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Vertical Farming and Urban Agriculture: A Comprehensive Review: Analyzing the feasibility, benefits, and challenges of scaling up urban-based agricultural practices

Joshua Oyeboade ^{1*}, Olasumbo Olagoke-Komolafe ²

¹ Western Illinois University (WIU), Macomb, IL, USA

² Sweet Sensation Confectionery Limited, Lagos Nigeria

* Corresponding Author: Joshua Oyeboade

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Abstract

This comprehensive review explores the scalability of vertical farming and urban agriculture within contemporary urban planning and sustainability frameworks. The study's primary objective is to analyze the feasibility, benefits, and challenges associated with scaling up urban agricultural practices. Employing a systematic literature review and content analysis methodology, the study scrutinizes peer-reviewed articles, reports, and case studies from 2013 to 2023, focusing on technological innovations, economic viability, social impacts, and environmental sustainability. Key findings reveal that while urban agriculture presents significant opportunities for sustainable urban development, its scalability is hindered by economic, technical, and policy-related challenges. The integration of innovative technologies, such as vertical farming and smart agriculture, emerges as a crucial factor in enhancing productivity and sustainability. However, challenges such as land availability, resource management, and regulatory hurdles pose significant barriers. The study highlights the need for supportive policies, community engagement, and integration of urban agriculture into broader urban planning. Conclusively, urban agriculture is identified as a key component in transforming urban environments into sustainable, resilient, and food-secure spaces. The study recommends developing supportive policies, facilitating resource access, and investing in technology to enhance urban agriculture's scalability. Future research directions include exploring innovative models suitable for different urban contexts, assessing long-term impacts on urban ecosystems, and examining the role of urban agriculture in climate change mitigation. This study provides a roadmap for stakeholders, policymakers, and researchers to advance urban farming as a sustainable urban development solution.

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1. Introduction

1.1. Overview of Urban Agriculture and Vertical Farming

Urban agriculture and vertical farming represent innovative responses to the challenges of urbanization and food security in the 21st century. As cities continue to grow, the need for sustainable, efficient, and local food production becomes increasingly critical. Urban agriculture, defined as the production of agricultural goods within urban areas, offers a solution to these challenges by integrating food production into the urban environment (Chatterjee, Debnath, & Pal, 2020). This practice not only contributes to food security but also plays a role in urban waste recycling, efficient water use, energy conservation, and urban beautification, thereby supporting the broader goals of urban sustainability (Chatterjee, Debnath, & Pal, 2020).

Vertical farming, a subset of urban agriculture, takes this concept to new heights, both literally and figuratively. It involves the cultivation of crops in vertically stacked layers, often in controlled environments, utilizing technologies such as hydroponics and

aeroponics. This method of farming is particularly suited to urban settings where space is limited and can lead to high-yield, sustainable crop production (Sharma, Dhanda, & Verma, 2023). Vertical farms can operate year-round, providing a consistent supply of fresh produce irrespective of external weather conditions. This not only ensures a steady flow of products for consumers but also offers a more predictable income stream for growers (Chatterjee, Debnath, & Pal, 2020).

The integration of vertical farming into urban environments is not without its challenges. However, it presents a unique opportunity to address several pressing issues associated with urban sprawl, such as food shortages, increased energy usage, and environmental degradation. By bringing food production closer to consumers, vertical farming can reduce the carbon footprint associated with transportation and storage of agricultural products (Tevatia, 2023). Moreover, the controlled environment of vertical farms allows for more efficient use of resources, such as water and nutrients, and minimizes the need for pesticides and herbicides, thereby contributing to environmental sustainability (Sharma, Dhanda, & Verma, 2023).

The economic, social, and environmental feasibility of scaling up urban agriculture, particularly vertical farming, is a subject of ongoing research and debate. Economically, the initial investment in vertical farming infrastructure can be substantial. However, the long-term benefits, such as reduced transportation costs, lower water usage, and higher crop yields, can offset these initial costs (Tevatia, 2023). Socially, urban agriculture can strengthen community ties, provide educational opportunities, and improve access to fresh produce, particularly in food deserts. Environmentally, the reduction in transportation emissions, efficient resource use, and potential for recycling urban waste into agricultural inputs present a compelling case for the expansion of urban agriculture (Chatterjee, Debnath, & Pal, 2020).

In summary, urban agriculture and vertical farming are at the forefront of innovative solutions to the challenges posed by urbanization and food security. These practices offer a multitude of benefits, including environmental sustainability, social well-being, and economic viability. As cities continue to evolve, the role of urban agriculture and vertical farming in shaping sustainable, resilient, and food-secure urban environments will undoubtedly become more significant.

1.2. Urban Agriculture in Contemporary Urban Planning

Urban agriculture is increasingly recognized as a pivotal element in urban planning, addressing critical issues such as food security, environmental sustainability, and social well-being in rapidly urbanizing societies. As cities expand and face various challenges, integrating agriculture into urban landscapes offers a multifaceted solution to enhance urban sustainability and resilience.

The integration of urban agriculture into city planning is not just about producing food; it's a comprehensive approach to addressing urban food security risks and contributing to sustainable development objectives (Steenkamp, Cilliers, Cilliers, & Lategan, 2021). Urban agriculture can mitigate the risks associated with food deserts, unemployment, and community decline, thereby enhancing the overall quality of urban life. By establishing shorter, more sustainable agricultural production practices and food supply chains, urban agriculture can significantly contribute to the resilience of urban systems against climate change impacts (Steenkamp

et al., 2021).

The need for urban agriculture is further emphasized by the growing urbanization trend and its associated challenges, such as climate change and limited space in urban areas. Urban agriculture offers a solution that not only addresses the issue of food supply but also contributes to ecological practices within cities (Guenther, 2019). The implementation of ecological agricultural practices, such as Conservation Agriculture, can improve soil health, resulting in higher crop yields and reduced transport emissions. Furthermore, expanding green spaces in urban areas through ecologically cultivated land can mitigate the urban heat island effect, enhance carbon sequestration in soils, and improve water runoff management, reducing the likelihood of urban flood events (Guenther, 2019).

In Australia, recognized as one of the most urbanized countries, urban agriculture is seen as a viable means to enhance urban sustainability. However, despite the consensus on its potential benefits, urban agriculture has often been overlooked in planning processes. The most significant barriers include regulatory and legal frameworks, access to suitable land, and the lack of direct public policy support and institutional recognition (Sarker, Bornman, & Marinova, 2019). To make urban agriculture an integral part of urban development and planning, clear planning policies, laws, and programs supporting urban agriculture are essential. These policies can help address competing land demands and integrate the advantages of growing food within a greener urban environment (Sarker *et al.*, 2019).

Urban agriculture's role in contemporary urban planning extends beyond food production. It encompasses environmental, social, and economic dimensions, contributing to the creation of sustainable, resilient, and livable cities. By integrating agriculture into urban landscapes, cities can tackle various urban challenges, including food security, environmental degradation, and social inequities. The development of supportive policies and frameworks is crucial in realizing the full potential of urban agriculture in enhancing urban sustainability.

1.3. Historical Evolution and the Rise of Urban Farming

The historical evolution of urban farming is a testament to human ingenuity and adaptability in the face of changing environmental and social conditions. From ancient civilizations to modern cities, the practice of urban agriculture has been a crucial component of human settlements, evolving to meet the needs of growing urban populations.

The roots of urban farming can be traced back to ancient civilizations, such as the Mayans, who developed sophisticated agricultural techniques to sustain their urban populations. The Mayans, for instance, employed raised bed farming, a technique that showcased their adaptability to climatic changes and environmental challenges. This early form of urban farming was not only a means of food production but also a reflection of the civilization's understanding of and interaction with their environment (Kulathunga *et al.*, 2022). The diversity of landscapes and environmental conditions across different civilizations led to a variety of urban farming practices, each uniquely tailored to local contexts.

In more recent history, urban agriculture played a significant role in the growth of major urban centers, such as Milwaukee, Wisconsin. Even during the height of industrial expansion,

urban farming contributed to the economic, social, and spatial development of the city. As Milwaukee faced deindustrialization and other urban challenges in the 20th century, urban agriculture remained a viable tool for urban redevelopment, employed by both public and private sector actors (Carriere & Schalliol, 2022). This highlights the enduring relevance of urban farming, not only as a response to food scarcity but also as a means of urban renewal and community building.

Today, the role of urban agriculture is increasingly recognized in the context of global challenges such as climate change, urban population growth, and natural resource scarcity. Urban farming promotes local and sustainable food systems, contributing positively to the environment, ecosystems, and climate. It brings communities together, improves the health of citizens, and is seen as a key strategy for making cities more sustainable and resilient (Orsini & D'ostuni, 2022). The evolution of urban agriculture reflects a growing understanding of its multifunctional benefits, extending beyond food production to encompass environmental stewardship, social cohesion, and economic development.

The historical journey of urban farming, from ancient civilizations to contemporary urban landscapes, underscores its significance as a dynamic and adaptable practice. As cities continue to evolve, urban agriculture remains a vital component of sustainable urban development, offering solutions to some of the most pressing challenges of our time.

1.4. Aim and Objectives of the Study

The aim of this study is to conduct a comprehensive review of vertical farming and urban agriculture, analyzing their feasibility, benefits, and challenges in the context of contemporary urban planning and sustainability. The study seeks to provide an in-depth understanding of how urban-based agricultural practices can be scaled up effectively to address the growing needs of urban populations while contributing to environmental and socioeconomic sustainability.

The objectives of the study are;

1. To Evaluate the Feasibility of Scaling Urban Agriculture.
2. To Examine the Historical Evolution and Current State of Urban Agriculture and Vertical Farming.
3. To Investigate the Benefits and Challenges of Urban Farming at Scale.

2. Methodology

The methodology for this study on "Vertical Farming and Urban Agriculture: A Comprehensive Review" is structured as a systematic literature review combined with content analysis. This approach ensures a thorough and unbiased examination of existing research in the field.

2.1. Data Sources

The primary data sources for this study include academic databases such as JSTOR, PubMed, ScienceDirect, Scopus, and Google Scholar. These databases provide access to a wide range of peer-reviewed journals, conference proceedings, and academic publications relevant to urban agriculture and vertical farming. Additionally, reports from governmental and non-governmental organizations, policy documents, and case studies are considered to gain practical insights into the implementation and impact of urban

agriculture.

2.2. Search Strategy

The search strategy involves using specific keywords and phrases related to urban agriculture and vertical farming, such as "urban farming," "vertical agriculture," "sustainable urban agriculture," "urban farming technologies," and "urban agriculture scalability." Boolean operators (AND, OR, NOT) are used to refine the search. The search is conducted within the title, abstract, and keywords of the publications to ensure relevance.

2.3. Inclusion and Exclusion Criteria for Relevant Literature

The selection of literature for this comprehensive review on vertical farming and urban agriculture is guided by specific inclusion and exclusion criteria to ensure relevance and quality. For inclusion, the study focuses on peer-reviewed articles published between 2013 and 2023, which are pivotal in providing the most recent and relevant insights into the field. The scope of the literature encompasses studies that specifically focus on urban agriculture, vertical farming, and related technologies, ensuring that the content is directly pertinent to the study's objectives. Additionally, the review includes articles that offer substantial insights into the feasibility, benefits, and challenges associated with urban agriculture, thereby aligning with the study's aim of providing a comprehensive overview of the field. All selected publications are required to be in English to ensure accessibility and comprehension.

On the other hand, the exclusion criteria are set to maintain the study's academic rigor and relevance. This involves omitting non-peer-reviewed articles and grey literature, which might not meet the scholarly standards required for a comprehensive review. Publications outside the specified date range of 2013 to 2023 are excluded to focus on the most current developments and trends in urban agriculture and vertical farming. Studies that are not directly related to the core themes of urban agriculture or vertical farming are also excluded to maintain the focus and depth of the review. Lastly, articles that are not available in full text or are in languages other than English are excluded to ensure that a thorough analysis can be conducted based on complete information and in a language that is universally accessible for the intended audience. By adhering to these inclusion and exclusion criteria, the study aims to compile a body of literature that is both relevant and of high quality, providing a solid foundation for a thorough and insightful analysis of vertical farming and urban agriculture.

2.4. Selection Criteria

The selection of literature for review involves a two-stage process. Initially, titles and abstracts are screened to assess their relevance to the study's aim and objectives. This is followed by a full-text review where articles are evaluated based on their contribution to understanding the feasibility, benefits, and challenges of urban agriculture. Priority is given to recent studies, comprehensive reviews, and articles that offer innovative insights or significant findings.

2.5. Data Analysis

Data analysis involves content analysis of the selected literature. Key themes, patterns, and findings are identified and categorized. This process includes coding the data,

identifying recurring themes, and synthesizing the information to provide a comprehensive overview of the current state of knowledge in the field. The analysis aims to draw conclusions about the scalability, feasibility, and impact of urban agriculture and vertical farming, as well as to identify gaps in the literature and suggest areas for future research.

Through this systematic and rigorous methodology, the study aims to provide a detailed and nuanced understanding of vertical farming and urban agriculture, contributing valuable insights to the field.

3. Literature Review

3.1. Fundamental Concepts in Urban Agriculture

Urban agriculture, a practice that intertwines agricultural production with urban living, has evolved into a multifaceted concept encompassing environmental, social, and economic dimensions. This section delves into the fundamental concepts underpinning urban agriculture, exploring its principles, methodologies, and implications for urban communities.

One of the core principles of urban agriculture is permaculture, a design concept that integrates agricultural practices with ecological and sustainable living. In Jakarta, the implementation of an urban farming park based on permaculture principles serves as an educational platform for children, teaching them about agriculture's role in urban ecosystems. This approach not only focuses on plant cultivation but also emphasizes the social, cultural, and technological aspects of urban farming. Permaculture in urban settings aims to address food insecurity and land limitations, promoting a harmonious integration of landscape and community needs for food, energy, housing, and other necessities in a sustainable manner (Dewi *et al.*, 2023).

The mainstreaming of urban agriculture, particularly in its more radical forms such as edible rooftops, urban farms, and high-tech growing projects, is reshaping cityscapes globally. These innovative approaches enable large-scale production, enhancing the social, environmental, and economic value of urban agriculture. They contribute to job creation, biodiversity enhancement, and the establishment of short food supply chains. However, challenges such as public hesitation, financial barriers, and soil contamination often hinder the upscaling of urban farming. Addressing these barriers requires a pragmatic approach that acknowledges and navigates the complexities of urban agriculture (Hardman, Clark, & Sherriff, 2022).

The COVID-19 pandemic has further highlighted the significance of urban agriculture as an alternative and sustainable food system. Policies such as Work from Home (WFH) and Large-Scale Social Restrictions (PSBB) have underscored the socioeconomic impact on communities, including food access. Urban farming, as a concept of gardening utilizing space in homes or settlements, has proven beneficial during the pandemic. It is seen as an ideal agricultural concept for the future, increasing food locality value and reducing energy expenditure in the production process. However, challenges remain in monitoring, regulating, and minimizing environmental, economic, and socio-environmental risks. The role of city governments in supporting sustainable urban farming through specific regulations is crucial (Putri *et al.*, 2023).

In summary, the fundamental concepts of urban agriculture encompass a range of practices and principles aimed at

integrating agricultural production into urban environments in a sustainable and ecologically sound manner. The focus on permaculture, large-scale urban farming projects, and the response to contemporary challenges like the COVID-19 pandemic, underscores the adaptability and relevance of urban agriculture in addressing the needs of modern urban societies.

3.2. Architectural and Technological Framework of Urban Farming

The architectural and technological framework of urban farming is a critical aspect that shapes its effectiveness and sustainability. This framework encompasses a range of innovative techniques and systems designed to integrate agriculture into urban environments, addressing the challenges of urbanization and climate change.

In Lanuvio, near Rome, the transformation of a vacant site into a generative urban farm exemplifies the innovative application of urban farming techniques. The project, known as Green Symphony, utilizes smart and sustainable technologies focusing on urban agriculture. It incorporates aquaponic systems, permaculture, green walls, and vertical farming, combined with energy harvesting from footsteps, solar panels, water close circuits, and rainwater collection. This approach not only produces a significant yield of vegetables, fruits, herbs, and fish but also creates jobs and contributes to the city's sustainability goals. The integration of organic waste transformation into fertilizer further enhances the self-sustainability of the farm (Olakunle *et al.*, 2021).

In the United Arab Emirates (UAE), the development of a multi-dimensional innovative urban food production system framework highlights the role of technology in enhancing urban farming. The framework, validated through a survey-based methodology, emphasizes the importance of digital technology in moderating the relationship between innovative urban farming systems and sustainable urban farming. Resource efficiency and conservation practices are identified as key factors positively associated with sustainable urban farming. This study underscores the potential of technology-driven and resource-efficient urban farming systems in reducing dependency on food imports and scaling up sustainable agricultural practices (Sharma *et al.*, 2023).

The concept of vertical farming (VF) or high-rise farming technology is another pivotal element in the architectural and technological framework of urban agriculture. VF enables the fast growth and production of crops by maintaining controlled environmental conditions and nutrient solutions based on hydroponics technology. This method allows for year-round food production, irrespective of external weather conditions, thereby ensuring a steady supply of produce and a consistent income for growers. The advantages of VF over traditional farming, such as reduced farm inputs, crop failures, and restored farmland, have led to its large-scale implementation (Chatterjee, Debnath, & Pal, 2020).

In summary, the architectural and technological framework of urban farming is integral to its success and sustainability. Innovative techniques such as aquaponics, permaculture, green walls, vertical farming, and the integration of digital technologies are transforming urban landscapes into productive agricultural spaces. These approaches not only address food security and environmental sustainability but also contribute to the economic and social well-being of

urban communities.

3.3. Spectrum of Urban Agricultural Practices

Urban agriculture encompasses a diverse range of practices, each adapted to specific urban contexts and challenges. This spectrum of practices reflects the versatility of urban agriculture in contributing to sustainable urban development, food security, and environmental management.

In Rabat, Morocco, peri-urban farming demonstrates the multifunctionality of urban agriculture. This type of agriculture plays a crucial role in the economic development of the metropolis by creating jobs and generating income for farmers, contributing to food supply, and enhancing environmental beautification. The dominant practices in Rabat include vegetable crops, arboriculture, cereals, leguminous, and livestock rearing such as beef, sheep, and poultry farming. Despite its benefits, peri-urban agriculture in Rabat faces challenges like labor force precariousness, absence of regulatory laws, lack of training and technical supervision for farmers, and water resource shortages. Addressing these challenges is essential for the sustainability and development of peri-urban agriculture in urban planning (Hakimi, 2021).

In South Bogor, Indonesia, urban farming is explored for its potential to enhance the landscape quality of the city. The study identifies areas of agriculture covering 1,609.19 hectares and agricultural activities in 49 farmer groups. Urban farming in South Bogor contributes to ecological quality, aesthetic quality, and social quality of the community. The diversity of plants and the aesthetic appeal of the landscape demonstrate the potential of urban farming to improve the urban environment and foster social interaction among community members (Qoriyati & Nurhayati, 2020).

A study in mega-urban Shanghai, China, highlights the contribution of biodiversity to ecological intensification in urban agricultural systems. Monitoring data from rice fields in 34 community farms showed that border crops of soybeans and neighboring crops without weed control increased invertebrate predator abundance, decreased pest abundance, reduced dependence on insecticides, and increased grain yield and economic profits. This approach to diversifying farming practices in urban agriculture demonstrates the significant role of biodiversity in enhancing ecosystem services and sustainability in urban settings (Wan *et al.*, 2018).

The spectrum of urban agricultural practices, from peri-urban farming in Rabat to landscape-enhancing urban farming in South Bogor and biodiversity-intensive agriculture in Shanghai, illustrates the adaptability and potential of urban agriculture. These practices not only address food security and economic development but also contribute to environmental sustainability and social well-being in urban areas.

3.4. Technological Milestones in Urban Agriculture

Urban agriculture has undergone significant transformations with the advent of technology, leading to innovative practices that enhance efficiency, sustainability, and productivity. The development of digital mobile platforms represents a significant technological advancement in urban agriculture. Almeida, Miranda, and Vieira (2021) propose a mobile application designed to facilitate the management and monitoring of urban farming production. This application

caters to both experienced and novice farmers, providing relevant information on the best products per season, soil characteristics, and climate. The application's potential lies in increasing crop visibility, enhancing efficiency across the value chain, providing access to real-time business and financial data, customizing user profiles, improving marketing processes, and contributing to reduced transport costs. Such digital platforms are instrumental in revolutionizing urban farming by integrating technology into everyday agricultural practices.

In Johannesburg, South Africa, innovative farming practices have been implemented as part of urban transformational strategies. Ngie and Sithole (2023) assess these strategies, which include rooftop gardening and hydroponic farming, aimed at addressing food insecurity and optimizing land and water resources in limited urban spaces. These measures have improved household food security, created income-generating opportunities, and regenerated city infrastructure. However, challenges such as soil and water availability for rooftop gardens and the need for consistent energy supplies, input costs, and technological challenges in hydroponics persist. Despite these hurdles, hydroponics emerges as a promising solution for achieving resource use efficiency goals with proper governance and policy support.

In summary, technological milestones in urban agriculture, from digital mobile platforms to advanced farming techniques like hydroponics and rooftop gardening, have significantly contributed to the evolution of urban farming. These technologies not only enhance agricultural productivity and sustainability but also address broader urban challenges related to food security, resource optimization, and environmental management.

3.5. Current Innovations and Future Directions in Urban Farming Technologies

Urban agriculture is undergoing a dynamic transformation, driven by technological innovations and the pursuit of sustainability. Kanosvamhira (2024) examines the role of urban agriculture in South Africa, focusing on its evolution and future trends. The study underscores the importance of integrating urban agriculture into urban planning for sustainable cities, particularly in sub-Saharan Africa. It identifies gaps in the knowledge and practice of urban agriculture, such as the under-representation of secondary cities and a predominant focus on productivist approaches. Future research is encouraged to explore under-represented themes like environmental benefits, green infrastructure, and nature-based solutions. A holistic understanding of urban agriculture is crucial for interventions that accommodate urban farming within the urban environment, contributing to economic development, food security, and environmental sustainability.

The adoption of LoRa (Long Range) technology in smart agriculture represents a significant innovation in urban farming. Pagano *et al.* (2023) provide a survey on the use of LoRa in various agricultural scenarios, including irrigation systems, crop monitoring, tree monitoring, and livestock monitoring. LoRa-based solutions offer scalability, interoperability, network architecture, and energy efficiency, addressing diverse requirements in terms of bandwidth, sensor complexity, and energy demand. The study discusses future research directions and open issues in LoRa for smart agriculture, highlighting its potential in enhancing the efficiency and sustainability of urban farming practices.

Yan *et al.* (2023) explores the role of artificial intelligence (AI) in shaping smart cities, with implications for urban agriculture. AI technologies are instrumental in optimizing resource allocation, improving decision-making processes, and enhancing the overall quality of life in urban environments. The integration of AI into urban infrastructure marks a significant advancement in urban agriculture, offering novel solutions to challenges in food production, resource management, and environmental conservation. The study emphasizes the need to foster the development and advancement of AI technologies within the context of smart cities, underscoring their interconnectedness with technological progress and urban development.

In summary, current innovations in urban farming technologies, such as the integration of LoRa and AI, are reshaping the landscape of urban agriculture. These technologies not only enhance agricultural productivity and sustainability but also address broader urban challenges related to food security, resource optimization, and environmental management. The future of urban farming lies in embracing these technological advancements and exploring new research directions to fully realize their potential in sustainable urban development.

3.6. Trends in Urban Agricultural Expansion

Urban agricultural expansion is a critical aspect of sustainable urban development, reflecting the dynamic interplay between urbanization, land use, and food security. Güneralp *et al.* (2020) conducted a global synthesis of trends in urban land expansion from 1970 to 2010. Their findings reveal that small-medium urban areas lead larger counterparts in both rates of urban land expansion and decreases in urban population densities. Over 60% of reported urban expansion was formerly agricultural land, with China, Southeast Asia, and Europe leading in this transition. The study highlights the impact of decreasing urban population densities on land conversion, particularly in countries like India and Nigeria, where a significant portion of the population depends on agriculture. This research underscores the need for proactive management of urban land expansion, especially in small and medium cities, to preserve agricultural lands in peri-urban regions and create equitable urban landscapes.

Egidi *et al.* (2020) explore urban growth and population density in the context of metropolitan Rome, Italy. Their study indicates non-linear growth waves alternating between compact and discontinuous expansion, shaping fringe land. The future development of metropolitan regions is increasingly dependent on the relationship between urban diffusion and the economic viability of peri-urban agriculture. The study suggests that policies managing ex-urban development and promoting the recovery of fringe soils are required to contain the expansion of dispersed settlements and preserve agricultural systems from land conversion to urban use.

Aziz *et al.* (2022) focus on the urban expansion trends in Erbil and its impact on agricultural lands. Using GIS and remote sensing, the study reveals the encroachment of urbanization on agricultural lands due to population growth and lack of proper planning. The study recommends preparing a strategic plan for the use of agricultural lands that regulates urban development and achieves sustainable use of these lands. It emphasizes the importance of investing in lands and cultivating crops to meet the population's needs, highlighting the necessity for decision-makers to develop future

urbanization policies that consider the impact on agricultural areas.

Therefore, the trends in urban agricultural expansion reflect a complex interaction between urban growth, land use changes, and agricultural practices. The studies highlight the challenges and opportunities in managing urban expansion to ensure sustainable development, food security, and preservation of agricultural lands. Proactive and strategic planning is essential to balance urban development with the preservation and enhancement of agricultural spaces within and around urban areas.

3.6.1. New Developments in Sustainable Urban Farming

Urban farming, a critical component of sustainable city development, is evolving with new technologies and approaches to meet the challenges of urbanization and environmental sustainability. Grochulska-Salak's (2019) work on urban farming in sustainable city development highlights the integration of urban space and buildings with innovative production functions, such as municipal farms. These farms complement the functional structure of cities, connecting architecture and greenery. The implementation of new technologies, including hydroponic and aeroponic farming in buildings, enables the production of plants in urban settings. This approach not only enhances the environmental balance of urban spaces but also contributes to the social and economic aspects of sustainability (Grochulska-Salak, 2019).

Chaminuka *et al.* (2021) discuss how enhanced urban farming can be a strategy for sustainable development by localizing the Sustainable Development Goals (SDGs). Their study, conducted in Gweru urban, Zimbabwe, reveals that urban farming is a viable option for achieving sustainable development and domesticating the SDGs. Urban farming has the potential to reduce poverty and hunger and contribute to the health and well-being of households. However, challenges such as the shortage of farming land, lack of inputs, and supportive policies hinder its effectiveness. The study concludes that urban farming can either reduce or escalate poverty and hunger, emphasizing the need for stakeholder support, including local authorities, to achieve sustainable development (Chaminuka *et al.*, 2021).

Bisaga, Parikh, and Loggia (2019) study in Durban, South Africa, explores the challenges and opportunities for sustainable urban farming in low-income settlements. The study demonstrates the need for municipalities to support community-driven processes to ensure the sustainability of urban agriculture initiatives. Policymakers are encouraged to create an enabling environment for co-developing water-efficient solutions to manage the food-water nexus and capitalize on localized community structures, such as cooperatives and women's groups. This approach is essential for managing the challenges of urban centers attracting rural migrants and the consequent rise in informal settlements (Bisaga, Parikh, & Loggia, 2019).

In summary, new developments in sustainable urban farming are addressing the environmental, social, and economic challenges of urbanization. The integration of innovative farming techniques, community engagement, and supportive policies are key to enhancing the sustainability and effectiveness of urban agriculture. These developments not only contribute to the environmental balance of urban spaces but also play a crucial role in achieving sustainable development goals.

3.6.2. Smart Technology Integration in Urban Agriculture

The integration of smart technology in urban agriculture is a transformative development, reshaping the landscape of food production in urban environments. This integration, characterized by the use of digital technologies such as the Internet of Things (IoT), Artificial Intelligence (AI), and Big Data, is enhancing farming procedures to maximize productivity and efficiency. Joshi *et al.* (2023) delve into this concept, exploring how IoT can track crop growth, soil moisture, temperature, and humidity, while AI analyzes data to provide insights that help farmers increase yields. This integration of technology in agriculture is crucial for the future of food security and sustainable agricultural practices. In the realm of urban agriculture, the implementation of smart technologies is not just about enhancing productivity; it's about redefining the relationship between urban spaces and food production. Md Idros *et al.* (2023) propose a smart greenhouse accessible to every household, altering the way people experience and consume food by enabling home horticulture. This smart greenhouse uses sensors to monitor crucial variables like UV light exposure, soil moisture levels, temperature, and humidity, creating perfect growing conditions for plants. The integration of an ultrasonic mist generator and a UV light source tailored to specific plant species exemplifies the innovative approach to urban farming.

Elbeheiry and Balog (2023) provide a comprehensive survey of the most recent scientific literature on smart farming, identifying common practices toward technology integration, challenges, and solutions. The survey, conducted on numerous papers, analyzed contributions to identify necessary technologies that constitute smart farming. The identified themes include sensors, communication, big data, actuators and machines, and data analysis. This article discusses integrating more than one technology in systems to achieve independency, with the most common smart farming systems being remote monitoring, autonomous, and intelligent decision-making systems.

The integration of smart technologies in urban agriculture offers increased efficiency and productivity, enabling more efficient use of water, nutrients, and energy, leading to higher crop yields and reduced waste. Enhanced sustainability is another significant benefit, as smart urban agriculture contributes to more sustainable food production, reducing the environmental footprint of farming. Moreover, scalability and flexibility are inherent in smart urban farms, which can be adapted to various urban spaces, from small community gardens to large commercial operations.

However, challenges such as high initial investment, the need for technical expertise and training, and concerns over data security and privacy are prevalent. Addressing these challenges is crucial for the widespread adoption of smart technologies in urban agriculture. Future directions in this field include the integration of urban agriculture with broader smart city initiatives, contributing to urban sustainability goals, the development of low-cost technologies, and community engagement and education to enhance local food security and promote sustainable urban development.

In summary, the integration of smart technologies in urban agriculture represents a significant advancement in urban food production. While challenges exist, the potential benefits in terms of efficiency, sustainability, and scalability

are substantial. Future developments in this field are likely to focus on making these technologies more accessible and integrated into the fabric of urban life.

4. Discussion of Findings

4.1. Assessing the Feasibility of Scaling Urban Agriculture

The feasibility of scaling urban agriculture is a multifaceted issue that intertwines economic, social, and environmental considerations within the urban planning and sustainability framework. In exploring this topic, recent studies provide insights into various aspects of urban agriculture, from peri-urban agri-food start-ups to the integration of high-tech solutions in densely populated cities.

In the context of Milan, Italy, Zanzi *et al.* (2021) conducted a study focusing on the sustainability of agri-food start-ups in a peri-urban area. This research utilized the Sustainability Assessment of Food and Agriculture systems (SAFA) framework to evaluate these start-ups, considering four pillars of sustainability: good governance, economic resilience, environmental integrity, and social well-being. The findings revealed positive aspects of these enterprises, such as their contribution to local economies and job creation. However, the study also highlighted limitations typical of emerging businesses, including financial constraints and market volatility. This research underscores the importance of supportive policies and financial models in enhancing the economic feasibility of urban agriculture start-ups.

In Singapore, a study by Montesclaros, Liu, and Teng (2018) assessed the viability of leafy vegetable production using plant factories with artificial lighting. The research indicated economic viability but emphasized the need for significant initial investment and consistent policy support. This study highlights the role of technology and innovation in urban agriculture, particularly in land-scarce urban settings where traditional farming methods are impractical.

Costello, Oveysi, and McGarvey (2021) approached the feasibility of urban agriculture from a different angle, focusing on its impact on localized food systems in Chicago. Their research employed robust optimization techniques to evaluate the contribution of urban agriculture to meeting the nutritional needs of the local population. The study revealed that urban agriculture could significantly reduce the environmental footprint of food production. However, it also identified challenges, including the need for nutrient fortification and diverse food production systems to ensure a balanced diet.

The integration of urban agriculture into urban planning is essential for its scalability. This involves not only identifying suitable land and developing zoning regulations but also ensuring land availability for agricultural use. Technological advancements, such as hydroponics and vertical farming, can enhance the scalability of urban agriculture by maximizing production in limited spaces. Furthermore, effective governance and supportive policies are critical in addressing challenges related to land use, funding, and technology adoption in urban agriculture.

Therefore, scaling urban agriculture is feasible but requires a comprehensive approach that considers economic, social, and environmental aspects. The integration of technology, community engagement, supportive policies, and sustainable practices are key to enhancing the scalability and viability of urban agricultural practices.

4.1.1. Economic, Social, and Environmental Feasibility

The feasibility of scaling urban agriculture encompasses a broad spectrum of economic, social, and environmental factors. Recent studies provide a comprehensive understanding of these aspects, highlighting the potential and challenges of urban agriculture in various contexts.

Urban agriculture's economic feasibility is closely tied to its ability to contribute to local economies and job creation. Kafle, Hopeward, and Myers (2023) conducted a study focusing on the economic contribution of urban agriculture, considering factors like area, purpose, crop value, mechanization level, and market mechanism. Their research, which included a review of 15 past studies, primarily emphasized the economic viability and employment potential of urban agriculture. The findings suggest that while urban agriculture has the potential to contribute significantly to local economies, its economic sustainability requires careful planning and policy support.

The social feasibility of urban agriculture is linked to its capacity to enhance community well-being and social cohesion. Hardman, Clark, and Sherriff (2022) explored the opportunities and barriers to upscaling city farming, noting that urban agriculture can further social value through job creation, biodiversity enhancement, and the establishment of short food supply chains. However, the study also identified challenges such as public hesitation and soil contamination, which can hinder the development of urban agriculture. Addressing these social barriers is crucial for the successful integration of urban agriculture into urban communities.

The environmental feasibility of urban agriculture is evaluated in terms of its impact on greenhouse gas emissions and the urban microclimate. Kafle, Hopeward, and Myers (2023) investigated the environmental benefits and impacts of urban agriculture, focusing on employment, scale appropriateness, and carbon dioxide emissions for vegetable production. Their study found that urban agriculture, even with modest mechanization, can favor environmentally sustainable practices with better labor productivity. The research highlights the importance of considering the environmental footprint of urban agriculture, particularly in terms of emissions associated with distribution and production.

Scaling urban agriculture presents several challenges, including the need for supportive policies, access to land and resources, and addressing public concerns about urban farming. However, the opportunities are significant, with the potential for urban agriculture to contribute to economic development, social well-being, and environmental sustainability. Governments and planners are encouraged to facilitate appropriate mechanization and provide policy support to ensure the sustainability of urban agriculture practices.

The economic, social, and environmental feasibility of scaling urban agriculture is a complex but achievable goal. With careful planning, policy support, and community engagement, urban agriculture can become a sustainable and integral part of urban development, contributing to economic growth, social cohesion, and environmental sustainability.

4.1.2. Identifying and Overcoming Barriers to Scalability

The scalability of urban agriculture is influenced by a range of factors, including economic, social, and environmental barriers. Understanding and addressing these barriers is crucial for the successful expansion of urban agriculture

practices. Economic viability remains a significant concern among urban agriculture practitioners. Kafle, Hopeward, and Myers (2022) explored this aspect by analyzing land, labor, and distribution costs, and calculating the margin and benefit-cost ratio under various urban agriculture scenarios. Their study, which included examples from Adelaide, South Australia, and Kathmandu Valley, Nepal, revealed that high land costs are a primary driver of expenses in urban agriculture. Additionally, labor costs, especially in cities with higher wage rates, pose a critical constraint to economic viability. The study suggests that governments and planners should consider policies to avail subsidized land and labor arrangements to improve the economic feasibility of urban agriculture.

Environmental factors, particularly urban soil contamination, are significant barriers to the scalability of urban agriculture. Hardman, Clark, and Sherriff (2022) used a qualitative approach to explore the UK's largest urban farm and other urban agriculture sites, revealing public hesitation and concerns about soil quality. The study calls for a more pragmatic approach to these environmental barriers, proposing a path forward for enabling urban agriculture at scale.

To overcome these barriers, a multi-faceted approach is required. This includes developing supportive policies and financial models, enhancing community engagement, and addressing environmental concerns through sustainable practices. Additionally, integrating urban agriculture into broader urban planning and development strategies can help mitigate these barriers and promote the scalability of urban agriculture.

Identifying and overcoming the barriers to scalability in urban agriculture is essential for its successful expansion. Addressing economic, social, and environmental challenges through policy support, community involvement, and sustainable practices will be key to enhancing the scalability and viability of urban agricultural practices.

4.2. Benefits of Urban Farming at Scale

Urban farming, when scaled effectively, offers a multitude of benefits that extend beyond mere food production. These benefits encompass economic, social, and environmental aspects, contributing significantly to urban sustainability and community well-being. The economic impact of urban farming is profound, especially when it is scaled up. Hardman, Clark, and Sherriff (2022) discuss the potential of large-scale urban agriculture to further economic value through job creation and the establishment of short food supply chains. This not only enhances local economies but also reduces the carbon footprint associated with long-distance transportation of food. Additionally, urban farming can stimulate local entrepreneurship and innovation, contributing to a more resilient urban economy.

Urban farming programs have been shown to offer numerous social benefits. Nafisi *et al.* (2020) highlight the effectiveness of urban farming in Malaysia in enhancing community resilience and well-being. These programs foster community engagement, improve access to fresh produce, and can be particularly beneficial in low-income urban areas where access to healthy food options is limited. Urban farming also serves as a platform for community education and skill development, promoting social inclusion and community empowerment.

From an environmental perspective, urban farming

contributes to the reduction of carbon dioxide emissions and the enhancement of urban biodiversity. Kafle, Hopeward, and Myers (2023) model the environmental impacts of urban agriculture, noting that even modestly scaled urban farming can significantly reduce emissions associated with food production and distribution. Urban farms can also contribute to the greening of urban areas, improving air quality and creating habitats for urban wildlife.

While the benefits of urban farming are clear, realizing these benefits at scale requires overcoming certain challenges. These include addressing land availability, securing investment and funding, and ensuring community participation and support. Policies and initiatives that support urban agriculture, provide access to resources, and encourage community involvement are essential for maximizing the benefits of urban farming at scale.

Urban farming at scale offers a sustainable solution to many of the challenges faced by urban areas, including food security, economic resilience, and environmental sustainability. By addressing the barriers to scaling urban agriculture and harnessing its full potential, cities can reap the economic, social, and environmental benefits that urban farming offers.

4.2.1. Environmental and Ecological Advantages

Urban farming, a rapidly evolving practice in contemporary urban landscapes, offers significant environmental and ecological benefits. Urban farming contributes to the improvement of environmental quality, particularly in densely populated urban areas. Maulana *et al.* (2022) discuss the environmental benefits of urban farming in Semarang, Indonesia, highlighting its role in reducing the decline in environmental quality due to urbanization. The study emphasizes that urban farming activities, including the cultivation of various vegetables and fruits, contribute to the enhancement of green spaces, thereby improving air quality and urban biodiversity. Additionally, urban farming practices such as composting and rainwater harvesting contribute to sustainable resource management in urban areas.

The ecological advantages of urban farming are multifaceted. Zhou, Wei, and Zhou (2022) explore the benefits of urban farming initiatives in Taipei, focusing on edible landscaping and small-scale crop production. Their study reveals that urban agriculture practices contribute to the creation of more sustainable urban ecosystems by integrating food production with ecological landscaping. This approach not only enhances the aesthetic appeal of urban spaces but also supports biodiversity and provides habitats for urban wildlife. Ensuring the sustainability of urban farming is crucial for maximizing its environmental and ecological benefits. Kim and Sim (2023) investigate the sustainability of urban farming in apartment complexes in South Korea. The study proposes policy directions for facilitating urban farming in such settings, emphasizing the importance of public funding and technical support. By targeting apartments as urban farming sites, the study highlights the potential for urban agriculture to contribute to sustainable urban development, even in high-density residential areas.

To maximize the environmental and ecological benefits of urban farming, it is essential to address challenges such as securing agricultural land in urban areas and managing resource constraints. Policies that support urban agriculture, provide access to resources, and encourage community involvement are key to overcoming these challenges and

promoting the scalability of urban farming.

Urban farming offers substantial environmental and ecological benefits, contributing to the enhancement of urban green spaces, biodiversity, and sustainable resource management. By addressing the challenges and promoting supportive policies, urban farming can become an integral part of sustainable urban development, enhancing the environmental and ecological health of urban areas.

4.2.2. Socioeconomic Impacts and Community Benefits

Urban farming, as a sustainable practice, has profound socioeconomic impacts and offers significant community benefits. Urban farming initiatives contribute significantly to local economies and community well-being. Muttaqin, Danial, and Bestari (2022) explored the implementation of economy civics through citizen participation in urban farming programs in Bandung, Indonesia. Their study revealed that urban farming not only addresses food security issues but also generates economic benefits. By involving the community in urban farming activities, the program fosters a sense of ownership and responsibility, leading to sustainable economic and social development.

Nafisi *et al.* (2020) examined the effectiveness of urban farming programs in Malaysia, focusing on their ability to provide multiple benefits to urban communities. The study found that urban agriculture enhances community resilience and well-being, particularly in urban regions where job opportunities and public services are concentrated. Urban farming, especially small-scale projects like community gardens, contributes to food security, reduces food prices, and lessens dependency on food imports. This study underscores the necessity for urban authorities to support and promote urban farming practices among city residents.

Istiqomah, Qodri, and Radzi (2023) investigated the impact of urban farming during the COVID-19 pandemic in Malang City, Indonesia. Their study highlighted that urban farming significantly increased the community's economic well-being. The public's perception of urban farming was positive, recognizing its benefits in terms of food security and the use of green land around houses. The study concluded that community participation in urban farming is effective and enthusiastic, leading to individual and collective benefits.

The benefits of urban farming extend beyond economic impacts to include social and environmental advantages. Urban agriculture fosters community engagement, improves access to fresh produce, and can be particularly beneficial in low-income urban areas where access to healthy food options is limited. Additionally, urban farming serves as a platform for community education and skill development, promoting social inclusion and community empowerment.

To maximize the socioeconomic impacts and community benefits of urban farming, it is essential to address challenges such as securing agricultural land in urban areas, managing resource constraints, and ensuring community participation and support. Policies and initiatives that support urban agriculture, provide access to resources, and encourage community involvement are key to overcoming these challenges and promoting the scalability of urban farming.

Urban farming offers substantial socioeconomic benefits and positively impacts community well-being. By addressing the challenges and promoting supportive policies, urban farming can become an integral part of sustainable urban development, enhancing the economic, social, and environmental health of urban areas.

4.3. Challenges in Scaling Urban Agriculture

Scaling urban agriculture presents a unique set of challenges that must be addressed to realize its full potential in sustainable city development. The study by Martin-Moreau and Menasce (2019) highlights the critical role of companies, startups, and non-profit organizations in initiating urban agriculture projects. However, these initiatives often face challenges related to support from public authorities, particularly local government. The study emphasizes the need for work to raise consumer awareness of new production methods and to train urban farmers to create quality supply chains. This highlights the importance of commitment from local stakeholders, whether led by a startup or a large company, in any urban agriculture project.

Ghezalje, Gutberlet, and Cloutier (2022) focus on the regulatory challenges and limitations faced by urban agriculture activities, particularly in Victoria, British Columbia. Their qualitative research explores the main barriers to urban agriculture as perceived by community-based groups. The study identifies urban agriculture zones and garden-style apartment housing as important avenues for urban agriculture projects. These findings are particularly relevant in Victoria, where more than half of the population lives in apartments. The study suggests that a food action plan aligned with the official community plan can boost food production, but far-reaching changes require an efficient urban agriculture development process.

Van Tuijl, Hospers, and van den Berg (2018) provide insights into the opportunities and challenges of Urban Agriculture (UA) for sustainable city development. By using case examples from cities worldwide, the study shows that UA can contribute to the social, environmental, and economic pillars of sustainable city development. However, the study also points out limitations that should be considered by cities investing in urban agriculture. These include issues related to land availability, resource management, and the integration of UA into the broader urban planning framework. To overcome these challenges, a multi-faceted approach is required. This includes developing supportive policies and financial models, enhancing community engagement, and addressing environmental concerns through sustainable practices. Additionally, integrating urban agriculture into broader urban planning and development strategies can help mitigate these barriers and promote the scalability of urban agriculture.

Scaling urban agriculture is essential for sustainable urban development, but it faces significant challenges. Addressing these challenges through policy support, community involvement, and sustainable practices will be key to enhancing the scalability and viability of urban agricultural practices.

4.3.1. Technical and Infrastructural Limitations in Scaling Urban Agriculture

Scaling urban agriculture is a complex endeavor, often hindered by technical and infrastructural limitations. The study by Del Ángel-Lozano and Nava-Tablada (2019) in Xalapa, Veracruz, provides a detailed examination of the technical-productive limitations in urban agriculture. The research, focusing on the Urban and Peri-Urban Agriculture Network of Xalapa, reveals that despite the social, economic, and environmental benefits of urban agriculture, most of the population does not participate due to various constraints. Key among these are socioeconomic factors such as lack of

space in homesteads and limited free time, both of which are intricately linked to urban lifestyles. Interestingly, technical-productive limitations, such as the lack of agricultural knowledge or resources, were not considered as significant barriers by the participants.

Cilliers *et al.* (2020) investigate urban agriculture's potential and limitations as an urban greening tool in South Africa. Their study highlights the importance of urban agriculture in addressing urbanization pressures and impacts on global food systems. However, the research also points out significant challenges in integrating urban agriculture into spatial planning. These include issues related to land availability, regulatory frameworks, and the need for more supportive policies to facilitate urban agriculture as a sustainable urban greening strategy.

Kuusaana *et al.* (2022) explore the sustainability dynamics of urban agriculture in the Savannah Ecological Zone of Ghana, particularly in the Bolgatanga Municipality. Their study finds that urban land use planning is increasingly complex, with large portions of urban land parcels being converted to urban infrastructure, thereby threatening the sustainability of the food system. The research emphasizes that agricultural land use allocations on planning schemes are often converted to residential uses, posing a significant challenge to urban agriculture. The study recommends that food-inclusive planning schemes should guide land uses in peri-urban and rural zones to ensure the sustainability of urban agriculture. To overcome these technical and infrastructural limitations, a multi-faceted approach is required. This includes developing supportive policies and financial models, enhancing community engagement, and addressing environmental concerns through sustainable practices. Additionally, integrating urban agriculture into broader urban planning and development strategies can help mitigate these barriers and promote the scalability of urban agriculture.

Technical and infrastructural limitations present significant challenges to scaling urban agriculture. Addressing these challenges through policy support, community involvement, and sustainable practices will be key to enhancing the scalability and viability of urban agricultural practices.

4.3.2. Policy and Regulatory Hurdles in Scaling Urban Agriculture

Scaling urban agriculture is often impeded by policy and regulatory hurdles that can limit its potential impact on urban sustainability. The study by Ghezalje, Gutberlet, and Cloutier (2022) in Victoria, British Columbia, highlights the regulatory challenges faced by urban agriculture activities. The research, which employed qualitative methods, revealed that urban agriculture zones and garden-style apartment housing are crucial for urban agriculture projects. However, more than half of Victoria's population lives in apartments, posing a significant challenge in terms of space and regulatory limitations. The study suggests that a food action plan aligned with the official community plan can boost food production, but achieving far-reaching changes requires an efficient urban agriculture development process, including stakeholder participation and addressing high land prices.

Felipe and Briz (2018) discuss the governance challenges in urban agriculture, emphasizing the need for specific governance strategies to achieve sustainable urban agriculture. The paper identifies eight instruments for sustainable urban agriculture, including food security, economic development, environment, health, relationships,

regulatory, social, and others. Each city requires specific governance, looking for synergies, and the paper provides a general description of international cases, highlighting the diversity of approaches and challenges in different urban contexts.

Merino *et al.* (2021) analyzes the governance factors supporting urban agriculture in selected Sub-Saharan African cities. Using the Institutional Analysis and Development Framework, the study reveals that urban agriculture is beginning to receive policy attention for its contribution to food security and recognition for generating environmental, ecological, health, and human well-being benefits. However, the literature does not yet signal a local awareness and policy thrust regarding the climate adaptation benefits of urban agriculture. The study recommends trans-disciplinary, locally-led, planning-based, and multi-sectoral approaches involving various stakeholders to recognize and achieve the climate adaptation, environmental, and food security benefits of urban agriculture.

To overcome policy and regulatory hurdles, a multi-faceted approach is required. This includes developing supportive policies and financial models, enhancing community engagement, and addressing environmental concerns through sustainable practices. Additionally, integrating urban agriculture into broader urban planning and development strategies can help mitigate these barriers and promote the scalability of urban agriculture. Policy and regulatory hurdles present significant challenges to scaling urban agriculture. Addressing these challenges through policy support, community involvement, and sustainable practices will be key to enhancing the scalability and viability of urban agricultural practices.

4.4. Future Directions in Scaling Urban Agricultural Practices

The future of urban agriculture is poised at an exciting juncture, with potential directions that promise to reshape how cities approach food production, sustainability, and resilience. Sogang and Monkouop (2019) offer a comprehensive perspective on the evolution of urban agriculture in Cameroon, highlighting the importance of a multi-dimensional analysis. Their work underscores the need to understand urban agriculture's past and present to chart its future course effectively. The study suggests that a thorough understanding of the historical, social, economic, and diplomatic aspects of urban agriculture is crucial for addressing contemporary challenges and harnessing its full potential.

Gulyas and Edmondson (2021) focus on the role of urban agriculture in enhancing city resilience, particularly in the context of the Global North. Their systematic review identifies key factors that determine the success of urban agriculture in providing resilience benefits. The study develops a conceptual model that highlights ways to enhance urban agriculture through research, policy, and practice. This model emphasizes the importance of institutional and public support, a sufficient knowledge base, and effective communication and collaboration among different actors. Chatterjee, Debnath, and Pal (2020) discuss the implications of urban agriculture and vertical farming for future sustainability. The article highlights the advantages of vertical farming over traditional farming, such as reduced farm inputs, crop failures, and restored farmland. The study points out that vertical farms can grow food year-round,

regardless of external weather conditions, offering a steady supply of products and a consistent income for growers. This approach is particularly promising for urban areas where space is limited, and the need for sustainable food production methods is high.

To realize these future directions, urban agriculture must overcome challenges related to land availability, resource management, and integration into urban planning. Supportive policies, community engagement, and innovative practices are essential for scaling urban agriculture and making it a sustainable part of urban ecosystems. The future of urban agriculture lies in its ability to adapt to and address the challenges of urbanization, climate change, and food security. By embracing innovative practices such as vertical farming, enhancing city resilience, and understanding the historical and socio-economic context, urban agriculture can play a crucial role in sustainable urban development.

5. Conclusions

The study has revealed that scalability in urban agriculture is contingent upon a multifaceted approach that addresses economic, social, and environmental dimensions. Key insights include the necessity for innovative technological integration, community engagement, and policy support. Urban agriculture's scalability is significantly influenced by factors such as land availability, resource management, and the integration of these practices into broader urban planning. The economic viability, coupled with social and environmental sustainability, forms the cornerstone of successfully scaling urban agriculture.

Moving forward, the future landscape of urban agriculture is poised to overcome existing challenges and seize emerging opportunities. The study underscores the potential of urban agriculture in contributing to sustainable urban development, food security, and environmental resilience. Overcoming challenges such as regulatory hurdles, technical limitations, and infrastructural constraints will require collaborative efforts from various stakeholders. The opportunities presented by technological advancements, particularly in vertical farming and smart agriculture, offer promising avenues for the evolution of urban agriculture.

The study emphasizes the need for a collaborative and strategic approach from stakeholders and policymakers to enhance the scalability and impact of urban agriculture. It is recommended that policymakers develop supportive policies and financial incentives that encourage the adoption and expansion of urban agriculture. This includes facilitating access to land and essential resources, which are critical for the success of urban farming initiatives. Investment in research and development is crucial to advance urban agriculture technologies, making them more efficient and accessible. Additionally, promoting community-based urban agriculture initiatives can significantly enhance local food security and foster social cohesion. Integrating urban agriculture into broader urban planning and development strategies is essential to ensure its sustainability and effectiveness. These recommendations aim to create an enabling environment for urban agriculture, making it a viable and integral component of urban ecosystems.

Lastly, the study identifies urban agriculture as a pivotal element in the transformation of urban environments towards sustainability, resilience, and food security. To fully realize the potential of urban agriculture, it is imperative to address existing challenges and capitalize on emerging opportunities.

Future research should focus on exploring innovative urban agriculture models that are adaptable to various urban contexts, thereby enhancing their applicability and impact. Investigating the long-term effects of urban agriculture on urban ecosystems will provide deeper insights into its environmental benefits. Strategies to enhance the economic viability of urban farming are crucial to ensure its sustainability and attractiveness to stakeholders. Additionally, assessing the role of urban agriculture in climate change mitigation and adaptation will contribute to broader environmental goals. Examining the social impacts of urban agriculture, particularly on community dynamics and well-being, will provide a comprehensive understanding of its benefits beyond food production. These research directions are aimed at advancing the field of urban farming, ensuring its contribution to sustainable urban development.

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