

Research Article

Application of Vertical Farming Design Strategies in High-rise Housing Estates in Nigeria

Lawal Habibulahi Abayomi¹ , Jubril Adesanya Olanusi^{1,*} ,
Muhammed Adamu¹ , Adeyemi Kehinde Adetoyese²

¹Department of Architecture, College of Environmental Science, Joseph Ayo Babalola University, Ikeji Arakeji, Nigeria

²Department of Estate Management, College of Environmental Science, Joseph Ayo Babalola University, Ikeji Arakeji, Nigeria

Abstract

Urbanization in Nigeria has led to a significant increase in high-rise housing estates, which offer a viable solution to housing shortages in densely populated cities. However, these developments often result in limited green spaces and challenges in sustainable food production. The integration of vertical farming into high-rise housing estates holds potential for transforming these residential developments into self-sustaining ecosystems. Studies show that incorporating green infrastructure into urban design improves air quality, reduces urban heat, and enhances residents' well-being. Nigeria faces a dual challenge of rapid urbanization and food insecurity, which are further increased by limited fertile land and unsustainable agricultural practices. High-rise housing estates. This disconnect contributes to increased reliance on imported food, urban heat islands, and a diminished quality of life for residents. This study employs a qualitative research approach to assess the feasibility of integrating vertical farming into high-rise housing estates in Nigeria. A comprehensive review of existing studies on vertical farming, sustainable urban agriculture, and housing design strategies, with a focus on global practices and challenges specific to Nigeria and analysis of successful vertical farming projects in cities worldwide, such as Singapore and New York, to identify best practices and lessons that can be applied to Nigerian contexts. The paper was concluded by highlighting the feasibility of merging architecture with agriculture to create self-sufficient, environmentally conscious urban communities, promoting a sustainable future for high-density housing in Nigeria. The following points were recommended. Urban planning policies and building regulations in Nigeria should be updated to encourage the incorporation of vertical farming systems in high-rise housing estates. Developers, architects, and urban planners should collaborate with agricultural experts and sustainability consultants to design and implement effective vertical farming strategies tailored to local climate and socio-economic conditions.

Keywords

Food Security, High-rise Housing Estate, Sustainable Design, Urbanization Urban Agriculture Vertical Farming

*Corresponding author: jaolanusi@jabu.edu.ng (Jubril Adesanya Olanusi)

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1. Introduction

Nigeria is witnessing rapid urbanization, with over 50% of its population now residing in urban areas, which continues to grow at an unprecedented rate [16]. This surge in urban populations has led to significant pressures on housing, infrastructure, and food supply systems. High-rise housing estates have emerged as a solution to the housing shortage, offering a means to accommodate large populations in limited urban spaces. However, these residential structures are often designed with little consideration for the integration of sustainable food production systems, leaving urban areas heavily reliant on food imports and long supply chains that are vulnerable to disruption [10]. Integrating sustainable food production systems, leaving urban areas heavily reliant on food imports and long supply chains. Vertical Farming, which means growing food in skyscrapers, might help to solve many of these problems. [4]

Food security remains a critical issue in Nigeria, exacerbated by rapid population growth and the adverse effects of climate change on traditional agricultural practices. According to the Food and Agriculture Organization (FAO), Nigeria faces a significant food deficit, with millions experiencing hunger or undernutrition. Urban areas, in particular, are at a disadvantage due to limited space for conventional farming and the high cost of fresh produce transported from rural areas [10]. Vertical farming, a method of cultivating crops in vertically stacked layers, offers a promising solution to these challenges. By optimizing the use of vertical space, this approach can enable high-rise housing estates to produce fresh, nutritious food locally, reducing dependency on external food supplies.

Beyond food security, vertical farming aligns with global sustainability goals by addressing environmental concerns associated with traditional farming. Conventional agriculture contributes significantly to deforestation, water wastage, and greenhouse gas emissions [7]. Vertical farming, on the other hand, utilizes advanced techniques such as hydroponics and aeroponics, which require significantly less water and land. Moreover, by incorporating renewable energy sources and recycling systems, vertical farming can reduce the environmental footprint of food production while promoting circular economy principles [7].

The integration of vertical farming into high-rise housing estates is not merely a technological or agricultural endeavor; it is a holistic approach to urban planning that intersects with social, economic, and environmental dimensions. For residents of high-rise estates, vertical farming offers numerous benefits, including access to affordable fresh produce, opportunities for community engagement, and potential income generation through the sale of surplus crops. However, the adoption of vertical farming in Nigeria's urban context presents unique challenges, including high initial costs, limited technical expertise, and infrastructural constraints such as irregular power supply [12]. Addressing these barriers re-

quires a collaborative approach involving policymakers, urban planners, architects, and agricultural experts.

Globally, cities like Singapore and Tokyo have demonstrated the feasibility and benefits of integrating vertical farming into urban environments. For instance, Singapore's Sky Greens vertical farm has successfully combined compact, energy-efficient farming systems with urban living, serving as a model for densely populated regions (Sky Greens, n. d.). These international examples provide valuable lessons for Nigeria, where urbanization trends necessitate innovative solutions to food security and sustainability challenges. This underscores the relevance of the application of vertical farming design strategies within high-rise housing estates in Nigeria. It explores how architectural innovation can integrate food production into urban living spaces, creating multifunctional, self-sustaining communities. By considering Nigeria's unique climatic, economic, and cultural contexts, the research aims to develop adaptable models for integrating vertical farming into high-rise developments, offering a pathway to sustainable urban living for the growing population.

1.1. Statement of the Research Problem

Nigeria's rapid urbanization has resulted in significant challenges such as land scarcity, food insecurity, and environmental degradation. High-rise housing estates, particularly in densely populated cities like Lagos, Abuja, and Port Harcourt, are characterized by limited green spaces and a heavy reliance on imported and long-distance transported food supplies. This dependence increases food costs, contributes to food scarcity, and exacerbates environmental issues through carbon emissions from transportation.

Traditional agricultural practices are often insufficient to meet the growing urban demand for fresh produce due to constraints such as limited arable land, unpredictable weather conditions, and inefficient supply chains. Furthermore, the lack of integration between urban living spaces and food production contributes to the disconnection between residents and sustainable living practices.

Vertical farming presents an innovative solution to these challenges by enabling food production within urban residential structures. However, the application of vertical farming design strategies in high-rise housing estates in Nigeria remains underexplored. There is a need to investigate the feasibility, design considerations, economic viability, and potential challenges of integrating vertical farming systems into high-rise buildings in the Nigerian context.

1.2. AIM

This study aims to explore the application of vertical farming design strategies in high-rise housing estates in Nigeria, with the view of promoting sustainable urban agricul-

ture, while enhancing food security, within densely populated urban areas.

Objective

The objective of this study is to examine the principles of vertical farming and its relevance to urban agriculture.

2. Literature Review

The concept of vertical farming has gained significant attention in recent years as an innovative approach to addressing global food security and sustainability challenges. According to (8), vertical farming involves the cultivation of crops in stacked layers within controlled environments, often integrated into urban settings. This approach leverages advanced technologies such as hydroponics, aeroponics, and LED lighting to optimize resource efficiency and crop yields. Despommier's seminal work highlights the potential of vertical farming to transform urban food systems by reducing land and water use while eliminating the need for harmful pesticides.

Research on urban agriculture underscores the importance of vertical farming in densely populated cities where land availability is limited. A study by [7] explores the various configurations of vertical farming systems, including rooftop farms, vertical gardens, and indoor farming setups. The study emphasizes that these systems can be tailored to specific urban contexts, making them highly adaptable for integration into high-rise housing estates. Additionally, [7] highlights the role of renewable energy sources, such as solar panels, in powering vertical farming systems, thereby enhancing their environmental sustainability.

The application of vertical farming in developing countries like Nigeria has been relatively underexplored, although its potential is immense. According to the Food and Agriculture Organization [10], urban agriculture can play a pivotal role in improving food security and reducing the environmental footprint of food production in rapidly urbanizing regions. The FAO's report identifies several barriers to the adoption of vertical farming in developing countries, including high initial investment costs, lack of technical expertise, and infrastructural constraints. However, it also points to successful case studies in countries like Singapore, where vertical farming has been integrated into urban planning to great effect (Sky Greens, n. d.).

Several researchers have also examined the socioeconomic benefits of vertical farming in urban settings. [3] argues that vertical farming not only enhances food security but also fosters community engagement and creates economic opportunities. By providing urban residents with access to fresh produce and opportunities for income generation, vertical farming can contribute to poverty alleviation and social cohesion. This perspective is particularly relevant in the Nigerian context, where unemployment and income inequality remain pressing issues [18].

Despite its numerous advantages, vertical farming is not

without challenges. For instance [17], highlight the high energy demands of controlled-environment agriculture, which can be a significant barrier in regions with unreliable power supply. This is a critical consideration for Nigeria, where power outages are frequent. Specht et al. recommend the integration of off-grid solutions, such as solar energy and battery storage, to overcome this challenge. Moreover, they stress the importance of public awareness and education in promoting the acceptance and adoption of vertical farming technologies.

The literature on vertical farming provides a solid foundation for understanding its potential applications in high-rise housing estates in Nigeria. While much of the research focuses on developed countries, there is a growing recognition of the need to adapt these innovations to the unique challenges and opportunities of developing regions. By drawing on global best practices and addressing local constraints, vertical farming can become a cornerstone of sustainable urban development in Nigeria.

2.1. Urbanization and Housing Challenges in Nigeria

Nigeria's urban population is growing at a rate of over 4% annually, leading to increased pressure on housing and agricultural resources. The country faces challenges such as inadequate food supply, urban sprawl, and reduced agricultural land availability due to the conversion of rural land into urban settlements. Additionally, there is a growing demand for housing units in urban centers, where available land for new developments is scarce.

High-rise housing estates, often built to accommodate the increasing population in cities, could become vital spaces for integrating agriculture into urban life. However, these buildings typically focus on maximizing residential space and might not prioritize food production or sustainable agricultural practices. This gap in urban planning presents an opportunity for the introduction of vertical farming within these estates.

2.2. Vertical Farming: Concept and Technology

Vertical farming involves growing crops in stacked layers or vertically inclined surfaces, often in controlled environments that optimize resource use such as water, light, and nutrients. Technologies used in vertical farming include: hydroponics-growing plants in water-based, nutrient-rich solutions without soil, aeroponics- growing plants with their roots suspended in the air and misted with nutrients, aquaponics- a combination of aquaculture and hydroponics, where fish waste provides nutrients for plants. This solution, called vertical farming, involves growing crops in controlled indoor environments, with precise light, nutrients, and temperatures. In vertical farming, growing plants are stacked in layers that may reach several stories tall. [6]

These methods are well-suited for urban environments,

where land is scarce but the need for food production is high.

2.3. Design Strategies for Integrating Vertical Farming in High-rise Estates

To successfully integrate vertical farming into high-rise housing estates in Nigeria, several design strategies need to be considered, such as Space Optimization and Planning. In high-rise buildings, space is limited, and efficient use of every square meter is crucial. Vertical farming can be incorporated by utilizing rooftop spaces, unused building facades, or even the interior of buildings such as corridors and atriums. These areas can be transformed into growing spaces using modular farming units. These soil-less techniques use nutrient-rich water or air to grow plants, offering higher yields in less space and using less water than traditional agriculture [11].

Large-scale farming systems on rooftops can take advantage of the ample sunlight exposure. These farms could support a range of crops from vegetables to small fruits and herbs. Inside buildings, vertical towers or wall-mounted gardens can be installed in common areas or individual apartments. These systems would use hydroponic or aeroponic technologies to minimize water and space use. Mobile or modular farming units that can be adjusted based on available space and tenant needs offer flexibility in high-rise buildings.

The design of these systems needs to consider efficient water and nutrient circulation, which could be facilitated through rainwater harvesting systems and solar-powered pumps [1]. Vertical farming must align with the broader goals of sustainable urban design. Integrating renewable energy sources, such as solar panels and wind turbines, can offset the energy required for artificial lighting, temperature control, and water circulation in vertical farming systems [3]. Using renewable energy sources such as solar or wind power to supply energy for lighting and temperature regulation. Incorporating rainwater harvesting systems and water recycling technologies to reduce dependency on municipal water supplies. Organic waste from residents can be composted and used as fertilizer for farming, creating a closed-loop system that reduces waste sent to landfills. Therefore [9] observed that there is an increasing importance of fresh food production in urban areas, and the methods for achieving efficient production involve the resource inflow and waste outflow. Then, the possibility of significantly reducing outflow waste by using a large portion of it as an essential resource for growing plants in urban ecosystems.

Additionally, utilizing organic waste from households in high-rise estates as compost or feedstock for biogas production can create a circular economy that supports both farming and energy needs [13]. To foster community participation, housing estates should provide educational programs and workshops that teach residents about vertical farming practices. Incorporating community gardening initiatives within the estate can create a shared sense of responsibility and connection to food production. Involving residents in the

farming process not only ensures the efficient use of space but also promotes food security and community cohesion [14]. Moreover, vertical farming initiatives can provide job opportunities in urban agriculture, training young people in farming technologies and management skills [11].

2.4. Benefits of Vertical Farming in High-rise Housing Estates

Incorporating vertical farming into high-rise housing estates can help address food security challenges by providing residents with access to fresh produce year-round. This would reduce dependence on external food sources and minimize the carbon footprint associated with transportation and food distribution. Vertical farming can contribute significantly to food security in Nigeria, particularly in urban areas where food supply chains are often disrupted [14].

Vertical farming can promote environmental sustainability by reducing the use of arable land, conserving water, and lowering greenhouse gas emissions. Urban farms also contribute to biodiversity by supporting various plant species and providing green spaces in otherwise concreted environments. Vertical farming reduces the carbon footprint of food production by minimizing the need for transportation and using less water and land [3].

Vertical farming could create job opportunities for local communities, particularly in the areas of urban agriculture, technology, and design. Additionally, it could generate revenue for housing estates through the sale of produce, providing a supplementary income source for residents. By promoting local food production, vertical farming can create jobs and boost the economy, especially in sectors such as agriculture, construction, and renewable energy [15]. Promoting green and sustainable building practices, integrating renewable energy sources, and incorporating green spaces in urban design can significantly improve urban environmental performance [2].

2.5. Challenges to Implementation

Despite its potential, several challenges must be addressed to successfully implement vertical farming in high-rise housing estates. Setting up vertical farming systems requires significant upfront investment in infrastructure, technology, and training. However, these costs can be offset in the long term through the savings generated from reduced food purchases and the potential for income generation. The high capital investment required for setting up vertical farming systems, including infrastructure, technology, and skilled labour, can be a significant barrier to widespread adoption in Nigeria [1].

The technology required for vertical farming, such as hydroponics systems and climate control, may be unfamiliar to many stakeholders, requiring training and adaptation. Access to affordable, quality equipment and skilled labour is also a

concern. Government policies that promote urban agriculture, renewable energy adoption, and sustainable building practices are essential for the success of vertical farming initiatives. Nigeria currently lacks a comprehensive urban agriculture policy, which hinders largescale adoption of such projects. Lack of supportive policies and regulatory frameworks for urban farming in Nigeria poses a challenge to the widespread adoption of vertical farming [15].

3. Research Methodology

This study adopts a qualitative research method to explore the application of vertical farming design strategies in high-rise housing estates in Nigeria. A comprehensive literature review will be conducted to explore existing research on vertical farming, urban agriculture, and the application of such systems in high-rise buildings.

3.1. Research Method

The descriptive research approach was chosen for this study since it was the most appropriate for the project's objectives. This method of analysis identifies what information is significant and correct in regard to the study topic or the problem of application findings facts, allowing for a fair and acceptable reduction. The investigation was conducted using visual inspection and an observation checklist. A case study, according to [14], is a research into a case study methodology. The case study method is now widely used in architectural research.

3.2. Data Type and Sources

To achieve the study's aim and objectives, primary and secondary data sources were evaluated to obtain the various data used throughout the study.

3.2.1. Primary Data

This is data that an investigator acquires for the first time for a specific purpose. Basic data is referred to as 'pure' because it has not been treated or altered. During the case studies, the primary data source was a visual survey with photos and a well-planned viewing schedule.

3.2.2. Secondary Data

They are data that were sourced from a source that first collected it. This indicates that some researchers or investigators have previously collected this type of material, which is available in both published and unpublished form. Secondary map data (region, region, and domain) were collected for this study, and the literature was reviewed to determine the research project's theoretical foundation. The collected data acts as a basis, principles, and flexibility for monitoring, planning, and building the proposed high-rise housing estate in other to

incorporate vertical farming design strategy.

3.3. Population of Study

The population of the study will entail high-rise housing estate located around the world to design a high-rise housing estate while incorporating vertical farming design strategy.

Sampling Method and Technique

The most basic sampling strategy is simple random sampling; in which we select a set of participants (a sample) for research from a larger group (a population). Each structure is chosen at random, and every building in the population has an equal chance of being included in the sample as long as they meet the requirement. Every sample of a certain size has the same chance of being chosen. During the investigation, a simple random sampling procedure was utilized to select 20 samples at random. The high-rise housing estates were chosen with care, and the observation schedule was applied to all twenty samples at the same time. Table 1 depicts the sample sizes and location.

Table 1. Sample Size and Location.

S/N	Sample size	Location
1	Osborne towers	Ikoyi, lagos State.
2	Rising Lagos Apartments	Amuwo Odofin, Lagos.
3	1004 housing estate	Victoria island, Lagos.
4	Eko court complex	Victoria Island, Lagos.
5	Eko pearl towers	Eko Atlantic, Victoria Island, Lagos.
6	Irele towers	Lagos
7	Vita towers	Victoria Island, Lagos.
8	Ogundele Samuel Estate	Victoria Island, Lagos.
9	La tour tower	Victoria island, Lagos.
10	Kuramo beach residence	Victoria island, Lagos.
11	A&A Towers	Eko Atlantic, Lagos.
12	Akanbi court	Victoria Island, Lagos.
13	4 tower	Ikoyi, Lagos.
14	Cuddle handbuilt	Ikoyi, Lagos
15	Salvadors towers	surulere, Lagos.
16	One central park	Sydney Australia.
17	Tel Aviv tower	Israel.
18	La tour vivante	rennes, france.
19	Bosco vertical	Milan, Italy.
20	The tree house	Singapore.

4. Findings

The findings of this study are based on a synthesis of data gathered through literature review. The key findings are as follows.

4.1. Type of Apartment Available

There are different types of apartments available in the high rise housing estate as shown in Figure 1. From the research conducted 80% of the cases has 2 & 3 bedroom apartments, 10% has 3 bedroom apartments only, 5% has 4 bedroom apartments only and the remaining 5% has 1 bedroom, 2 bedroom and 3 bedroom apartments combined. The deduction made from this analysis showed that in the design of high rise housing estates, 2 & 3 bedrooms are the most important apartment in an high rise housing estate.

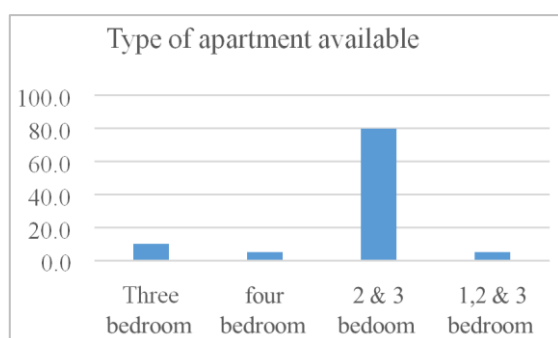


Figure 1. The type of apartment available.

4.2. Availability of Support for Growing Systems, Equipment, and Water Tanks

Vertical farming requires support for growing system. In Figure 2 Below it shows that 25% of the case study has support for growing system while the other 75% has no support for growing system.

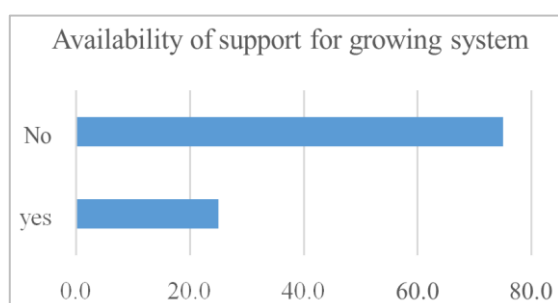


Figure 2. The availability of support for growing system.

Vertical farming contributes immensely to the quality of Air within the building. It is observed from Figure 3 that 75% of the

case study contributes to the air quality while 25% does not have any effect on the indoor air quality.

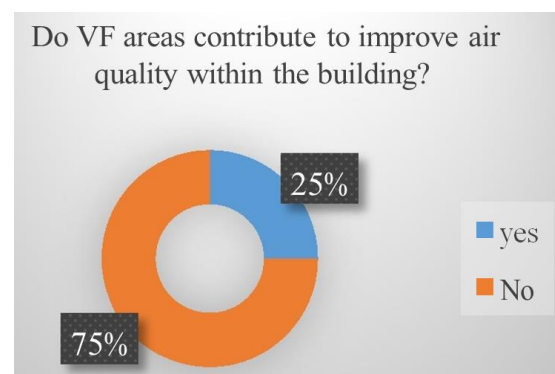


Figure 3. Vertical farming Areas Contribute to Improved Air Quality Within the Building.

4.3. Type of Vegetation

Different types of vegetation can be used. It is observed from Figure 4 below that 45% of the case study has Trees, flowers, grass and shrubs, while 45% of the case study has just trees and shrubs, and 10% has only trees. It is essential to have trees, shrubs, flowers and grass in a high rise housing estate because it will help to control the temperature within the estate and inside the building. Vegetation cover also help to control erosion in the estate and also add to the quality of living of the occupants.

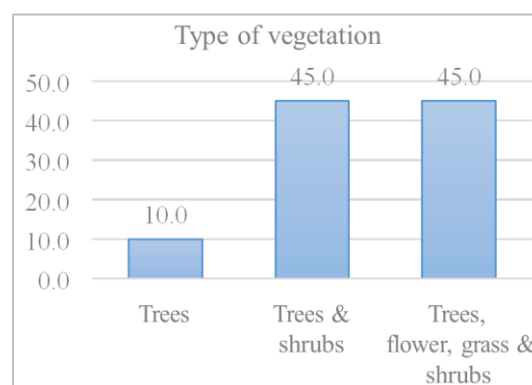


Figure 4. Type of Vegetation.

5. Conclusion

Vertical farming presents an innovative and sustainable solution to the challenges of food insecurity and urbanization in Nigeria's high-rise housing estates. As the country's population continues to urbanize rapidly, particularly in cities such as Lagos, Abuja, and Kano, the demand for both housing and food is growing at an alarming rate. Traditional agricultural practices, which rely on vast tracts of arable land, are not

viable solutions in densely populated urban environments. In contrast, vertical farming systems, which use vertically stacked layers of crops in controlled indoor environments, offer a practical alternative for producing food in spaces that would otherwise be unsuitable for conventional farming (9).

The integration of vertical farming into high-rise housing estates could enhance food security by reducing dependence on external food supply chains and providing local, fresh produce to urban residents. Vertical farming technologies such as hydroponics, aeroponics, and aquaponics are space-efficient and resource-conserving, making them ideal for urban settings where land and water resources are scarce (5). Furthermore, these systems can contribute to environmental sustainability by reducing carbon emissions associated with food transportation and by promoting the recycling of nutrients and water. In addition, the incorporation of such systems into high-rise buildings can help mitigate urban heat islands and improve the overall environmental quality of cities.

However, the successful implementation of vertical farming in Nigeria's high-rise housing estates is not without its challenges. The initial investment required for infrastructure, technology, and training can be a significant barrier, particularly in low-income housing areas. The technical expertise needed to design, install, and maintain vertical farming systems also remains a constraint. As highlighted by Urban Green Development in 2021, cities that have successfully implemented vertical farming, such as Singapore and New York, have benefitted from government policies that provide incentives and subsidies for both developers and residents. In Nigeria, clear regulatory frameworks and policy support are essential to facilitate the growth of urban agriculture and ensure its viability in high-rise housing estates.

Despite these challenges, the potential benefits of vertical farming are too significant to ignore. Vertical farming systems could be a transformative solution to the growing food insecurity in Nigeria's urban centres, promoting self-sufficiency in food production and improving the quality of life for residents. Government support, public awareness, and community engagement will be crucial to the successful adoption of vertical farming. Policies that incentivize the use of vertical farming technologies, alongside educational programs that equip residents with the skills to participate in urban agriculture, will be key to creating a sustainable urban food system in Nigeria.

Vertical farming offers a way to meet the needs of growing urban populations without sacrificing the environment [8]. The time is ripe for stakeholders in Nigeria to invest in this innovative solution, ensuring that high-rise housing estates not only serve as homes but also as hubs of sustainable food production. Ultimately, the integration of vertical farming into Nigeria's urban landscape could play a vital role in building resilient, self-sustaining cities that can thrive in the face of increasing urbanization and environmental challenges.

Recommendations

High-rise housing estates, which are becoming increasingly prevalent in urban areas, offer a unique opportunity to implement innovative agricultural solutions such as vertical farming. Vertical farming has the potential to address the challenges of food security, space limitations, and sustainability in urban areas. However, for vertical farming systems to be successfully integrated into high-rise housing estates in Nigeria, several key recommendations must be considered.

Government Policy and Support: A fundamental recommendation for the integration of vertical farming in Nigeria's high-rise housing estates is the development of supportive government policies. The lack of clear regulations and incentives for urban agriculture is a significant barrier to the widespread adoption of vertical farming technologies. Government intervention is crucial to providing the necessary framework and resources for the successful implementation of vertical farming systems. Policies should include incentives such as tax breaks, grants, or subsidies for developers who incorporate vertical farming into new or existing high-rise buildings. These financial incentives would help reduce the high initial investment required for the establishment of vertical farming infrastructure, making it more accessible to developers and residents.

Additionally, urban agriculture policies should address zoning regulations, water usage, and energy consumption, which are critical factors in the feasibility of vertical farming projects. By establishing a regulatory environment that supports urban farming, the government can encourage the growth of local food production and reduce dependency on food imports, which often contribute to high food prices and food insecurity. For instance, Singapore has implemented clear policies to encourage vertical farming, providing a model for Nigeria to follow (8).

Public Awareness and Education: Another key recommendation is the implementation of public awareness campaigns and educational programs focused on vertical farming and its benefits. The success of vertical farming in high-rise housing estates depends significantly on the willingness of urban residents to adopt these practices. Informing the public about the potential of vertical farming to provide fresh, locally grown food and promote environmental sustainability is essential. Public awareness campaigns should target urban dwellers, particularly those in high-rise housing estates, highlighting the role of vertical farming in improving food security, reducing transportation costs, and creating a healthier urban environment.

In addition to raising awareness, educational programs should be developed to equip residents with the knowledge and skills needed to actively participate in vertical farming initiatives. Community based workshops, training sessions, and partnerships with local agricultural experts could foster a sense of ownership and engagement among residents. These programs would also enable residents to learn how to manage vertical farming systems effectively, enhancing the overall success and sustainability of the initiatives.

Research and Development: Investing in research and development (R&D) is another critical recommendation for the successful integration of vertical farming in Nigeria's high-rise housing estates. While vertical farming technologies such as hydroponics, aeroponics, and aquaponics are well-established globally, their adaptation to Nigeria's specific climate, urban conditions, and economic realities is necessary. Research should focus on developing affordable, locally appropriate technologies that are easy to scale and maintain. For example, hydroponic systems that are optimized for Nigerian crops and climate conditions could be developed to enhance productivity while minimizing water and nutrient waste.

In addition to technical innovations, R&D should also focus on identifying suitable crop varieties that can thrive in vertical farming environments, considering factors such as local food preferences, market demand, and resilience to pests and diseases. Collaborations between universities, research institutions, and the private sector could foster innovation and drive the development of cost effective, efficient vertical farming solutions for Nigerian urban areas. International examples, such as the "Sky Greens" project in Singapore, offer useful insights into how vertical farming can be successfully implemented in high-rise buildings, and these can inform R&D efforts in Nigeria [5].

Community Engagement: Finally, community engagement is vital for the successful adoption of vertical farming in high-rise housing estates. High-rise buildings often house diverse populations, and involving residents in the planning, design, and operation of vertical farming systems can promote a sense of community and collective responsibility. Establishing community gardens or farm cooperatives within high-rise estates can encourage collaboration and provide a platform for residents to exchange knowledge, resources, and experiences related to urban agriculture.

Additionally, community engagement helps address potential challenges such as resistance to new technologies or the fear of high costs. When residents are actively involved in the decision-making process and see the direct benefits of vertical farming—such as access to affordable, fresh produce—they are more likely to embrace the idea. Social cohesion, sustainability, and food security can be enhanced when vertical farming systems are embedded in the fabric of urban communities.

Vertical farming has the potential to enhance local food production within urban environments, addressing issues of food scarcity and reducing dependence on imported or transported produce. Residents of high-rise housing estates expressed strong interest in growing their own food, which could contribute to a more reliable and accessible supply of fresh produce. Vertical farming offers a significant reduction in water and land usage compared to traditional farming. Hydroponic, aeroponic, and aquaponic systems can be implemented in a way that maximizes resource efficiency. Additionally, these farming systems produce fewer greenhouse

gases due to their proximity to consumption, reducing the carbon footprint associated with food transportation. Through the use of renewable energy sources like solar panels, energy-efficient lighting systems, and LED grow lights, vertical farming systems can be designed to operate with minimal energy input. Residents of the surveyed estates preferred sustainable, energy-efficient solutions that would not significantly increase utility costs. Vertical farming has the potential to foster community engagement and social cohesion among high-rise residents. It can be a common activity space for residents to collaborate, exchange knowledge, and contribute to local food production. Additionally, such systems can create new opportunities for local employment in urban agriculture, system maintenance, and management.

Author Contributions

Jubril Adesanya Olanusi: Funding acquisition, Project administration, Writing – review & editing

Lawal Habibulahi Abayomi: Conceptualization

Conflicts of Interest

The authors declare no conflicts of interest.

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