop production by promoting local markets and reducing transportation, with positive impacts on mitigating climate change. Social networks and collective values are strengthened through local agriculture, as the distance between producers, workers, and consumers is reduced. |
| Responsible consumption and production | **12.8** Ensure that people everywhere have the relevant information and awareness for sustainable development and lifestyles in harmony with nature<br>**12. A** Support developing countries to strengthen their scientific and technological capacity to move towards more sustainable patterns of consumption and production<br>**12. B** Develop and implement tools to monitor sustainable development impacts for sustainable tourism that create jobs and promote local culture and products | Urban agriculture can foster environmental awareness among city-dwellers, thereby promoting responsible, sustainable food consumption and production, reducing food waste, and diversifying diets. These practices could be very important for maintaining biodiversity in urban ecosystems and for reducing the expansion of traditional agriculture into natural ecosystems, which, in turn, supports biodiversity in natural forests. |

**Table 4** (continued)

| Sustainable Development Goal | Target (sensu SDGs) | The role of urban agriculture (this paper) |
|---|---|---|
| Climate action | **13.1** Strengthen resilience and adaptive capacity to climate-related hazards and natural disasters in all countries<br>**13.2** Integrate climate change measures into national policies, strategies, and planning<br>**13.3** Improve education, awareness-raising, and human and institutional capacity on climate change mitigation, adaptation, impact reduction, and early warning | Urban agriculture can contribute to climate change mitigation, as this sustainable agricultural system growing in cities can create green cover across urban landscapes. |
| Life on land | **15.1** Ensure the conservation, restoration, and sustainable use of terrestrial and inland freshwater ecosystems and their services, in particular forests, wetlands, mountains, and drylands, in line with obligations under international agreements<br>**15.2** Promote the implementation of sustainable management of all types of forests, halt deforestation, restore degraded forests, and substantially increase afforestation and reforestation globally<br>**15.3** Combat desertification, restore degraded land and soil, including land affected by desertification, drought, and floods, and strive to achieve a land degradation-neutral world<br>**15.4** Ensure the conservation of mountain ecosystems, including their biodiversity, to enhance their capacity to provide benefits that are essential for sustainable development<br>**15.5** Take urgent and significant action to reduce the degradation of natural habitats, halt the loss of biodiversity | Urban agriculture can provide suitable habitats for the growth of many food species and animals, including pollinators. Therefore, urban agriculture can promote biodiversity conservation and help to sustain life on land. |

due to land-use and climate change (Potts et al., 2010). Although pollination by bees is crucial for the reproduction of several crops (Klein et al., 2007; Oliveira et al., 2024), vertebrate pollinators (e.g., bats and birds) are also important (IPBES, 2016), yet these specialized pollination systems remain highly neglected in studies of both tropical and temperate urban areas (Silva et al., 2021; Maruyama et al., 2025).

The lack of data on plant-pollinator interactions in urban agriculture further hinders conclusions about biodiversity in these environments. Building pathways for biodiversity conservation and for realizing the full potential of urban agricultural systems to provide ecosystem services has become even more difficult. We have identified urban agriculture as having the potential to sustain biodiversity and ecosystem services, but it needs greater attention from policymakers and researchers. We therefore recommend the following for potential researchers and policymakers: (i) intensify studies of plant-pollinator interactions and/or biodiversity in urban sites supporting small-scale agriculture; (ii) conduct high-quality studies in regions outside the Global North to expand our knowledge of the potential of urban agriculture to enhance food production; (iii) research the economic, cultural, and equity contributions of pollination in urban agriculture to explore its value for local, national, and regional economies; (iv) allocate research funding for plant-pollinator interactions in urban agriculture, mainly in the tropics; (v) focus conservation policy documents on biodiversity in urban agroecosystems to promote the development of urban agriculture as a nature-based solution for maintaining biodiversity and sustainable food production.

Urban agriculture harbors a diverse array of animal and food plant species, most of which rely on pollinators to set fruit and seed. Maintaining these practices helps meet biodiversity conservation goals. By promoting the development of urban agriculture as a novel food source, decisionmakers can support local food production, strengthen local food systems, and create new economic opportunities that enhance food security and nutrition for urban populations (Fig. 4). Furthermore, urban agriculture can enhance the resilience of cities to climate change and other environmental challenges (FAO, 2021), reduce the carbon footprint of food production (Kortright & Wakefield, 2011), improve urban biodiversity (Barthel et al., 2010), and promote the conservation of urban green spaces (FAO, 2021). Hence, urban agriculture can play a critical role in building more sustainable and livable cities (Table 4; Fig. 5), providing a wide range of benefits for both humans and other organisms (Royer et al., 2023). Finally, we concur with McGreevy et al. (2022) that transforming global agrifood systems for sustainability requires moving beyond the growth paradigm. This is a major challenge because it requires reconceptualizing values, food practices, and lifestyles to enhance sufficiency, regeneration, distribution, and care. Urban agriculture could promote this necessary change by integrating ecological imperatives into urban planning to ensure the sustainable development of urban food production (Fig. 4). Notably, urban agriculture is a promising ‘win-win’ solution


**Fig. 5** United Nations Sustainable Development Goals (SDGs; United Nations, 2015) that urban agriculture could meet, and the potential roles of urban agriculture in achieving those SDGs

to address food insecurity and poverty in urban areas while also contributing to biodiversity and nature conservation.

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**Data Availability** Data is provided within the manuscript and will be available upon request.

## Declarations

**Ethical Approval** Not applicable.

**Competing interests** The authors declare no competing interests.



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