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Review

Mapping thematic evolution and collaboration networks in agricultural innovation for urban solutions

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Abstract: Urban areas are facing increasing pressure to ensure sustainable food systems, improve living standards, and reduce socio-environmental vulnerabilities. These challenges can be addressed through insights derived from globally relevant research. Using a bibliometric analysis of 4,950 filtered documents retrieved from the Scopus database (2015–2024), this study employed VOSviewer (version 1.6.20) to examine co-authorship networks, keyword co-occurrences, thematic, and evolutionary patterns of agricultural technologies for urban applications. The results indicate a steady increase in publications related to urban sustainable development, with strong international collaboration among highly productive authors and leading research institutions, particularly in major scientific hubs across Asia, Europe, North America, and Oceania. The findings reveal strong trends in innovation in urban agriculture, urban development, sustainability, and urbanization. The technological evolution of agricultural innovation for urban solutions progressed from an initial phase focused on problem definition (from early years up to mid-2019), to a system development and feasibility phase (from mid-2019 to mid-2020), and subsequently to a solution implementation phase (from mid-2020 onward), emphasizing resource optimization and enabling leading countries to enhance sustainability, productivity, and efficiency.

Keywords: Agri-tech and Innovation; bibliometric analysis; food system; urban agriculture; urban sustainable development

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1. Introduction

Nowadays, urbanization is accelerating worldwide, driving cities to confront challenges in securing food systems, managing resources, achieving climate resilience, and promoting sustainability (Lai et al., 2025; UNDESAPD, 2025). The population in urban areas is expanding, thereby limiting the capacity of traditional agricultural systems to meet the growing demand for fresh, locally produced food (Khan et al., 2024). The urban environment is facing increased pressure from limited land availability, environmental degradation, and shifting climatic conditions (Hu et al., 2025). To support urban communities, agricultural innovation is emerging through technologies and systems such as vertical farming, smart agriculture, circular resource use, and peri-urban food production, which are being recognized as a vital strategy (Verma et al., 2024; Mills, 2025; Wu et al., 2025). This is a representation of agricultural convergence, technology, and urban development that generate and expand the body of scientific knowledge.

Global research on agricultural innovations that directly support urbanized environments remains fragmented and diverse in focus, despite growing interest in urban agriculture and sustainable food systems (Dange and Lawande, 2025; Thwaites et al., 2025). Several studies vary widely across regions, development, goals, and technologies, and their contributions are distributed among different authors, institutions, and countries. This has made it difficult to systematically evaluate how research in this interdisciplinary area has progressed over time (Yan et al., 2022). For instance, the publications about urban agriculture have increased significantly year by year (Idamokoro et al., 2025); however, the intersection of urban food systems, agricultural innovation, and city planning remains under-mapped in terms of collaboration networks, evolution of technology, and the application of relevant policy (Wei et al., 2025).

These gaps can be addressed by the bibliometric analysis of global research related to agricultural innovation for urban applications, confirming the analysis of the publication trends over time to understand the growth and evolving focus of urban-oriented agricultural studies, examines the collaborative networks among authors, institutions, and countries to reveal patterns of partnership and knowledge exchange, identifies core themes relevant to urban agricultural innovation, sustainability, and resilience.

This study contributes a systematic and data-driven perspective on the knowledge landscape, bridging agriculture and urban development. The scientific progress, priority themes, networks, and influential contributions mapped in this study support more informed decision-making and strengthen strategies to advance agricultural innovation for sustainable urban futures (Mamun & Laszlo, 2025; Suryaningrum and Swasono, 2025), especially for developing cities in local and even global contexts.

Hence, this study was conducted to map the thematic evolution and collaboration networks in agricultural innovations for urban solutions. Specifically, it sought to analyze the publication trends over time in global research related to agricultural innovation for urban applications, assess the collaborative networks among influential authors, institutions, and countries working on agricultural innovations for urban solutions, evaluate the main topics of study and their evolution in urban farming innovation by seeing which keywords researchers used together most often, and determine the significance of findings for planning research and policy development in developing cities.

2. Materials and Methods

This study employed a bibliometric analysis to systematically visualize and evaluate the thematic evolution and collaboration networks in agricultural innovations for urban solutions. This study used a structured approach, encompassing data collection, extraction, and analysis, utilizing VOSviewer (version 1.6.20) for visualization and interpretation.

2.1. Data Selection

Scopus was selected as the primary database for its extensive coverage of peer-reviewed scientific literature across multiple disciplines and its robust bibliometric capabilities. Scopus ensures comprehensive data access to journal articles and reviews as filtered during searching, enabling a reliable representation of urbanization. Scopus's wide-ranging multidisciplinary coverage and citation metrics provide a reliable basis for analyzing research productivity, collaboration patterns, and technological themes and evolution.

2.2. Search Strategy

To identify publications relevant to mapping thematic evolution and collaboration networks in agricultural innovation for urban solutions, a Boolean search string was constructed and applied to the Scopus database using the TITLE-ABS-KEY fields, which restrict the search to the article title, abstract, and author keywords. The exact query used was TITLE-ABS-KEY ("urban agriculture" OR "urban solutions" OR "urban development" OR "urban sustainability" OR "urban food systems"). This search retrieves any publication containing at least one of these exact phrases within the specified fields. The use of quotation marks ensures that only the complete phrases are matched, while the OR operator broadens the search to include multiple related terms. Each keyword was carefully selected to capture key aspects of urban agricultural research: *urban agriculture* focuses on farming practices within cities; *urban solutions* cover innovations addressing urban challenges; *urban development* encompasses planning and infrastructure intersecting with agriculture; *urban sustainability* includes environmentally and socially sustainable practices; and *urban food systems* address the broader supply chain from production to consumption. This initial search forms the foundational dataset for analyzing thematic evolution and collaboration networks in urban agricultural innovation, ensuring comprehensiveness while maintaining relevance to the study's focus. The constructed Boolean search string was entered into the "search documents" section of the Scopus database/Scopus search interface, initially retrieving 73,350 publications; nonetheless, many were not directly relevant to urban agricultural innovation, including papers from unrelated fields or lacking focus on technologies and sustainability. Therefore, filtering by year range, keywords, subject areas, and document types was necessary to refine the dataset and ensure that only high-quality, relevant publications were included for analysis of thematic evolution and collaboration networks.

A year range filter was applied, limiting publications to the period 2015–2024. The year 2015 was chosen as the starting point because it marks the period when urban technologies began to achieve significant influence on agricultural innovation (Dange and Lawande, 2025), heralding the introduction of novel approaches and transformative practices within urban agriculture and related fields. Extending the search to 2024 ensures that the dataset includes the latest developments, thereby capturing recent trends, collaboration patterns among researchers, emerging technological themes, and the evolving landscape of leading journals.

To further emphasize the dataset on publications most relevant to urban agricultural innovation, the search results were filtered using the Scopus database keyword options. Specifically, the search was limited to include three key terms: Urban Development, Urban Agriculture, and Urban Sustainability. These keywords were selected to capture studies addressing core aspects of urban agriculture, sustainable urban food systems, and urban solutions that integrate technological and environmental considerations.

To refine the dataset, the search results were further limited to two subject areas using the Scopus database filter options: Engineering and Agricultural and Biological Sciences. These subject area filters were applied to focus on publications directly relevant to urban agricultural innovation and technological or sustainability aspects, while excluding unrelated fields such as social sciences or economics.

The search in the Scopus database was further refined by limiting the document types to articles and review papers. This filtering was applied to ensure the inclusion of peer-reviewed or methodologically rigorous publications, thereby enhancing the reliability, consistency, and scholarly relevance of the bibliometric dataset while excluding less formal document types such as conference papers, notes, editorials, and book chapters.

This comprehensive filtering process, which resulted in a final dataset of 4,950 publications, enhanced the relevance of the dataset, reduced noise and irrelevant records, improved the accuracy of bibliometric indicators, facilitated comparative and trend analyses, and ensured that the dataset was manageable for detailed mapping of thematic evolution and collaboration networks in agricultural innovation for urban solutions.

2.3. Data Extraction

The search yielded 4,950 documents that met the selection criteria. These documents were analyzed for the years 2015 to 2024, and their contents were extracted in CSV format on November 27, 2025, for use in network and overlay mapping via VOSviewer.

2.4. Analytical Tools and Visualization

VOSviewer (Version 1.6.20) was used for bibliometric analysis due to its robust capabilities in mapping and clustering bibliometric data. The following analyses were conducted:

1. Co-authorship Analysis - Mapping collaborations among authors, institutions, and countries.
2. Co-occurrence Analysis - Identifying frequently occurring keywords and clustering them into thematic research areas, and examining the temporal evolution of research topics in the field.

For network visualization, VOSviewer (version 1.6.20) was used to generate graphical representations of author networks, institutional and country collaborations, and keyword co-occurrence clusters. Overlay visualization was also performed to examine the evolution of keyword occurrence over time. Networks were constructed using the full-counting method, and association strength normalization was applied to standardize link weights and accurately represent the strength of relationships between nodes. Keywords were sourced from author-provided keywords, and data cleaning included merging synonyms, standardizing spelling, and removing irrelevant or general terms to ensure meaningful thematic clusters.

The threshold criteria for VOSviewer analyses are shown in Table 1. Thresholds were set to

Table 1. Threshold Criteria for VOSviewer Analysis.

Type of Analysis	Unit of Analysis	Minimum Number of Documents/Occurrences	Selected Threshold
Co-authorship	Authors	5	94
Co-authorship	Organizations	5	619
Co-authorship	Countries	5	81
Co-occurrence	Author Keywords	5	824

balance network clarity and data comprehensiveness: lower thresholds could result in overly dense networks, making patterns difficult to interpret, while excessively high thresholds might exclude important connections.

2.5. Limitations of the Tools Used

While Scopus is comprehensive, it may exclude some region-specific or non-English publications, potentially causing a slight geographic bias. The VOSviewer software may oversimplify complex relationships in highly dense datasets, limiting the granularity of network interpretations.

2.6. Interpretation and Writing Support

The figures depicting clusters, patterns, and collaboration networks generated using VOSviewer were analyzed and interpreted by the author. An AI-assisted language tool was utilized solely to enhance clarity of expression, refine academic language, and improve the organization and articulation of explanations. All investigative decisions, particularly those related to the technical construction of the results and the corroboration of findings, were undertaken exclusively by the author.

2.7. Summary of the methods

For a comprehensive understanding of the methods, Table 2 presents the step-by-step procedures for the Scopus search interface and VOSviewer.

Table 2. Step-by-step procedures for searching Scopus documents in the Scopus search interface and generating maps through VOSviewer.

Steps	Procedures
1. Formulating a query.	The Scopus query was constructed based on the research objectives and applied to the TITLE-ABS-KEY fields as follows: TITLE-ABS-KEY ("urban agriculture" OR "urban solutions" OR "urban development" OR "urban sustainability" OR "urban food systems").
2. Accessing the Scopus database.	The Scopus database was queried via the Advanced Search interface to ensure systematic and reproducible record retrieval.
3. Executing the search.	The Scopus query was entered into the Advanced Search interface and executed to retrieve the initial set of documents.
4. Applying filters and dataset retrieval.	The initial set of documents retrieved from Scopus was refined using the following criteria: publication years 2015–2024; inclusion of keywords related to urban development, urban agriculture, and urban sustainability; subject areas limited to Engineering and Agricultural and Biological Sciences; and document types restricted to articles and reviews. No filters were applied for language, affiliation, funding sponsor, country/territory, and source type. The final dataset consisted of 4,950 documents
5. Analyzing temporal distribution.	The number of documents published per year was analyzed using Scopus's "Analyze Results" function.
6. Exporting and preparing the dataset.	The 4,950 documents retrieved from Scopus were exported in CSV format, including all necessary bibliographic information such as authors, titles, abstracts, keywords, and source details. Fields not required for the planned bibliometric and science mapping analyses, including correspondence addresses and funding information, were excluded to streamline the dataset, reduce redundancy, and improve data processing efficiency, while retaining

	all core information necessary for performance analysis and network visualization.
7. Bibliometric mapping using VOSviewer.	The exported dataset was imported into VOSviewer by selecting the option to create a map based on bibliographic data and reading data from bibliographic database files. The types of analysis—co-authorship and co-occurrence—and the units of analysis—authors, organizations, countries, and author keywords—were specified in accordance with the study objectives. The full-counting method was applied, and a minimum occurrence threshold was set to select the most relevant items. Bibliometric network maps were then generated, including network visualization of co-authorship (authors, organizations, countries) and co-occurrence of author keywords, as well as overlay visualization of keyword co-occurrence. The resulting maps were refined for clarity and exported as high-resolution images for interpretation and presentation.

3. Results

3.1. Documents Published by Year

The number of relevant documents by year is presented in Figure 1. The result indicates that a total of 4,950 documents were obtained, considering the study's filtering criteria. These documents reflect a steady growth from 2015 to 2019 (n = 1,593), followed by a sharp increase from 2020 to 2021 (n = 1,201), a slight decline in 2022 (n = 657), and a subsequent recovery with continued growth from 2023 to 2024 (n = 1,499).

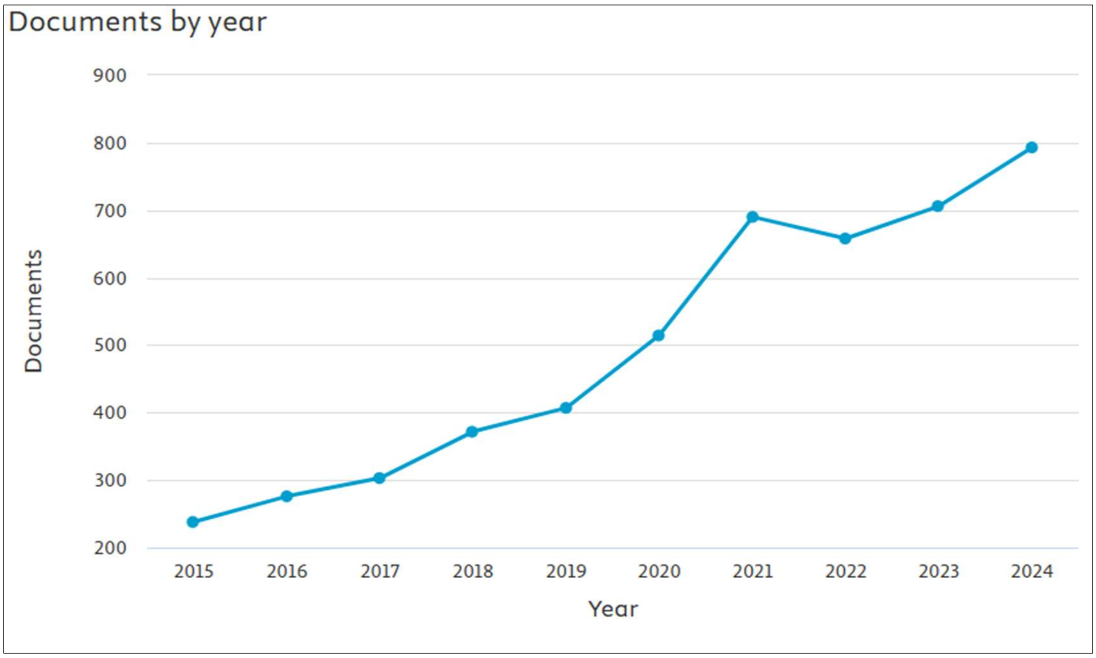

Figure 1. The increasing number of relevant documents published each year.

3.2. Network Visualization of Co-Authorship of Authors

The network visualization of co-authorship among authors is shown in Figure 2, and the top 5 authors with the highest total link strength are listed in Table 3. The VOSviewer mapped that Rieradevall, Joan Rieradevall I (blue cluster); Josa, Alejandro; Gabarrelli I Durany, Xavier; Buerkert, Andreas; and Steiner, Christoph (light blue cluster) are the top 5 authors who obtained the highest total link strength of 37, 24, 23, 21, and 21, respectively. The authors with a higher TLS, not visible in the visual, belong to separate connected components that are not linked to the main collaboration network. The VOSviewer displays only the largest connected component to ensure interpretability, thereby excluding highly productive but structurally independent collaboration groups from the visual map (CSTS, n.d.).

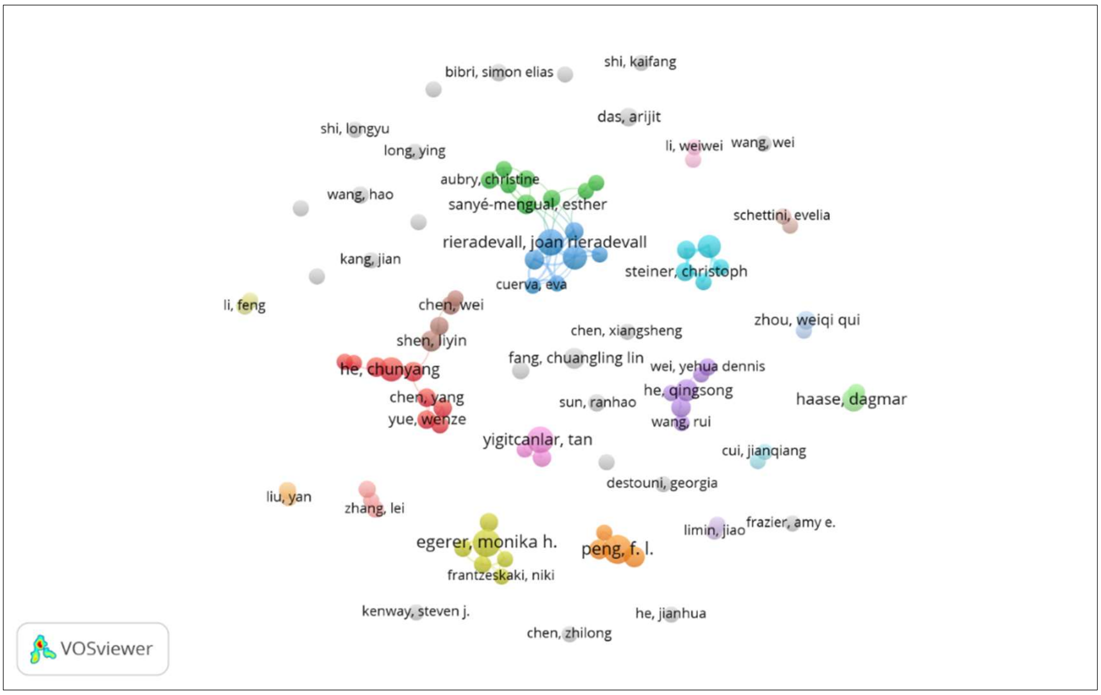

Figure 2. The VOSviewer network visualization of co-authorship indicates that Joan Rieradevall (blue cluster) ranks first in terms of total link strength, reflecting the highest level of collaborative connectivity among authors.

Table 3. The top five authors with the highest total link strength were mapped using VOSviewer.

Authors	Documents	Citations	Total Link Strength
Rieradevall, Joan Rieradevall I	14	576	37
Josa, Alejandro	8	407	24
Gabarrelli I Durany, Xavier	12	449	23
Buerkert, Andreas	11	209	21
Steiner, Christoph	7	1267	21

3. 3. Network Visualization of the Co-Authorship of Organizations

The network visualization of co-authorship among organizations is presented in Figure 3, and the top 5 with the highest total link strength are also in Table 4. The VOSviewer mapped that the University of Chinese Academy of Sciences obtained the highest total link strength (79), followed by the Institute of Geographic Sciences and Natural Resource Research (36), Research Center for Eco-Environmental Sciences (30), School of Resource and Environmental Sciences, Wuhan University (30), and Wuhan University, Wuhan, Hubei, China (21).

While the quantitative data identifies five primary organizations as influencers in total link strength, not all are noticeable in the global network visualization. Specifically, the Institute of Geographic Sciences and Natural Resources Research (CAS), the Research Center for Eco-Environmental Sciences (CAS), and Wuhan University are present in the dataset but concealed in the

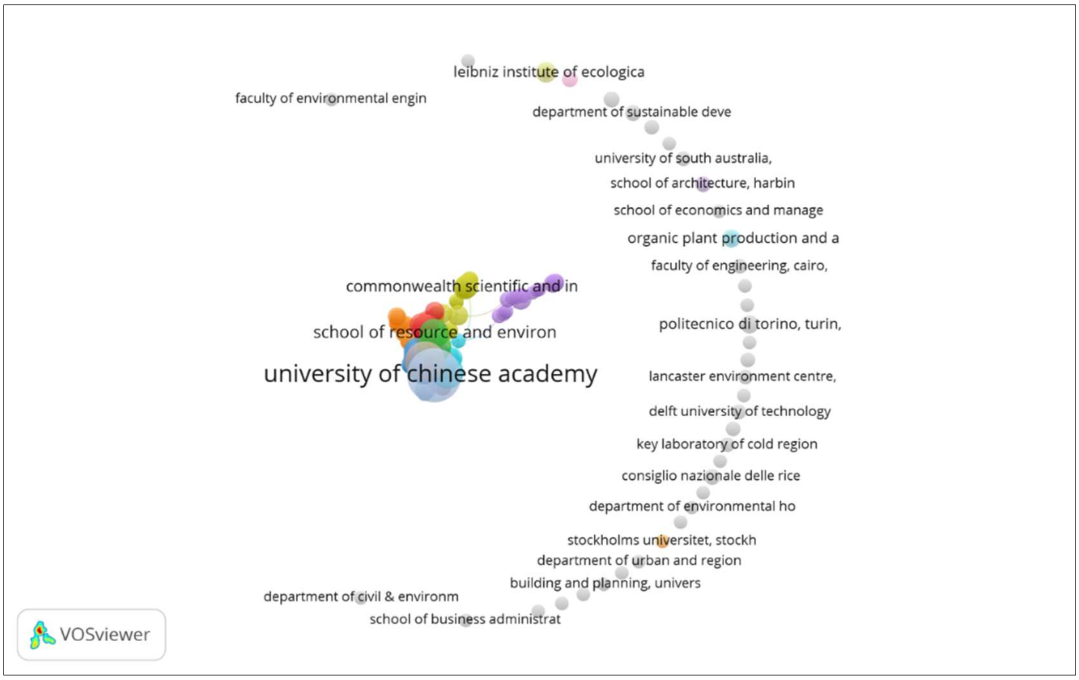

Figure 3. The VOSviewer network visualization of the co-authorship among organizations with the University of Chinese Academy of Sciences (light blue cluster) obtained the highest total link strength.

Table 4. The top five most influential organizations with higher total link strength were mapped using VOSviewer.

Organizations	Documents	Citations	Total Link Strength
University of Chinese Academy of Sciences	77	2428	79
Institute of Geographic Sciences and Natural Resource Research	45	3472	36
Research Center for Eco-Environmental Sciences	30	356	30
School of Resource and Environmental Sciences, Wuhan University	23	1437	30
Wuhan University, Wuhan Hubei, China	31	1985	21

visual output. This lack of visibility is attributed to VOSviewer's label overlap inhibition algorithm, which prioritizes legibility of enormous labels in high-density areas (VOSviewer Manual 2025). In this analysis, the strong collaboration between the various Chinese Academy of Sciences (CAS) branches and Wuhan University, which is revealed under several naming variants, creates a dense 'node stack.' Because these entities are geographically and mathematically centered in the same collaborative clusters (primarily the light blue and light green/orange clusters), the software presents only the most dominant representative label to prevent graphical clutter (VOSviewer 2025).

Accordingly, the nonappearance of these labels does not replicate a lack of research impact but rather confirms their intense integration and central placement within the core research network.

3.4. Network Visualization of Co-Authorship of Countries

The co-authorship network among countries is illustrated in Figure 4, with the top five countries exhibiting the highest total link strength presented in Table 5. The VOSviewer revealed that China (yellow cluster) obtained the highest total link strength (514), followed by the United States (458), the United Kingdom (347), Germany (243), and Australia (227). The visual displays show that the yellow cluster, dominated by China, forms a powerful Asia-centered research hub. China's large node size and widespread links with countries (e.g., Singapore, Vietnam, Malaysia, and Macau) designate both high productivity and a determined global influence.

The red cluster represents the principal Western research core, uniting leading scientific nations including the United States, Germany, Italy, France, Spain, Sweden, Belgium, and Australia. The density of networks within this cluster reflects a mature, deeply integrated collaborative framework. Australia's positioning within this core cluster leads to its tight alignment with major Western research networks and its significant role in global research collaboration, mostly together with the

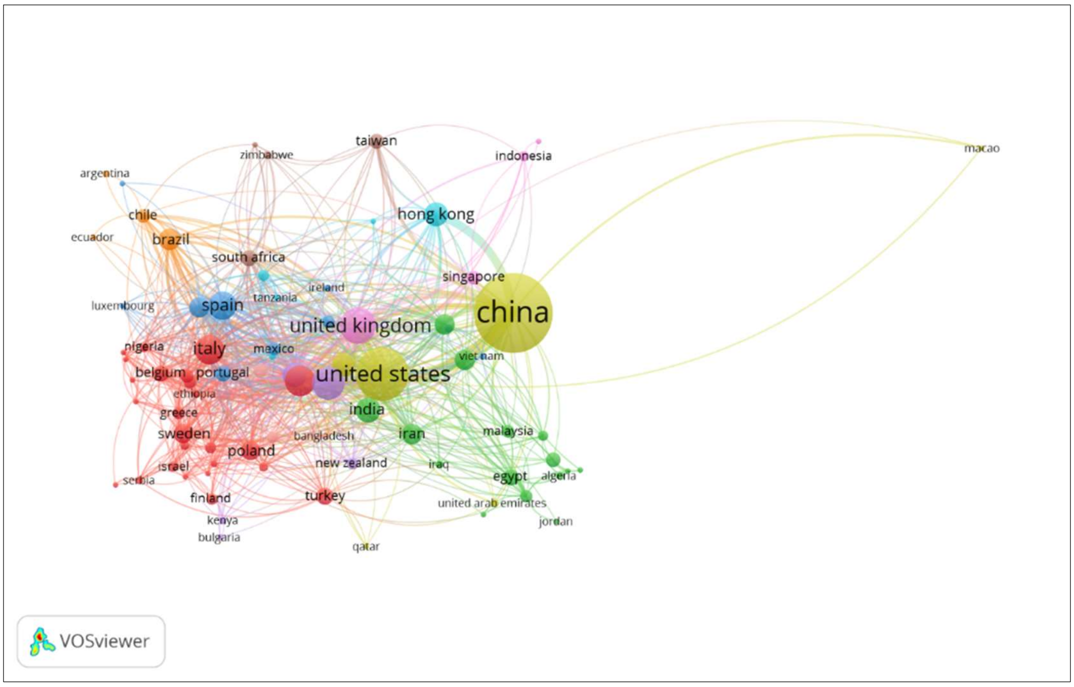

Figure 4. The VOSviewer network visualization of co-authorship among countries identifies China as the leading contributor.

Table 5. The top five most influential countries with higher total link strength were mapped using VOSviewer.

Countries	Documents	Citations	Total Link Strength
China	1293	49169	514
United States	585	23438	458
United Kingdom	279	12160	347
Germany	201	7752	243
Australia	228	10179	227

United States and key European partners.

The purple cluster, representing the United Kingdom, functions as a critical link between the Western (red) and Asian (yellow) clusters. The central positioning of the United Kingdom and its extensive cross-cluster linkages indicate its role as a key conduit for global knowledge exchange.

The green cluster highlights a developing collaboration community linking South Asia and the Middle East, including India, Iran, Egypt, Algeria, Jordan, and Malaysia, reflecting the growing participation of these regions in the global research network.

The blue cluster, centered on Spain, links parts of Southern Europe, Africa, and Latin America, exemplifying regionally focused but globally connected collaboration patterns.

3.5. Network Visualization of Co-Occurrence of Author Keywords

The network visualization of the co-occurrence of the author keywords is presented in Figure 5, and the top 5 main topics with the highest total link strength are also in Table 6. The VOSviewer analysis revealed that the main topics are urban agriculture (purple cluster) with a total link strength of 752, followed by urban development (red cluster) (615), urban sustainability (green cluster) (446),

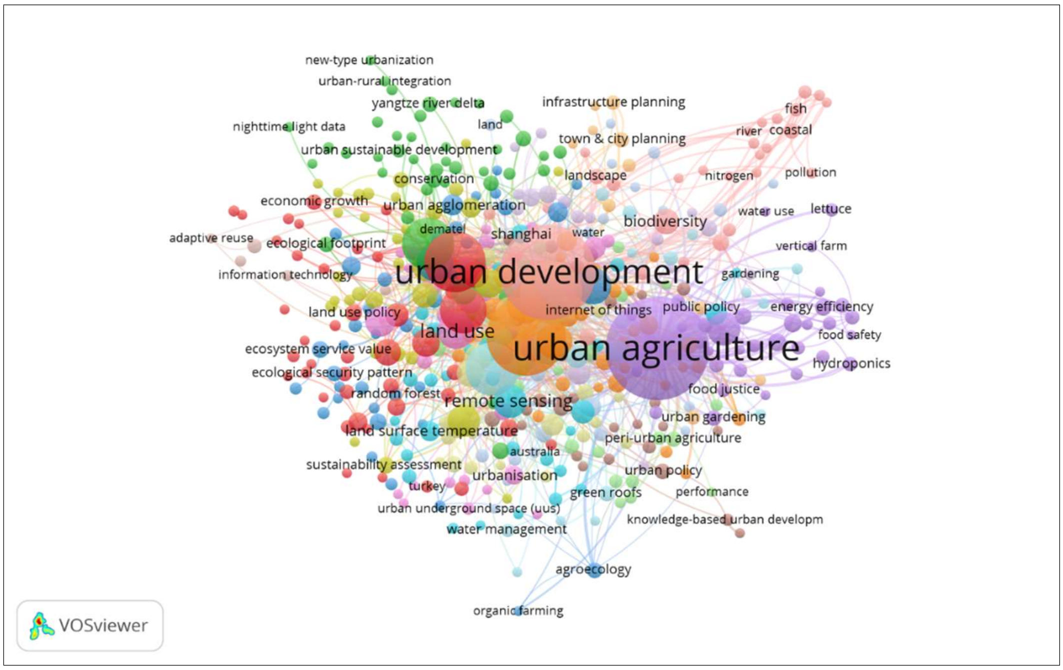

Figure 5. The VOSviewer network visualization of author keyword co-occurrence highlights *urban agriculture* (purple cluster) and *urban development* (light pink cluster) as the primary topics.

Table 6. The top five author keywords with higher occurrence in the documents were mapped using VOSviewer.

Author Keywords	Occurrences	Total Link Strength
Urban Agriculture	487	752
Urban Development	416	615
Urban Sustainability	286	446
Sustainability	177	361
Urbanization	169	244

sustainability (green cluster) (361), and urbanization (blue cluster) (244).

3.6. Overlay Visualization of Co-Occurrence of the Author Keywords

The overlay visualization of the co-occurrence of the author keywords is presented in Figure 6. In the overlay mapping via VOSviewer, the numerical values on the color scale (2019.0, 2019.5, 2020.0, 2020.5, and 2021.0) represent the average publication year of the documents in which each keyword appears. These values are expressed in a decimal-year format, such that intermediate values (e.g., 2019.5 or 2020.5) indicate that the associated keyword is, on average, distributed across publications from adjacent years. Accordingly, the color gradient represents the relative temporal positioning of research themes, with lower values reflecting earlier research emphasis and higher values indicating more recent or emerging topics. These values should therefore be interpreted as a continuous temporal indicator rather than as discrete time intervals or analytically defined phases.

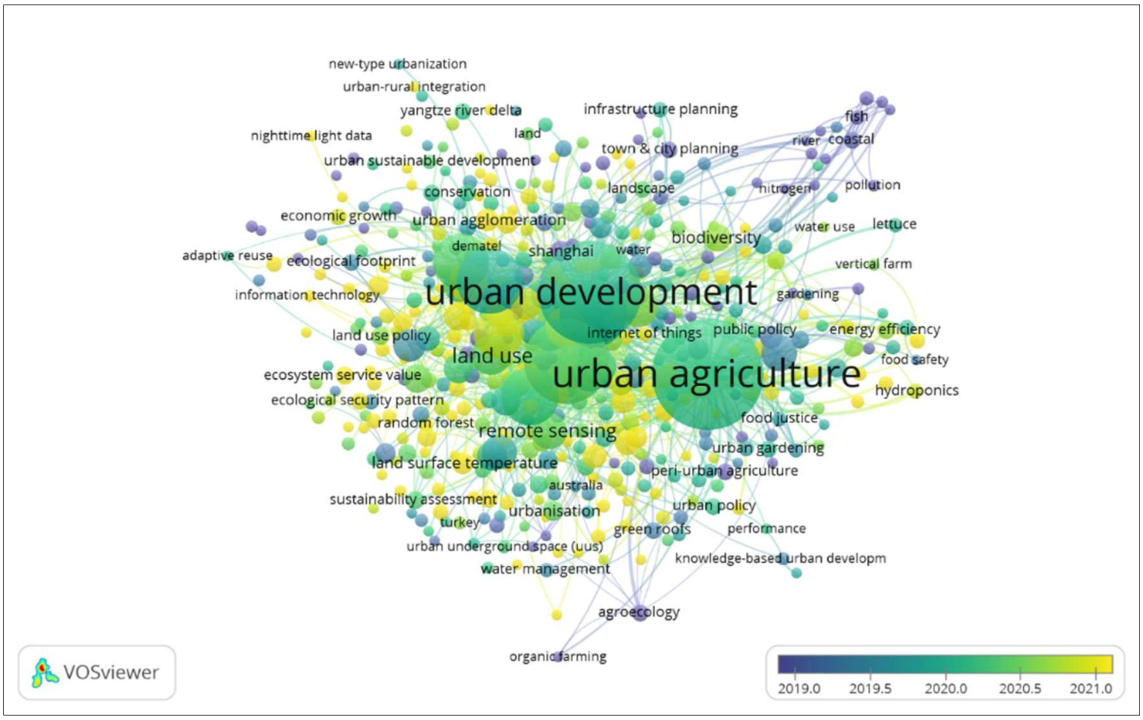

Figure 6. The VOSviewer overlay visualization of the co-occurrence of the author keywords shows that the rapid advancement of technologies for urban development began in 2020.

The VOSviewer analysis revealed that the evolution of technologies in agricultural innovation towards urban solutions started by defining the Problem as a foundation context from the previous years to 2019.5 (purple to blue cluster), as the keywords emphasize the historical foundation, highlighting the core challenges of urban development and land use that drive the need for innovation, as also confirmed by Citaristi (2022). This was followed by establishing viability or system development from 2019.5 to 2020.5 (light blue to green cluster), as the keywords highlight Sustainability, Policy, and Governance, reflecting efforts to establish the frameworks necessary for the long-term success of innovation pathways, as also reported by Canton (2021). Finally, the implementation of solutions emerged from 2020.5 to 2021 (yellow green to yellow cluster), as the keywords such as Vertical Farming, Hydroponics, and other high-tech solutions, along with resource optimization, enabled leading countries to maintain sustainability, productivity, and efficiency, as also discussed by Dutta et al. (2025), Kluczkovski et al. (2025), Padhiary et al. (2025), and Zareba et al. (2025).

Notably, the color scale in the map (Figure 6) visually concentrates between approximately 2019 and 2021. This apparent mismatch does not indicate exclusion of later records but rather reflects the distribution of keyword occurrences within the dataset. Because overlay colors are computed from the mean publication year of each keyword's occurrences, recently emerging terms from 2022–2024 have relatively low frequencies and shorter citation windows, causing them to appear less prominently or to cluster near the upper end of the scale. Additionally, database indexing lag for the most recent years and the threshold settings used in keyword inclusion further compress the visible temporal spread.

To provide an interpretable structure while remaining faithful to the data, the period 2015–2024 was cautiously divided into three analytically derived phases based on (i) inflection points in annual publication growth, (ii) shifts in keyword density and co-occurrence patterns, and (iii) the temporal gradients shown in the overlay map. Phase 1 (2015–2018) represents the formative stage, characterized by relatively few publications and the dominance of foundational keywords such as urban agriculture, urban development, and land use. Phase 2 (2019–2021) represents the expansion stage, characterized by a substantial increase in both publication volume and thematic diversity. During this period, terms such as *remote sensing*, *Internet of Things*, and *sustainability assessment* emerged, reflecting a broadening of methodological and technological approaches. Phase 3 (2022–2024) captures the most recent but still emerging developments, including vertical farming, hydroponics, energy efficiency, and urban food systems; however, these appear in lighter or transitional colors in the overlay due to their lower cumulative occurrence and shorter time exposure.

Nevertheless, because overlay visualization represents a continuous temporal gradient rather than discrete breaks, the phase boundaries should be interpreted as heuristic rather than absolute. Accordingly, the overlay map is also discussed as a continuous evolution of themes across 2015–2024 to avoid over-segmentation and to remain fully representative of the dataset.

4. Discussion

The temporal distribution of the 4,950 documents reveals a clear increase in research on agricultural innovation for urban solutions, characterized by steady growth from 2015 to 2019, a rapid increase during 2020–2021, a short-term decline in 2022, and renewed growth through 2023–2024. This pattern reflects the evolution of urban agriculture from a niche research topic into a priority area, responding to escalating challenges related to urban food insecurity, land scarcity, and sustainability, particularly during and after the COVID-19 period (Gunapala et al., 2025; Senthamizh, 2025). The post-2022 recovery coincides with a growing emphasis on technology-driven approaches, such as vertical farming, hydroponics, precision agriculture, and digitally enabled food systems, which are increasingly framed as viable solutions for highly urbanized contexts (Fei et al., 2025). Recent studies further indicate that innovation in urban agriculture is becoming more interdisciplinary, integrating smart technologies, governance frameworks, and socio-economic dimensions to enhance resilience and sustainability within urban food systems (Adeyemi et al., 2025). The increasing publication trend in 2023–2024 highlights not only intensified academic interest but also a broader shift toward recognizing agricultural innovation as a central component of sustainable urban development and resilient city food systems.

Research on agricultural innovation for urban solutions is increasingly shaped by a core group of highly interconnected scholars who function as collaborative and intellectual hubs within the field. Authors such as Rieradevall, Joan; Josa, Alejandro; Gabarrelli I Durany, Xavier; Buerkert, Andreas; and Steiner, Christoph exhibit high total link strength, indicating strong co-authorship ties and intensive collaborative relationships, which are characteristic of mature and interdisciplinary research domains (van Eck and Waltman, 2010). Their central positions suggest a significant role in linking thematic areas related to sustainability assessment, resource efficiency, and innovation pathways relevant to urban agriculture, thereby facilitating knowledge integration across research clusters. Such dense collaboration patterns are consistent with recent findings that progress in urban agricultural innovation increasingly depends on networked research efforts to address complex urban challenges, including food security, environmental sustainability, and system resilience (Adeyemi et al., 2025; Senthamizh, 2025). The co-authorship network illustrates that technological pathways for urban agricultural solutions do not evolve in isolation but emerge through sustained collaboration among leading researchers, facilitating the dissemination of ideas, methods, and innovations across the urban agriculture research landscape.

The University of the Chinese Academy of Sciences exhibits the highest total link strength, highlighting its central role in coordinating and contributing to research across organizational boundaries, followed by the Institute of Geographic Sciences and Natural Resources Research, and the Research Center for Eco-Environmental Sciences. The prominence of these institutions reflects the systematic integration of urban agriculture, environmental science, and resource management within large, multidisciplinary research organizations, which are well-positioned to advance technological pathways such as sustainable urban food systems, environmental impact assessment, and resource-efficient agricultural innovations. Similar hierarchical collaboration patterns have been reported in recent bibliometric studies, where highly connected institutions play a dominant role in shaping research priorities and fostering international collaboration, thereby facilitating innovation diffusion while also concentrating knowledge production within specific organizational networks (van Eck & Waltman, 2010; Adeyemi et al., 2025; Senthamizh, 2025). This institutional concentration suggests that future progress in urban agricultural innovation may increasingly depend on expansion of cross-institutional and global collaborations to promote broader knowledge exchange and more inclusive technological development.

China is establishing a central Asia-centered hub that links with countries such as Singapore, Vietnam, Malaysia, and Macau, reflecting both high productivity and major global influence (Zhang et al., 2025). The United States, the United Kingdom, Germany, and Australia form a Western research core characterized by dense interconnections, reflecting a mature and highly integrated collaboration structure that drives innovation in urban agricultural practices (Verma et al., 2025). The United Kingdom occupies a key bridging position between Asian and Western clusters, facilitating cross-regional knowledge exchange that is essential for translating research outputs into practical urban solutions. Emerging regions, including South Asia and the Middle East (e.g., India, Iran, Egypt, Algeria, Jordan, and Malaysia), as well as Spain as a linking hub across Southern Europe, Africa, and Latin America, highlight the growing involvement of these areas in shaping the future trajectory of urban-focused agricultural innovation. These findings indicate that research influence and technological development in agricultural innovation are increasingly organized around regional hubs and cross-regional partnerships, underscoring the critical role of global research networks in addressing complex urban challenges.

The main research areas in agricultural innovation for urban solutions are urban agriculture, followed by urban development, urban sustainability, and urbanization. The prominence of these keywords indicates that the field has evolved toward a highly integrated research framework, reflecting the growing recognition that sustainable urban futures depend on the coordinated interaction of urban growth management, food systems, and environmental governance. In particular, urban agriculture has emerged as a central component of contemporary urban development and sustainability policy, serving as a practical integrative link between technological innovation, environmental management, and community resilience (Alumasa and Magnaye, 2025; Saputra et al., 2025; Tabrez, 2025). This trend underscores the importance of interdisciplinary approaches in developing agricultural innovations that not only enhance urban food security but also support ecological sustainability and equitable urban development.

From the early years up to mid-2019, research primarily focused on problem definition, addressing key urban development and land-use challenges that drive the need for agricultural innovation (Citaristi, 2022). Between mid-2019 and mid-2020, studies emphasized feasibility and system-level frameworks, with prominent keywords such as sustainability, policy, and governance, reflecting efforts to establish the structural, regulatory, and social foundations necessary for viable innovation pathways (Canton, 2021). From mid-2020 to 2021, the research focus shifted toward solution-oriented applications, highlighting the adoption of advanced technologies such as vertical farming, hydroponics, and resource optimization to enhance productivity, efficiency, and sustainability in urban agriculture (Dutta et al., 2025; Kluczkovski et al., 2025; Padhiary et al., 2025; Zareba et al., 2025). The development of these urban agricultural technologies has important implications, as it demonstrates how research and innovation can respond to urban challenges, inform policy and investment priorities, and provide scalable models for sustainable urban food systems. The progression from problem identification to applied solutions underscores the critical role of integrated technological, governance, and sustainability frameworks in shaping the future of urban agriculture and highlighting the potential of innovation to generate both environmental and socio-economic benefits.

5. Conclusions

The research impact on technologies for urban solutions is increasingly structured around powerful regional hubs, with China leading the Asia-centered network, Western nations upholding a profoundly central research core, the United Kingdom serving as a vital bridge for cross-regional knowledge exchange or sharing, and evolving regions in South Asia, the Middle East, and Southern Europe obtaining planned importance. Beyond national collaboration patterns, the intellectual structure of the field is secured by a group of prominent authors led by Rieradevall, Joan; Josa, Alejandro; Gabarrelli I Durany, Xavier; Buerkert, Andreas; and Steiner, Christoph who have high publication output and strong total link strengths indicating them as central drivers of conceptual development, methodological innovation, and the diffusion of technological knowledge across the global urban agriculture research community. The field has evolved toward an integrated research framework in which urban agriculture, urban development, sustainability, and urbanization converge as dominant research foundations. This evolution follows a practical path from early problem identification and governance frameworks to the application of advanced urban agricultural technologies, including vertical farming, hydroponics, and resource-optimization systems. These findings validate that the future of agricultural innovation for urban environments is being shaped by the combined influence of globally linked collaboration networks, leading to the interdisciplinary integration and the strategic deployment of emerging technologies to build resilient, sustainable, and efficient urban food systems.

Therefore, the following are recommended:

1. Encourage collaboration among key authors and research organizations to translate the mapped research trends into a clear, strategic roadmap for agricultural innovation in developing urban areas.
2. Use the roadmap to explicitly define the optimal roles of high-tech solutions (e.g., vertical farming, hydroponics) to optimize resource utilization and guide municipal/city policy, zoning, and public investment decisions.
3. Prioritize the integration of the solutions into urban infrastructure, ensuring they contribute to the city's overall circular economy goals.
4. Leverage the mapped trends to pinpoint and advocate for targeted research and development funding opportunities for urban agriculture projects.

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6. References

1. Adeyemi TR, Afolabi H, Adetayo OD, Oyedele OI (2025): Urban agriculture and food systems: A tool for sustainable development. International Journal of Research 12, 138–142. https://doi.org/10.51244/IJRSI.2025.12010013

2. Alumasa SU, Magnaye DC (2025): Urban farming and food security nexus for food sovereignty and food system planning: The case of a highly urbanized city in Metro Manila, Philippines. International Journal of Research and Innovation in Applied Science 10(5), 926–942. https://doi.org/10.51584/IJRIAS.2025.100500083

3. Canton H (2021): Organisation for Economic Co-operation and Development—OECD. In The Europa Directory of International Organizations, pp. 677–687. Routledge. https://doi.org/10.4324/9781003179900-102

4. Centre for Science and Technology Studies (CSTS) (n.d.): VOSviewer online documentation: Linking to a visualization. Available from: https://app.vosviewer.com/docs/sharing/linking/ [12 December 2025]

5. Chimi PM, Nkoué BB, Kamdem MEK, Pokam EYN, Ngamsou KA, Yonga G, Mala WA (2025): Trends in agricultural sustainability research: a 40-year bibliometric review. Discover Environment 3(1), 120. https://doi.org/10.1007/s44274-025-00269-9

6. Citaristi I (2022): United Nations Human Settlements Programme—UN-Habitat. In The Europa Directory of International Organizations, pp. 240–243. Routledge. https://doi.org/10.4324/9781003292548

7. Dange P, Lawande N (2025): Evaluating research trends in urban agricultural indicators through bibliometrics. Discover Sustainability 6(1), 1348. https://doi.org/10.1007/s43621-025-02314-2

8. Dutta M, Gupta D, Tharewal S, Goyal D, Sandhu JK, Kaur M, Alanazi JM (2025): Internet of Things-based smart precision farming in soilless agriculture: Opportunities and challenges for global food security. IEEE Access. https://doi.org/10.1109/ACCESS.2025.3540317

9. Fei S, Wu R, Liu H, Yang F, Wang N (2025): Technological innovations in urban and peri-urban agriculture: Pathways to sustainable food systems in metropolises. Horticulturae 11(2), 212. https://doi.org/10.3390/horticulturae11020212

10. Gunapala R, Gangahagedara R, Wanasinghe WCS, Samaraweera AU, Gamage A, Rathnayaka C, Merah O (2025): Urban agriculture: A strategic pathway to building resilience and ensuring sustainable food security in cities. Farming System 3(3), 100150. https://doi.org/10.1016/j.farsys.2025.100150

11. Hu G, Li X, Liu X, Wang S, Zhang X, Shi X, Hubacek K (2025): Mitigating the ripple effects of urbanization on farmland productivity and ecological security through inclusive urbanization strategies. npj Urban Sustainability 5(1), 12. https://www.nature.com/articles/s42949-025-00199-8

12. Idamokoro EM, Niba AS, Akuru EA (2025): A bibliometric assessment of urban agriculture indexed in Scopus and WoS from 1978–2023. OnLine Journal of Biological Sciences 25(3), 659–673. https://doi.org/10.3844/ojbsci.2025.659.673

13. Khan MM, Younis A, Akram MT, Ijaz MM, Al-Sadi AM (2024): Feeding the cities: Urban agriculture for food security and sustainability of urban areas. CABI Reviews 19(1). https://doi.org/10.1079/cabireviews.2024.0053

14. Kluczkovski A, Hadley P, Yap C, Ehgartner U, Doherty B, Denby K (2025): Urban vertical farming: Innovation for food security and social impact? Philosophical Transactions B 380(1935), 20240154. https://doi.org/10.1098/rstb.2024.0154

15. Lai Y, Wang P, Xia J (2025): Systematic review of sustainable urban community development trends, challenges, and opportunities. Discover Sustainability 6(1), 616. https://link.springer.com/article/10.1007/s43621-025-01539-5

16. Mamun AY, László V (2025): Bibliometric analysis of sustainable development goals in agricultural development: Trends, challenges, and future directions. Journal of Agricultural Informatics 16(2). https://doi.org/10.17700/jai.2025.16.2.751

17. Mills E (2025): The emergence of indoor agriculture as a driver of global energy demand. npj Sustainable Agriculture 3(1), 52. https://doi.org/10.1038/s44264-025-00091-z

18. Padhiary M, Kumar A, Sethi LN (2025): Emerging technologies for smart and sustainable precision agriculture. Discover Robotics 1(1), 6. https://doi.org/10.1007/s44430-025-00006-0

19. Pinheiro A, Govind M (2020) Emerging global trends in urban agriculture research: A bibliometric analysis. Journal of Scientometric Research 9(2), 163–175. https://doi.org/10.5530/jscires.9.2.20

20. Saputra A, Abdoellah OS, Utama GL (2025): Exploring the role of urban agriculture in Indonesia's socio-economic and environmental landscape: A systematic literature review. Jurnal Ilmu Lingkungan 23(1), 175–188. https://doi.org/10.14710/jil.23.1.175-188

21. Senthamizh R (2025): Urban agriculture in a changing world: a thematic review of global trends, innovations, governance, and pathways to sustainability. Frontiers in Sustainable Food Systems 9, 1624426. https://doi.org/10.3389/fsufs.2025.1624426

22. Suryaningrum DA, Swasono MAH (2023): Bibliometric analysis of the adoption and innovation of agricultural processing technologies: A global perspective. West Science Interdisciplinary Studies 1(7), 448–458. https://doi.org/10.58812/wsis.v1i07.123

23. Tabrez Z (2025): Sustainable cities: Enhancing food systems with urban agriculture. Discover Food 5(1), 173. https://doi.org/10.1007/s44187-025-00439-x

24. Thwaites HJ, Hume IV, Cavagnaro TR (2025): The case for urban agriculture: Opportunities for sustainable development. Urban Forestry & Urban Greening 110, 128861. https://doi.org/10.1016/j.ufug.2025.128861

25. United Nations, Department of Economic and Social Affairs, Population Division. (2025): World Urbanization Prospects 2025: Summary of Results. United Nations. https://doi.org/10.18356/9789211576788

26. van Eck NJ, Waltman L (2010): Software survey: VOSviewer, a computer program for bibliometric mapping. Scientometrics 84(2), 523–538. https://doi.org/10.1007/s11192-009-0146-3

27. Verma R, Kumar A, Mashroofa MM, Gupta N (2025): A comprehensive bibliometric analysis of research trends in sustainable inclusive economic growth within the SDG 8 framework from 2015 to 2025 using Biblioshiny and VOSviewer. Discover Sustainability 6(1), 1221. https://doi.org/10.1007/s43621-025-02124-6

28. Verma S, Kumar A, Kumari M, Kumar N, Hansda, S., Saurabh, A., Rathore, S. D. (2024). A review on hydroponics and vertical farming for vegetable cultivation: Innovations and challenges. Journal of Experimental Agriculture International 46(12), 801–821. https://doi.org/10.9734/jeai/2024/v46i123190

29. VOSviewer (2025): Smart labeling and label display in visualizations. In VOSviewer documentation. Available from: https://www.vosviewer.com/features/highlights. [Accessed 12 December 2025]

30. VOSviewer Manual (2025): Label display and overlap settings. Available from https://www.vosviewer.com/documentation/Manual_VOSviewer_1.5.7.pdf. [Accessed 12 December 2025]

31. Wei Y, Wei X, Ye Z, Fan J (2025): A bibliometric analysis of food security and urbanization: Insights and implications. Frontiers in Sustainable Cities 7, 1459493. https://doi.org/10.3389/frsc.2025.1459493

32. Wu J, Cheng YW, Lin G, Xu D, Wang Y, Chong C, Ge T (2025): Toward sustainable agriculture: The design of environmentally friendly, economical, and modular vertical farming systems. Engineering. https://doi.org/10.1016/j.eng.2025.07.043

33. Yan D, Liu L, Liu X, Zhang M (2022): Global trends in urban agriculture research: A pathway toward urban resilience and sustainability. Land 11(1), 117. https://doi.org/10.3390/land11010117

34. Zareba A, Krzeminska A, Adynkiewicz-Piragas M, Stojanovski T, Jia H, Privitera R, van der Horst D (2025): Multifunctional vertical farming systems as a basis for transforming urban food systems amid climate change. Sustainability 17, 8668. https://doi.org/10.3390/su17198668

35. Zhang L, Gong J, Yang Y, Li J (2025): Cities in global and sustainable scientific collaboration network: Unveiling cooperation centers. Humanities and Social Sciences Communications 12(1), 1–17. https://www.nature.com/articles/s41599-025-05667-1