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Vertical Farming: A Key To Sustainable Compact Cities

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REVIEW

Vertical farming for Compact Cities

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Abstract

Urbanization continues to surge, with projections indicating that by 2050, around 70% of the global population will reside in urban areas. In response, urban planners are exploring novel urban paradigms to ensure food security through urban agriculture, a cornerstone of sustainable development encompassing environmental, economic, and social dimensions. This study addresses a critical research gap within urban agriculture, conducting a comparative analysis between horizontal and vertical farming (VF) methodologies within urban contexts. By categorizing various typologies of VF, from container farms to mixed-use structures, this research highlights their distinct contributions to sustainable urban development. Emphasis is placed on VF's role within the framework of sustainable compact urban development, with a comprehensive examination of its environmental, economic, and social benefits. Furthermore, the study aligns VF with the 'Work, Live and Play' urban model, illustrating how it fosters vibrant, mixed-use communities conducive to convenience, reduced transportation demand, and heightened quality of life. In conclusion, this research emphasizes the pivotal role of VF in addressing contemporary urban challenges and advocates for its integration into urban development policies. It emphasizes the necessity of regulatory reforms, financial viability, and community involvement to realize the full potential of VF within compact city planning. By contributing to the discourse on sustainable urbanization, this study emphasizes the transformative impact of innovative agricultural practices on the future fabric of cities.

Keywords: Food security, Sustainable development, Urban agriculture, Urbanization, Vertical farming

1. Introduction

Although agriculture is fundamental to establishing civilizations and the growth of big cities, the Specialized Studies of Urban Agriculture refers to the relationship between agriculture and the rural environment outside of cities. The two most important aspects of the human experience are food and civilization. It is important to note that agriculture is handled intellectually differently today than in old eras (Thompson et al., 2007). Three main factors have combined to remove agriculture from the urban environment in the contemporary era: the Industrial Revolution, urban development, and urban expansion. Due to this, agriculture's harmonious interaction with the urban environment has gradually declined, creating several barriers to urban agriculture, such as the issue of expensive land and inadequate green infrastructure in metropolitan areas, urban environment pollution, unsecured food sources, and crops high prices (Panagopoulos et al., 2018; Sousa and Batista, 2013).

Consequently, cities have become hubs for sophisticated, alluring sectors that appeal to rural residents. Because of this, urban planners and designers now understand the value of urban agriculture and incorporate it into their plans as a crucial element that complements the world's ongoing sustainability movements (Deelstra and Girardet, 2000). This research aims to address the existing gap in the field of urban agriculture by conducting a comprehensive literature review and analysis of the state-of-the-art research. By synthesizing existing knowledge and insights, this study

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seeks to contribute to the understanding of urban agriculture's multifaceted benefits, including food security, employment generation, biodiversity conservation, and other socio-environmental advantages. Through rigorous examination of relevant literature and research papers, this paper aims to provide valuable insights and recommendations for enhancing the role and impact of urban agriculture in sustainable urban development.

1.1. Scope of study

This study delves into the multifaceted realm of urban agriculture, focusing particularly on the comparative analysis between horizontal and vertical farming (VF) methodologies within urban contexts. By synthesizing existing literature and research, the study aims to unravel the historical origins, evolution, and diverse typologies of VF. It explores the advantages and disadvantages of both horizontal and VF methods, scrutinizing their environmental, economic, and social implications. Furthermore, the study investigates the potential of VF to contribute to sustainable urban development, with a specific emphasis on its role in achieving compact cities. Through a rigorous examination of these aspects, the research seeks to provide valuable insights and recommendations for integrating VF into urban planning and development strategy. How does urban agriculture contribute to sustainable urban development in the context of contemporary challenges such as food security, environmental degradation, and urbanization? (Thompson et al., 2007; Panagopoulos et al., 2018; Sousa and Batista, 2013).

The research questions addressed in this study include:

(a) What are the advantages and disadvantages of horizontal and VF methods in urban environments, considering their environmental, economic, and social impacts?
(b) What are the historical origins and evolution of VF, and how does it contribute to addressing contemporary urban challenges?
(c) What are the various typologies of VF, and how do they optimize space and increase efficiency in urban settings?
(d) How does vertical urban agriculture contribute to sustainable compact cities, and what are the potential benefits and challenges associated with its integration into urban planning and development?

These research questions form the foundation of the study's investigation into the role of VF in achieving sustainable compact cities and addressing contemporary urban challenges.

2. Farming types

Farming practices have evolved significantly over centuries to meet the growing demands of an increasing global population while addressing the challenges posed by limited land availability, climate change, and urbanization. Among the innovative approaches gaining traction are horizontal and VF methods, each offering unique advantages and considerations in the quest for sustainable food production, as shown in Fig. 1, which includes some examples of horizontal and VF types.

Historically, the traditional method of agriculture has been horizontal land cultivation. However, due to the growth in urban population density, the increased demand for land in cities for more profitable uses, and the scarcity of resources suitable for the demands of traditional farming methods, this method of agriculture is becoming less and less common (Lovell, 2010). As a result, a new alternative agriculture model known as horizontal agriculture on building roofs called 'green roofs' has emerged Fig. 2.

The green roof model uses vacant and underutilized land to create green spaces within cities, which addresses the shortage of ground for agriculture and the need for such areas (Kim, 2018). However, there are several drawbacks to this agricultural paradigm, which Table 1 summarizes according to the three pillars of sustainability as follows:

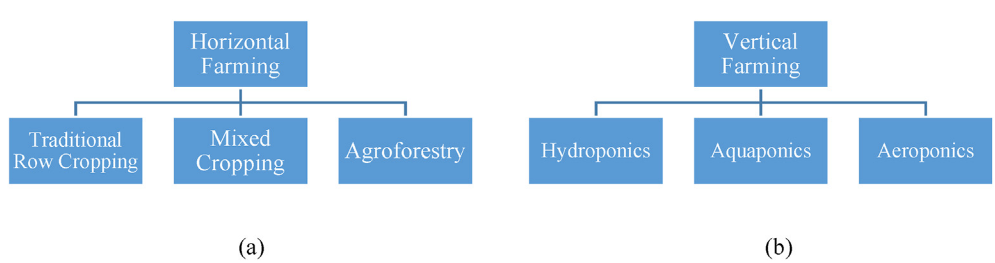


Fig. 1. Examples of Horizontal and vertical farming types. Source (Author). (a) Horizontal farming. (b) Vertical farming.

(a) (b)

Fig. 2. Rooftop soil farm examples. (a) Brooklyn Grange rooftop farming and intensive green roofing in the United States (b) The Roulant's roof garden, Montreal, Canada. Source (Hsieh et al., 2018).

So, VF, a style of agriculture practiced in vertical and varied forms inside or outside of structures and at various levels within multi-story buildings, represented the need for an innovative form of urban agriculture (Zareba et al., 2021). VF, a sustainable agriculture approach, has promise as a substitute for conventional horizontal agriculture, supplying food to cities and maintaining the urban environment. Additionally, there needs to be a means to use these abandoned areas rather than attempt to flee from them. Such places include shipping containers, abandoned warehouse space, and buildings solely used for vertical agriculture (indoor or outdoor) (Birkby, 2016), as shown in Fig. 3.

VF is described as a technology that combines high-rise building farms with cutting-edge architecture to showcase the degree of a city's connection to the natural world. It involves planting vertically using various techniques, including hydroponics, aeroponics, and aquaponics (Mir et al., 2022), as shown in Fig. 4. Therefore, the numerous benefits of VF that make it a viable model and substitute for the traditional agricultural model can be summed up as follows in Table 2.

2.1. Difference between horizontal and vertical farming

Horizontal and VF represent contrasting approaches to agricultural production, each with its distinct characteristics and applications.

Horizontal farming follows the traditional approach of growing crops in open fields, greenhouses, or green roof structures on a single level. It requires larger land areas (horizontal extension) and is typically practiced in rural settings with access to ample agricultural land {Specht et al., 2014}. Horizontal farming accommodates a broader variety of crops, including grains, fruits, vegetables, and specialty crops, making it versatile for different agricultural contexts. While it may have a larger environmental footprint due to factors like land conversion and pesticide runoff, horizontal farming remains essential for large-scale agricultural production to meet global food demand. Overall, vertical and horizontal farming serve complementary roles in addressing food security, environmental sustainability, and resource management, with each method offering unique benefits and challenges (Benke and Tomkins, 2017).

Table 1. Urban Horizontal agricultural disadvantages. Source (Author).

No.	Sustainability Pillar	Drawback
1	Environmental	1. Urban horizontal agriculture is not an ‘environmentally friendly’ activity due to carbon emissions from production as it uses soil as traditional farming (Vatistas et al., 2022). 2. Using chemicals and pesticides for a shortened production time harvesting is not safe (Dugje et al., 2008). 3. It cannot contribute as sound insulation to the city's daily life practices as it is found on roofs and far from street level (Raimbault and Dubois, 2005). 4. It purifies air on rooftops (air above buildings only), leaving air pollutants on street level as they are (Fithian, 2019).
2	Economical	1. Excessive use of water from 300 to 400 water liters to produce 1 kg of vegetables (Wallace, 2000) 2. Green roofs consume large quantities of raw materials such as seeds, water, and soil (Getter and Rowe, 2006). 3. It needs a sizable area for food production; for instance, horizontal agriculture needs a minimum of 72 m2 of horizontal space to grow 150 kg of vegetables monthly with ongoing maintenance (Su et al., 2020). 4. Direct exposure to sunlight for an extended period leads to the loss of crops (Qu et al., 2021).
3	Social	1. Building rooftops are used for horizontal agriculture, which places them outside the human field of perception from vision, sense, or smell. This leads humans to practice daily activities within hard-building enclosures (Specht et al., 2014).

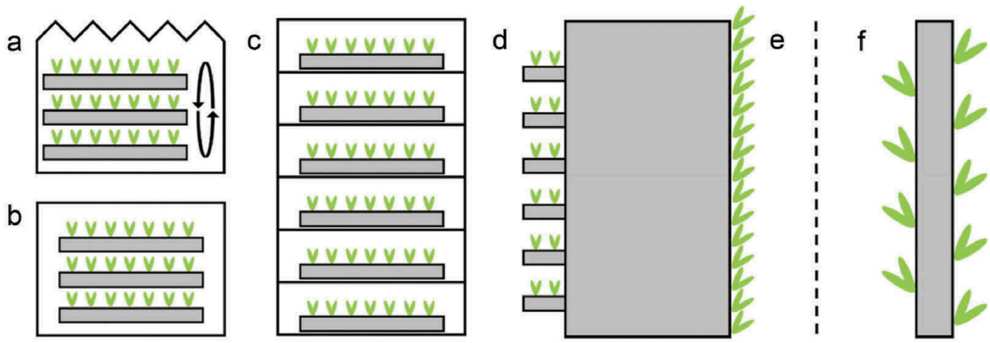


Fig. 3. Representation Stacked horizontal vertical farming (VF). Source (Beacham et al., 2019).

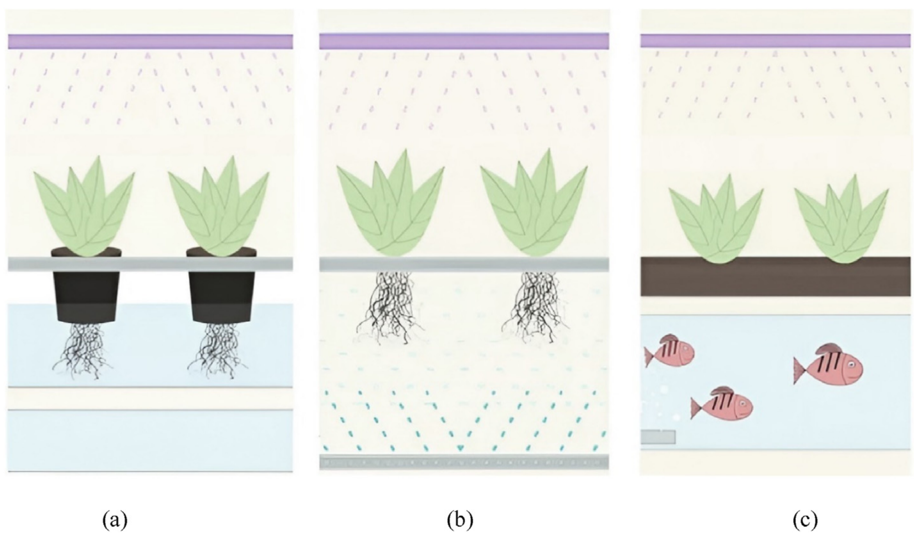


Fig. 4. Sample of vertical farming different technologies. Adopted by Author. (a) Hydroponics – (b) Aquaponics – (c) Aeroponics.

Table 2. Vertical farming advantages.

No.	Sustainability Pillar	Benefits
1	Environmental	1. No hazardous emissions are released throughout the production or transportation processes. Crops have a shorter production rate and do not require chemical pesticides (Vatistas et al., 2022). 2. Due to its higher evaporation rate and wider urban street climate influence, vertical farming, especially green walls, significantly affects the local temperature. 3. Vertical farming on the building walls adds to the sound insulation and reduces the city's everyday activities, particularly traffic noise (Raimbault and Dubois, 2005). 4. By lowering infrared emissions, vertical farming on building walls helps to improve the urban environment by purifying and lowering the temperature of the air near vegetation cover and the wall surface. It also helps to mitigate the climate of the city's alleys and streets (Fithian, 2019).
2	Economical	1. As one kilogram of vegetables needs twelve liters of water to grow, vertical agriculture may solve the issue of water scarcity (Wallace, 2000). 2.75% fewer raw materials are used than ordinary agriculture (Getter and Rowe, 2006) 3. Just 6 m of vertical space are needed for 150 kg of vegetables to be produced monthly with vertical farming, which consumes more than ten times less space than traditional horizontal agriculture (Su et al., 2020). 4. Vertical farming on building walls exposes them to direct and indirect sunlight, making them more resilient to deterioration (Qu et al., 2021).
3	Social	5. Vertical farming is found on exterior and interior walls, which places them within the human field of vision (Specht et al., 2014)

In contrast, VF involves growing crops in vertically stacked layers within controlled environments such as skyscrapers, shipping containers, or multistory buildings (Valerio Trujillo, 2020). This method maximizes space utilization by utilizing vertical structures efficiently, making it particularly suitable for urban areas with limited land availability. VF relies on innovative techniques like hydroponics, aeroponics, or aquaponics, offering resource-efficient solutions for water usage and energy consumption. It is well-suited for growing leafy greens, herbs, and certain fruits and vegetables, contributing to local food production and reducing transportation distances {Panotra, 2024}.

3. Vertical farming

It is not a new, innovative concept. One of Philon's Seven Wonders of the Ancient World, the Hanging Gardens of Babylon, as shown in Fig. 5, dates back to about 600 BC and is home to historical examples (Srivastava, 2011). Gilbert Ellis Bailey wrote a book named 'VF' and created the phrases" in 1915. He maintained that hydroponically farming in a regulated vertical setting would benefit the environment and the economy (Bailey, 1915). William Frederick Gericke invented hydroponics in the early 1930s at the University of California at Berkley. Swedish ecological farmer Åke Olsson also suggested vertical farming to grow vegetables in cities in the 1980s. He is credited for creating the spiral-shaped rail system for plant growth (Al-Kodmany, 2018; Corvalan et al., 2005).

American ecologist and public health professor Dickson Despommier fervently brought back the idea of VF around the turn of the century. 'The mass cultivation of plant and animal life for commercial purposes in skyscrapers' is how he defined the vertical farm (Newton, 2020). The vertical farm might produce fish, poultry, grains, fruit, and vegetables using cutting-edge greenhouse techniques, including hydroponics and aeroponics'. In comparison to conventional farming, which is large-scale outdoor agriculture that uses systems that involve heavy irrigation, intensive tillage, and excessive use of pesticides, fertilizers, and herbicides, vertical farms are thought to promote sustainable agricultural practices more (Despommier, 2010; Healy and Rosenberg, 2013).

3.1. Why vertical farming

VF offers a sustainable solution that integrates environmental stewardship, social well-being, and economic viability.

4. Vertical farming varied typologies

Vertical urban farming has evolved to encompass various forms and methods to optimize space and increase efficiency.

4.1. Container farm

Agricool, a new VF business based in Paris, France, is well-known in the media. The company was established in 2015 and creates aeroponic strawberry farms in container farms, as shown in Fig. 6 (Fourdinier, 2019).

One of the most promising and recently proposed high-potential techniques is growing crops in shipping containers because it offers a scalable and adaptable way to produce food all year long in a range of climates and because shipping containers are known for their mobility, regularity, simplicity, productivity, and efficiency (Butturini and Marcelis, 2020).

4.2. In-store farms

Founded in 2013, Infarm is a Berlin-based start-up that creates in-store farms for restaurants and shops to grow microgreens, leafy greens, and herbs in-store, as shown in Fig. 7. Over the years 2013–2019, Infarm has already raised over 120 million from investors. As of August 2019, the company harvested more than 150 000 plants monthly and was present

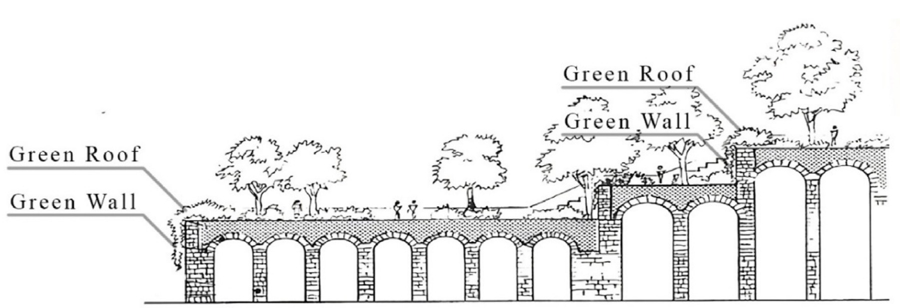


Fig. 5. The Hanging Garden of Babylon section drawing shows vegetation as green roofs and walls. Source (Srivastava, 2011).

(a) (b)

Fig. 6. Vertical Farming container in the Bercy district of Paris. Source (Fourdinier, 2019). (a) Container exterior shape – (b) container from inside.

Fig. 7. An in-store farm in the Metro's store in Paris, France. Source (Butturini and Marcelis, 2020).

at more than 350 in-store retail and distribution sites throughout Germany, France, Switzerland, and Luxembourg. Due to their partnerships with over 25 large shops, including Auchan, Amazon Fresh, Electroka, Metro, Migros, Casino, and Intermarche, Infarm was able to expand internationally (Butturini and Marcelis, 2020; Khan et al., 2020).

4.3. Vertical green wall

The term 'green wall' refers to any method used to green a vertical wall, including separating walls, exterior walls made of glass or solid, inner walls, and decorative components used to package and shade structures, as shown in Fig. 8 (Hopkins and Goodwin, 2011). In addition to features that improve the urban environment by fostering biodiversity, purifying the air, lowering temperatures, lessening the effects of urban heat islands, and enhancing the building's sustainability, vertical green walls fall into several categories (such as living walls and vertical green facades).

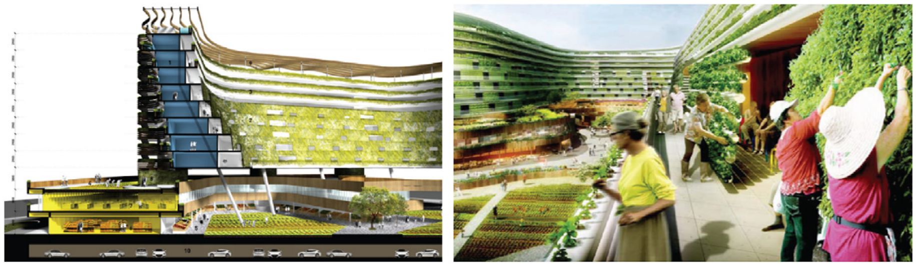
4.4. Mixed-use building

These vertical farms combine agricultural with already-existing commercial, residential, or administrative purposes, converting the structure into a multipurpose space, as shown in Fig. 9. Valerio Trujillo (Valerio Trujillo, 2020). Studies have indicated that the integration of VF activities with other purposes while utilizing the 20:5:50 land area ratio is seen. They reserve 50% of the building's overall space for residential use. 20% for agricultural and 5% for commercial units guarantees economic solid efficiency and a sustainable, healthful lifestyle (Block and Bokalders, 2010).

Fig. 8. Living green wall, Semiahmoo Library in South Surrey. Source (Timur and Karaca, 2013).

4.5. Dedicated vertical farming structures

It is a multi-story building with multiple floors stacked on top of one another. Each floor is



(a) (b)

Fig. 9. Vertical Framing in a mixed-use building. Source (Kalantari et al., 2020). (a) Conceptual vertical farming design — (b) daily practices of people who are living and working in the same place.

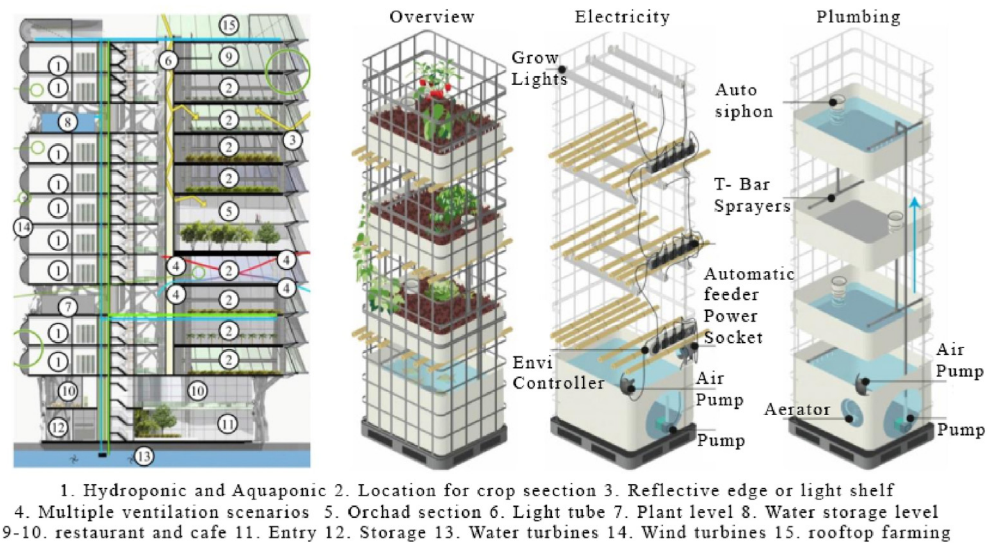


Fig. 10. Vertical Aquaponics farm Conceptual layout design. Source (Kalantari et al., 2020).

specifically designed to produce large quantities of plant crops and fish, and it is outfitted with advanced techniques that mimic the natural environment of plants and unique systems and components from crop cultivation to harvest, as shown in Fig. 10 (Zeidler and Schubert, 2014). The concept behind this type of agriculture is to provide a fresh, helpful strategy to stop additional encroachment on the urban landscape.

5. Vertical urban agriculture's contribution to compacted urban

5.1. Sustainable urban compactness

Sustainable urban compactness generally refers to effective land planning, diversity, land-use mix, sustainable mobility, density of the built environment, and intensification of its activities, as shown in Fig. 11 (Bibri et al., 2020). It aims to achieve a more sustainable city through institutionalized practices by creating and executing various strategies and measures that support sustainability objectives. This includes creating a more varied, denser, mixed-use city with sustainable transportation and green space (Bulkeley and Betsill, 2005).

Compactness of the built environment is a commonly recognized technique for attaining sustainable urban forms. It also refers to urban contiguity, connectedness, and agglomeration. Therefore, it implies that any future land use changes related to the physical aspect of urbanization should occur next to the current urban structures and fabrics (Angel et al., 2020). Thus, taking advantage of the building zones' potential to facilitate future structural development in the current urban regions through inward development techniques is crucial. This concerns built-form intensification, a key tactic for attaining compactness through denser construction and more effective land use (Williams et al., 1996).

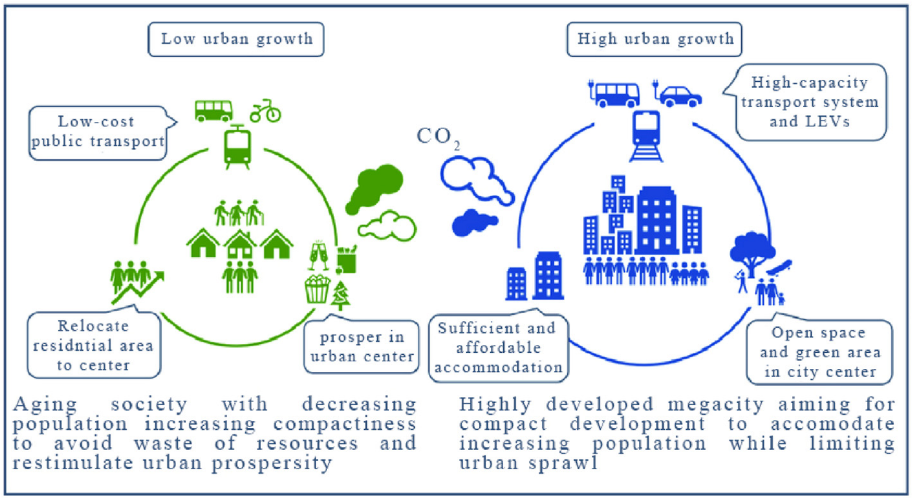


Fig. 11. Characteristics of cities that can adopt a compact city strategy. Source (Fan and Chapman, 2022).

Therefore, VF offers opportunities on an environmental, economic, and social level; as shown in Table 3, it is crucial and successful in helping to achieve the sustainable compactness of urban environments. The significance of the agricultural system's potential inclusion has been abundantly evident in recent decades, and the current agricultural practices endanger the ecosystem's health and human well-being (Butler and Oluoch-Kosura, 2006). However, to create sustainable compact cities, people must reconsider how integrated agriculture fits into the urban fabric in light of climate change. This calls for enacting laws by the public sector, accountable organizations, governments, municipalities, and others that motivate people to participate in these activities. It also calls for the implementation of awareness-raising and educational campaigns by nongovernmental organizations in the private sector that spread information about the significance of incorporating VF practices. In already-existing structures (such as green walls both inside and outside or green balconies) (Delgado, 2017).

5.2. Vertical mixed-use development

City planners have used zoning regulations and land use segregation as the fundamental guiding concepts in the construction of cities in traditional urban planning (Raman and Roy, 2019). Despite its many benefits, zoning laws and land use segregation have been criticized by scholars in recent years for several unfavorable aspects. For example, seclusion and lack of energy; greater distance and cost of commute from home to work; inappropriate setting for small investments; higher cost of travel to facilities and amenities, leading to increased spending; and safety concerns (Giuliano and Agarwal, 2004). Vertical mixed-use development, a 'vertical urban superblock,' has been recommended as a tactic to get around these restrictions and unfavorable circumstances.

Table 3. Main reasons behind vertical farming.

No.	Sustainability Pillar	Benefits of vertical farming
1	Environmental	1. Water Efficiency: Vertical farming uses 98% less water than traditional agriculture, addressing water scarcity and promoting sustainability {Kalantari, 2018}. 2. Reduced Environmental Impact: By growing crops indoors, vertical farms eliminate major polluters like agricultural runoff and minimize greenhouse gas emissions (Al-Kodmany, 2018).
2	Economical	1. Food Safety: Vertical farming reduces contamination risks, as crops are less likely to be exposed to harmful bacteria like Listeria, Salmonella, or E {Macieira, 2021}. 2. Higher Quality Produce: Without pesticides, vertical farming yields safer and higher-quality crops for consumers {Avgoustaki, 2020}.
3	Social	1. Year-Round Production: Vertical farms can grow crops continuously, overcoming seasonal limitations (Al-Kodmany, 2018). 2. Space Efficiency: Higher productivity in smaller areas leads to increased crop yield per square foot (Benke and Tomkins, 2017). 3. Local Food Supply: Fresh produce grown closer to consumption points reduces transportation needs and supports local economies (Benke and Tomkins, 2017).

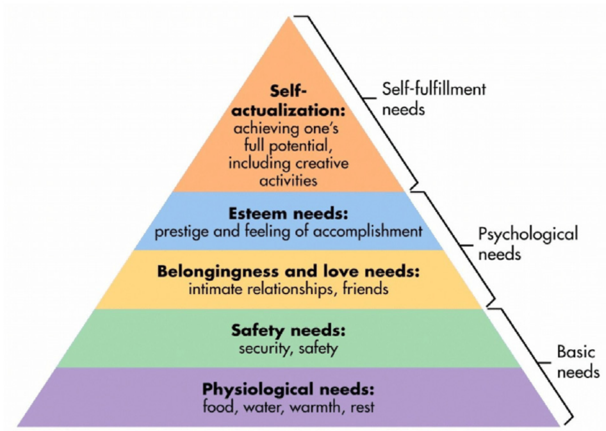


Fig. 12. Maslow's hierarchy of needs. Source (Maslow, 1962).

Vertical urban superblock also provides other benefits, such as greater diversity and density of housing, an economically balanced mix of appropriate land uses, compact development, a more robust neighborhood character, reduced walkability footprint, and the production of jobs (Lehmann, 2016). Vertical urban superblocks could not always result in these benefits. For instance, combining more than a reasonable amount of mixed uses can result in undesirable outcomes like parking spill out, unintentional very high-density housing, encroachments, traffic congestion, chaos and noise, overstressed infrastructure, and nonresidential uses operating on residential property while paying less tax creating a new urban model which is 'work, live and play.' (Maing, 2022).

5.3. 'Work, live and play' compacted urban model

'A Theory of Human Motivation,' written by Abraham Maslow in 1943, contained what is now referred to as Maslow's hierarchy of needs, as shown in Fig. 12 (Maslow, 2000). In summary, it presents the idea that before humans can develop into the advanced, self-actualized social creatures that he/she believe themselves to be, basic human needs must be met. The fundamental needs are to live in a place with property and shelter; to work and earn a living; to play and maintain essential socialization and a sense of 'belongingness'; to eat and drink; and, lastly, to shop and have access to clothing and 'security of resources.' (Baqutayan et al., 2015).

The aim is to create an urban model for a vibrant place that allows for a symbiotic relationship between LIVE, PLAY, and WORK lifestyle elements. The district houses a mix of live-work units. Urban compaction can achieve this model through the use of vibrant mixed land.

5.3.1. Benefits of the 'work, live and play' urban model

The 'Live, Work, Play' urban plan firmly emphasizes developing integrated, mixed-use communities that let locals work, live, and enjoy leisure activities in a small, walkable neighborhood. As listed below in Table 4, this strategy has various advantages for both individuals and communities (Edwards and Tsouros, 2006):

Overall, the 'Live, Work, Play' urban model provides an all-encompassing urban development and planning strategy that aims to build more vibrant, sustainable, and livable cities. This model capitalizes on economic growth, social engagement, and environmental stewardship prospects while addressing many problems associated with contemporary urbanization. It accomplishes this by integrating numerous parts of daily life inside a condensed and interconnected framework.

5.3.2. Limitations and constraints

Although the 'Live, Work, Play' urban paradigm has many advantages, some restrictions and limitations should be appropriately considered before implementing it, as shown in (Tables 5–7) (Al Gharibi, 2015).

5.4. How can vertical farms create solutions for the challenges facing sustainable compact cities?

VF contributes to sustainable and resilient urban agriculture, addressing critical challenges while enhancing environmental, social, and economic well-being.

Table 4. Urban Vertical Farming technology as part of a sustainable compact city. Source (Author).

No.	Sustainability Pillar	Benefits
1	Environmental	1. Reduce Carbon emissions 2. Improve sound insulation 3. Air purification 4. Enhance biodiversity 5. Reduce raw material usage 6. Secure.
2	Economical	1. Food security 2. Healthy crops 3. Reduced embodied energy.
3	Social	1. More job opportunities 2. Reduce stress and anxiety from outdoor daily activities 3. Achieve spiritual and mental health.

Table 5. Benefits of the 'Live, Work, Play' urban model Source (Author).

No.	Sustainability Pillar	Benefits
1	Environmental	1. Green Spaces: Creating parks, green areas, and recreational spaces enhances the environment, promotes biodiversity, and improves air quality. 2. Sustainable Transport: Integrated public transportation systems reduce traffic congestion, lower emissions, and improve overall mobility. 3. Energy Efficiency: Efficient building design and renewable energy sources contribute to reduced energy consumption.
2	Economical	1. Quality of Life: Access to amenities, cultural events, and social interactions enhances residents' well-being. 2. Community Engagement: Mixed-use developments foster community cohesion and interaction. 3. Health and Safety: Proximity to work, leisure, and healthcare facilities positively impacts health outcomes.
3	Social	1. Attracting Investment: A vibrant urban environment attracts businesses, investors, and talent. 2. Job Creation: Diverse employment opportunities within the same area benefit residents. 3. Increased Property Values: Well-planned mixed-use neighborhoods often lead to higher property values.

Table 6. 'Live, Work, Play' detailed limitations and constraints. Source (Author).

No.	Sustainability Pillar	Limitations and constraints
1	Environmental	1. Land Use Conflicts: Integrating residential, commercial, and recreational spaces can lead to conflicts over land use and zoning regulations. 2. Infrastructure Strain: Concentrating activities in one area may strain existing infrastructure (e.g., transportation, utilities). 3. Ecological Impact: Increased urban density can affect local ecosystems and green spaces.
2	Economical	1. Gentrification: Revitalization efforts may displace existing communities, affecting affordability and social cohesion. 2. Equity: Unequal access to amenities within the same district can exacerbate social disparities. 3. Community Identity: Balancing diverse functions while maintaining a cohesive neighborhood identity is challenging.
3	Social	1. Market Dynamics: Mixed-use developments require careful market analysis to ensure sustained demand. 2. Investment Risk: High upfront costs and uncertain returns pose risks for developers and investors. 3. Business Viability: Co-locating businesses and residences requires strategic planning to foster economic vitality.

Table 7. Solutions for challenges facing sustainable compact cities. Source (Author).

No.	Sustainability Pillar	Solutions
1	Environmental	1. Water Conservation: Vertical farming uses up to 98% less water than traditional agriculture, addressing water scarcity and promoting sustainability1. 2. Reduced Land Footprint: By growing vertically, it maximizes land utilization, making it suitable for compact urban areas.
2	Economical	1. Local Food Security: Vertical farms can supply fresh produce directly to urban communities, reducing dependence on distant sources. 2. Community Engagement: Urban farms create opportunities for education, employment, and social interaction.
3	Social	1. Year-Round Production: Vertical farms operate year-round, ensuring a steady food supply. 2. Job Creation: Local farming generates employment and supports the local economy.

6. Conclusion

This paper emphasizes the significance of VF in contributing to the 'Work, Live and Play' urban model, promoting integrated, mixed-use communities that enhance convenience, reduce transportation demand, and improve quality of life. The research emphasizes the interconnectedness of sustainable urban development strategies, fills the research gap in urban agriculture, and illustrates how VF aligns with the goals of compact city planning, environmental stewardship, and social integration.

With the world's population growing and cities becoming increasingly urbanized, planners and designers have started to see cities as places where food is produced to meet specific ecological and social demands. The urban region requires the most intense efforts, but it also benefits from incorporating local food production services into planning. The primary causes are the dense population with limited access to farm fields and fresh food, as well as the high concentration of customers. Global resource scarcity has progressively prompted precision farming practices. This strategy provides for the needs of the plant. As a result, it can reduce energy use, water waste, and loss of nutrients and natural light, as well as minimize product loss.

The study's findings may strengthen the case for the significance of the VF concept concerning food security in high-density metropolitan regions. Because of this, researchers try to figure out how to use productive land just for production and increase food production above buildings in extremely crowded urban regions. Urbanism in the twenty-first century has created some challenging situations for our cities. One potential option could be VF. When these goals are combined, the strategy contributes to food safety worldwide and ensures that international sustainability's public acceptability and environmental compatibility requirements are satisfied.

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Author contribution/author credit statement

In preparing the research paper on the introduction of a new concept for vertical farming, each author contributed distinct roles. MT, as the primary contributor to study conception and design, established the framework and objectives of the review. SE provided essential guidance on the conceptualization and scope of the paper. AK offered valuable insights into the practical implications of vertical farming. For data collection and tools, MT curated relevant literature and references, SE facilitated access to key resources, and AK reviewed and curated specific datasets. In data analysis and interpretation, MT synthesized key themes from the literature, SE provided expert interpretation of data trends, and AK conducted comparative analyses of farming techniques. Methodologically, MT designed the review's methodology, SE refined it, and AK suggested improvements for rigor. Drafting the manuscript fell primarily to MT, with critical inputs and refinement from SE, and specific sections contributed by AK. All authors contributed substantially to critical revision, with MT integrating feedback, SE ensuring academic rigor, and AK enhancing clarity and coherence. Finally, as corresponding author, MT ensured all revisions were incorporated, with SE and AK approving the manuscript for submission and publication.

Conflict of interest

There are no conflicts of interest.

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