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ASSESSMENT OF BARRIERS TO ADOPTION OF VERTICAL FARMING AMONG FARMERS IN MAKURDI LOCAL GOVERNMENT AREA OF BENUE STATE, NIGERIA

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Abstract
The study assessed barriers to adoption of vertical farming among farmers in Makurdi Local Government Area of Benue State, Nigeria. One hundred and twenty (120) farmers were selected using simple random sampling technique and a well-structured questionnaire was administered to them to obtain information. Descriptive statistics such as mean and standard deviation were used to analysed objective one while factor analysis was used as an inferential statistic to analyse objective two. The findings revealed that increased crop yield ($\bar{x}$=2.87), reduced land use ($\bar{x}$=2.81), resilience to weather conditions ($\bar{x}$=2.66) promotion of sustainable agriculture (x=2.60), improved food security ($\bar{x}$=2.58) among others were the benefits of vertical farming in the Study area. Barriers to vertical farming include impact on the economic viability (0.7184), cost of energy and labor (0.7147), high initial cost (0.5877), high energy consumption (0.7913), energy source (0.7835), market demand and access to market (0.7583) and Small-scale farmers (0.3167). The study concluded that benefits of vertical farming include Increased crop yield, Reduced land use, Resilience to weather conditions among others. The study recommended that government and Non-Governmental Organizations (NGOs) should made available credit facility to ease high cost of starting vertical farms or creation of farmers' cooperatives should be encouraged to enable them put resources together to majority the challenge of high initial cost.
Keywords: *Assessment, barriers, adoption, Vertical Farming, Farmers.*

1.0 Introduction

Vertical farming is a novel method of growing crops by artificially stacking plants above each other either in skyscrapers or by using the third dimension of space (Van Gerrewey *et al.* 2021). In other words, vertical farming is a technique that grows crops in vertically stacked layers, using soilless methods like hydroponics, aeroponics, and aquaponics, to maximize production in a limited space. This approach is also known as growing up or skyward farming (Modarelli *et al.*, 2022). Vertical farming can be implemented in various structures, including skyscrapers or dedicated indoor facilities.

It is predicted that the world population will reach 9 billion by 2050, of which 70 percent will live in urban centre (Modarelli *et al.*, 2022). This change, alongside a changing climate, will strain earth's resources, specifically the ability to supply food. A valuable investigation would be to determine other ways to supply food to cities alongside current agricultural practices in a sustainable manner. One idea is the concept of vertical farming. This might help to solve many of future's problems like malnutrition and polluted food that could become evident along with food scarcity.

The practice allows a huge number of crops to be grown in a much lesser space, when compared to traditional farming and other alternatives like permaculture, biodynamic and agro-ecological farming, thus reducing the use of agricultural land. This practice recycles and reuses

natural resources such as water and nutrients and creates less waste as plants grow in soil-less media. As a result, vertical farming leads to smaller carbon footprint and causes much less pollution to the environment (Huo *et al.*, 2024). Vertical farming has been there for decades; however, the demand for more food production, pollution free produce and inclusion of modern technologies have drive farmers, farming societies, and commercial companies to take up vertical farming in large scale. (Modarelli *et al.*, 2022).

The first vertical farm came in existence in 1950s to grow cress indoors at a large scale. Today many biotechnology companies and startups have taken this concept to the next level making vertical farming an economically viable model considering the pollution free or organic cultivation (Ismail and Thamrin, 2017). Vertical farms may be expensive to construct but once built they are actually less expensive to run compared to land-based farms (Benke and Tomkins, 2017). Vertical farms are generally of better quality and pollution free as it grows mostly using water and nutrients, thus, crops grown in can fetch premium price. Traditional farming put farmers to multiple odds such as weather disasters, long hours of labor, yield uncertainty, vulnerability of crops to pest and disease, lower return on investment. Vertical farming is a welcome change, as it has given ease of operation and higher yield percentage. (Benke and Tomkins, 2017).

Vertical farming has the potential to provide a sustainable and efficient solution to the challenges of traditional agriculture, such as land scarcity, water scarcity, and pest control. (Modarelli *et al.*, 2022). Crops in traditional farming systems are vulnerable when it comes to global warming, natural calamities, and weather changes. There is also immense pressure on natural resources to feed the ever-growing population considering shrinking cultivable land, fresh water, and low yields. Vertical farming appears to be one of the most preferred alternatives for sustainable crop production.

2.0 Objectives of the Study

The broad objective was to assess barriers to adoption of vertical farming among farmers in Makurdi Local Government Area of Benue State, Nigeria and the specific objectives were to:

i. describe the benefits of vertical farming to the respondents; and
ii. identify barriers to adoption of vertical farming to the respondents

3.0 Methodology

The study was conducted in Makurdi Local Government Area (LGA) of Benue State, Nigeria. Benue State located in the Middle Belt region of Nigeria; Makurdi is the capital city of Benue State and is known for its fertile soil and favorable climate, making it an ideal location for agricultural activities. The area's geography is characterized by a mix of savanna and grassland vegetation, with the Benue River flowing through it, providing a source of water for irrigation and other agricultural purposes. The LGA shares boundaries with Guma LGA to the North-east, Gwer LGA to the South, Gwer-West LGA to the West and Doma LGA of Nasarawa State to the North-west. It is situated on the banks of the River Benue, which provides a significant source of irrigation for agricultural activities, including crop farming and animal husbandry. Makurdi LGA covers an approximate area of 804 km² and has a population of 472,000 people [National Bureau of Statistics (NBS,2024)]. Makurdi LGA is made up of 11 council wards, they include; Agan, Clerk Mission, Fiidi, Mbalagh, Ankpa/Wadata, Bar, Central-South Mission, Modern Market, North Bank I, North Bank II and Walomayo.

The climate of Makurdi Local Government Area is tropical savanna, with two distinct seasons - the wet season and the dry seasons. The wet season typically runs from May to October, while the dry season runs from November to April. The area receives an average annual rainfall of about 1,200 mm vertically, with the majority of the rainfall occurring during the wet season. The area's climate is suitable for agriculture, and many farmers in the area engage in crop production

and livestock rearing (Kughur *et al.* 2025). The population of Makurdi Local Government Area is diverse, with various ethnic groups, including the Tiv, Idoma, and Igede.

The population for this study consisted of vertical farmers in Makurdi Local Government Area of Benue State, Nigeria. The sampling frame for this study consisted of a list of vertical farmers in Makurdi Local Government Area. In the first stage, three council wards were purposively selected. The council wards selected were Bar, ankpa/Wadata and Walomayo wards. In the second stage, two communities were purposively selected from each of the wards due to high density and population. Finally, a sampling frame was developed for each of the communities and using proportional allocation of 10% (0.10), a total sample size of 120 respondents were randomly selected using a questionnaire. Data for this study were analyzed using descriptive statistics, such as mean, standard deviation and factor analysis

4.0 Result and Discussion

4.1 Benefits of Vertical Farming to Respondents

Table 1 shows that the majority of the respondents had a very positive perception of vertical farming and believed it offered significant advantages over conventional systems. Most notably, ($\bar{x}$=2.87) of farmers rated increased crop yield as very beneficial, while ($\bar{x}$=2.04) believed that vertical farming improves water efficiency. These responses indicated that the farmers were aware of the potential of vertical farming to optimize resource use and enhance productivity. FAO (2023) reported that vertical farming can reduce water use by up to 90 percent and land use by more than 70 percent when compared with traditional open-field cultivation.

Similarly, $\bar{x}$=2.81 of respondents viewed reduced land use as very beneficial, which reflects the growing awareness of land scarcity in peri-urban area. Akintuyi (2024) noted that the primary attraction of vertical farming in Nigerian cities is its ability to produce more on smaller plots of land, especially where urban expansion has limited arable space. The result also shows that ($\bar{x}$=2.6) of the farmers acknowledged the importance of production regardless of season, and ($\bar{x}$=2.66) of the respondents indicated that the perceived the benefit of vertical farming and highlighted the desire for all year-round farming made possible by controlled-environment systems.

Overall, the findings indicate that the farmers strongly recognized the advantages of vertical farming in increasing yields, saving water and land, and ensuring consistent production. The pattern aligns with Leddi *et al.* (2025) that most Nigerian farmers considered vertical farming a viable approach to urban food security if initial costs and energy constraints are addressed.

Table 1: Benefits of vertical farming to the respondents (n=120)

Variables	Mean ($\bar{x}$)	S.D.
Increased crop yield	2.87	0.356512
Improved water efficiency	2.04	0.2718079
Reduced land use	2.81	0.4296438
Year-round production (regardless of season)	2.16	0.4167367
Resilience to weather conditions	2.66	0.5182928
Reduced greenhouse gas emissions	2.31	0.5397375
Improved food security	2.58	0.5588604
Reduced environmental impact	2.35	0.5468909
Promotion of sustainable agriculture	2.60	0.5407744
Water conservation	2.51	0.564843
Crops grown all year round	2.50	0.5499554

<2 = not beneficial
≥2= beneficial
S.D = Standard Deviation

4.2 Barriers to the Adoption of Vertical Farming

Table 2 reveals that 11 attributes yielded three-dimensional factors based on factor analysis. The three main factors were financial and economic, technical and energy factors and socioeconomic/farmer and market factors.

For factore1, (financial and economic factor) attribute with high loading included Impact on the economic viability (0.7184), Cost of energy and labor (0.7147), High initial cost (0.5877), Limited access to finance and funding (0.5870) and The cost of infrastructure (0.4111) were major individual factors in factor 1 that were identified by the respondents as major barriers to adoption of vertical farming. For instance, Impact on the economic viability (0.7184), Vertical agriculture can improve economic viability by producing high yields on small areas of land and reducing transportation costs. However, high costs of electricity, equipment, technology, and maintenance can reduce profitability. Its success depends on efficient energy use, suitable crops, market demand, and good management. The cost of energy and labor (0.7147) has a major impact on the profitability of vertical farming. Vertical farms require electricity for artificial lighting, cooling, ventilation, and water-pumping systems, which can increase operating costs. Labor is also needed for planting, monitoring, harvesting, cleaning, and maintaining equipment. High energy and labor costs can reduce profits and make produce more expensive for consumers. Therefore, using energy-efficient technology and automation can help reduce costs and improve the economic viability of vertical farming. High initial costs (0.5877) in vertical farming arise from purchasing structures, lighting systems, irrigation equipment, sensors, and other technologies. These costs can make it difficult for small-scale farmers to start and may increase the time needed to recover the investment. However, with proper planning, efficient technology, and good management, the investment can generate long-term returns. The outcome is in agreement with Benke and Tomkins (2017) that high initial costs and cost of energy and labor are barriers to vertical farming and controlled agriculture.

In factor 2, (Technical and Energy Factors) the respondents identified High energy consumption (0.7913), Energy source (0.7835) among others as barriers to adoption of vertical farming. High energy consumption in vertical farming results mainly from artificial lighting, cooling, ventilation, and climate-control systems. This increases production costs and can reduce the economic and environmental sustainability of vertical farms. The source of energy is also important because electricity from fossil-fuel-based grids can increase greenhouse-gas emissions. Using renewable sources such as solar and wind can reduce emissions and dependence on grid electricity, Thus, improving energy efficiency and adopting low-carbon energy sources can enhance the sustainability of vertical farming. The findings corroborate with Pennisi *et al*. (2025) that high energy consumption and energy sources post threat to adoption of vertical farming to farmers.

In factor 3, **(**Socioeconomic/Farmer and Market Factors) variables with high loading include Market demand and access to market (0.7583) and Small-scale farmers (0.3167). Market demand (0.7583) is an important factor that can either encourage or discourage the adoption of vertical farming. Low consumer demand for vertically farmed produce can make it difficult for farmers to recover their investment. Limited access to reliable markets may lead to unsold produce, low prices, and reduced income for farmers. Vertical farms may also face competition from conventional agriculture, which can offer similar crops at lower prices. Poor distribution and inadequate marketing channels can further increase transportation and post-harvest losses. Uncertainty about consumers' willingness to pay premium prices may discourage potential investors from adopting the technology. Therefore, farmers need stable markets, effective marketing strategies, and reliable buyers to make vertical farming economically attractive. The outcome disagreed with Gumisiriza, *et al* (2023) that a small-scale vertical hydroponic farming system could be economically viable, with positive net present value and profitability, despite the challenges associated with market conditions. This suggests that limited market access does not necessarily prevent adoption, particularly where farmers can target local consumers and manage production costs effectively. The

study therefore provides a contrasting view to the argument that market barriers always discourage adoption.

TABLE 6: Barriers to adoption of vertical farming of the respondents (n=120)

Variables	Factor 1	Factor 2	Factor 3
High initial cost	0.5877	0.0594	0.2128
The cost of infrastructure	0.4111	0.0295	0.1814
Limited knowledge and expertise	–0.3287	0.5652	0.2632
High energy consumption	–0.0169	0.7913	0.0937
Small-scale farmers	–0.5725	0.2649	0.3167
Cost of energy and labor	0.7147	-0.0934	0.0478
Impact on the economic viability	0.7184	–0.257	0.0417
Access to renewable sources	–0.0457	0.7193	0.2937
Energy source	0.0123	0.7835	–0.1368
Market demand and access to market	0.0816	0.0628	0.7583
Limited access to finance and funding	0.5870	0.1311	–0.0273

Method: Varimax with Kaiser Normalization
Factor 1 = Financial and Economic Factors
Factor 2 = Technical and Energy Factors
Factor 3 = **Socioeconomic**/Farmer and Market Factors

5.0 Conclusion and Recommendations

5.1 Conclusion

The study concluded that benefits of vertical farming include increased crop yield, reduced land use, resilience to weather conditions among others.

5.2 Recommendations

The study recommended that government and Non-Governmental Organizations (NGOs) should made available credit facility to ease high cost of starting vertical farms or creation of farmers' cooperatives should be encouraged to enable them put resources together to over the challenge of high initial cost. It's also recommended that information on market demand and access should be made available to vertical farmers to encourage adoption and sustainability in the business.

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