

Spatial Distribution, Productivity and Socio-Economic Impact of Urban Agriculture in Jos Metropolis, Plateau State, Nigeria

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Abstract

Urban agriculture (UA) plays an increasingly significant role in supporting urban livelihoods, diversifying income, and supplying fresh produce in rapidly growing cities. This study assessed the spatial distribution, productivity, and socio-economic contributions of UA in Jos Metropolis, Nigeria, using a mixed-method approach combining geospatial mapping, structured surveys, and experimental yield trials. GPS coordinates were recorded and analyzed with ArcGIS. Yield trials on standardized 0.002-hectare plots compared hydroponics, sack farming, and conventional open-field cultivation of yam (*Dioscorea* spp.) and bell pepper (*Capsicum annuum*). Socio-economic data were collected through semi-structured questionnaires and analyzed using SPSS. Greenhouses predominate at 76% of mapped urban farm practices, concentrated in peri-urban Jos South where land constraints are lower. Farm sizes range from small plots (<0.01 ha, used for sack and hydroponic systems) to the most common category of 0.01–0.05 ha (44%), with only 4% exceeding 0.1 ha. Vegetables dominate production at 72%, followed by Irish potatoes and yam at 14% each. Most farmers are relatively inexperienced: 44% reported 1–3 years of experience and only 16% exceeded six years. Yield trials demonstrated clear advantages for urban farming systems: the hydroponic system yielded 900 kg of bell pepper versus 210 kg from open-field plots (4.3-fold increase), and sack-farmed yam yielded 90 kg versus 29 kg from conventional plots (3.1-fold increase). Socio-economically, 49.09% of urban farmers earned above ₦140,000 monthly, and farming contributed 65.72% of respondents' total income. One-year micro-

economic analysis at a 26.25% lending rate showed hydroponics as the most viable system (NPV: ₦428,584; IRR: 280.28%; payback: 0.26 years), while sack farming yielded an NPV of ₦18,663, IRR of 43.70%, and payback of 0.70 years. Open-field yam farming returned a negative NPV of -₦101,594 (IRR: -61.63%), confirming its financial non-viability in urban contexts. These findings demonstrate that climate-smart urban farming systems particularly hydroponics and sack farming offer viable pathways for enhancing food security and generating income in space-constrained urban environments.

Introduction

Globally, urban agriculture has witnessed a significant resurgence in recent decades, driven by urbanization, population growth, and increasing concerns about food safety and environmental sustainability. Cities worldwide are exploring innovative methods such as hydroponics, vertical farming, and rooftop gardening to produce fresh, locally grown food within urban spaces (Altieri & Toledo, 2011; Mougeot, 2000).

Notable examples illustrate the scale of this phenomenon. In Paris, France, the government-backed *Parisculteurs* programme (launched 2016) spearheaded the development of *Nature Urbaine* Europe's largest rooftop farm atop the Paris Expo Porte de Versailles. Spanning 14,000 m², the facility is designed to produce up to 1,000 kg of fruits and vegetables per day across approximately 35 varieties, employing around 20 urban farmers. It currently delivers approximately 200 kg of produce daily through short supply chains, while also operating community plots, educational tours, and workshops (Nature Urbaine, 2020). In Shanghai, China, the integration of urban and peri-urban agriculture into city planning has enabled the city to source a substantial proportion of its vegetable supply locally, sustaining large numbers of jobs in farming, distribution, and agri-processing (Hou, 2020). These models demonstrate that urban agriculture can function simultaneously as a food production mechanism and an economic development tool.

In Africa, urban agriculture has gained momentum as a response to food insecurity and the need to create livelihoods in rapidly urbanizing regions. Evidence from Kampala, Uganda, indicates that over 35% of urban households engage in some form of urban agriculture, with these activities directly supporting the food needs of approximately 75% of participating households by reducing reliance on market purchased food. Urban farmers in Kampala were reportedly able to meet up to 60% of their vegetable consumption needs and a substantial portion of their poultry and egg requirements (Nchanji & Lutomia, 2021). Countries such as Kenya, South Africa, and Nigeria have witnessed a proliferation of urban farms, often supported by community-based initiatives and government policies (FAO, 2018).

In Nigeria, urban agriculture has grown as a grassroots response to food demand in cities such as Lagos, Abuja, and Kano. Empirical work in Lagos has mapped significant land and water assets suitable for urban agriculture and argued for explicit planning support (Akinmoladun &

Adejumo, 2011); Kano's long-established UA sector remains constrained by land tenure insecurity; and studies from south-eastern Nigeria document systemic limitations despite clear food-security benefits. At the federal level, formal policy support is relatively recent the Federal Ministry of Agriculture and Rural Development announced the National Urban Agricultural Programme (NUAP) in December 2024, including initiatives such as "Every Home A Garden" (FMARD, 2024).

Urban agriculture has become an essential component of food systems, particularly in developing regions where food insecurity is prevalent (Mougeot, 2000). In Jos Metropolis, Plateau State, Nigeria, urban agriculture holds considerable potential for improving food security by supplying fresh produce and creating economic opportunities. However, the region faces persistent agricultural challenges, including limited arable land, water scarcity, and climatic variability (Olawuyi & Adedeji, 2018). As a result, innovative practices such as hydroponics, sack farming, and greenhouse cultivation offer promising solutions for optimizing the use of constrained urban space and resources. Despite growing interest in UA, systematic assessment of its spatial distribution, productivity, and socio-economic impacts remains limited in Jos. This study aims to fill that gap by evaluating UA practices in Jos Metropolis using geospatial analysis, yield performance trials, and socio-economic surveys.

Problem Statement

Urban agriculture has emerged as a contemporary issue of growing significance, particularly in developing economies, where it is increasingly recognized as a viable strategy for enhancing livelihoods and addressing urban poverty. Despite these developments, systematic assessment of its spatial distribution, productivity, and socio-economic impacts remains limited. The sector has not been adequately supported by policymakers, largely because agriculture has historically been viewed as a rural activity. This perception has been rendered increasingly untenable by the prolonged farmer-herder conflict in Jos, Riyom, Barkin-Ladi, and Baasa local government areas a crisis spanning over two decades that has resulted in the displacement of communities into urban and peri-urban settlements (Kwaghtser, 2019).

Poverty, once largely associated with rural areas, has become a prominent feature of many Nigerian cities as a consequence of rapid urbanization. Food inflation, price instability, and relatively low wages have rendered the average Nigerian urban household highly vulnerable to food insecurity (Okolo, 2006). These conditions directly threaten the realization of Sustainable Development Goal 2 (Zero Hunger). In 2024, approximately 8.2% of the global population about 673 million people experienced hunger, and an estimated 28% were moderately or severely food insecure (FAO, IFAD, UNICEF, WFP & WHO, 2024).

Historically, urban food production in Jos has relied predominantly on conventional open-field farming, which is increasingly constrained by population growth, land fragmentation, climate variability, and ongoing insecurity. This has created an urgent need for a technological shift towards more space-efficient and climate-resilient alternatives. Innovative systems such as hydroponics soilless cultivation using nutrient solutions sack farming, and greenhouse production represent this transition, enabling food production within the urban fabric regardless of land availability. Yet, despite field observations of these practices in Jos, their

spatial distribution, comparative productivity, and economic viability remain undocumented. Yam (*Dioscorea* spp.) and bell pepper (*Capsicum annuum*) were selected as the experimental crops because they represent the two most economically significant produce categories identified during preliminary farmer surveys: yam as the dominant staple and cash crop cultivated in sack systems, and bell pepper as the highest-value vegetable cultivated both hydroponically and in conventional open-field plots in the study area.

Consequently, this study was designed to address the following research questions:

- What is the spatial distribution of urban agriculture in the study area?
- What are the types of agricultural produce cultivated in the study area?
- What are the socio-economic benefits of urban agriculture in the study area?

The broad objectives of the study are to:

1. Identify and map urban agricultural practices in the study area;
2. Identify the produce cultivated; and
3. Determine the socio-economic impact of urban agriculture in the study area.

The significance of this study lies in its delineation of the location of urban farms, the crop types produced, and their contributions to livelihood, and poverty alleviation. The findings will guide policymakers in formulating context-specific urban agriculture policy; encourage academic institutions and research bodies to develop innovations suited to low-income, space-constrained urban settings; and educate urban dwellers on the socio-economic incentives of engaging in urban agriculture as a business or livelihood strategy.

MATERIAL AND METHODS

Jos Metropolis is located between latitudes 9°54'30"N and 10°10'30"N, and longitudes 8°48'30"E and 9°30'30"E, in Plateau State, North-Central Nigeria. It comprises Jos North and Jos South Local Government Areas, with administrative headquarters at Jos and Bukuru respectively. The metropolis covers approximately 1,000 km² (Plateau State Government, 2020) and is home to a population exceeding 1.1 million (UN Population Prospects, 2024). Situated at an elevation of approximately 1,200 m above sea level (Lee, 1972), with the Shere Hills rising to about 1,800 m, the city's plateau terrain and temperate climate distinguish it from the surrounding lowlands. The region is characterized by diverse cultures and languages and supports a forest-savanna mosaic ecoregion.

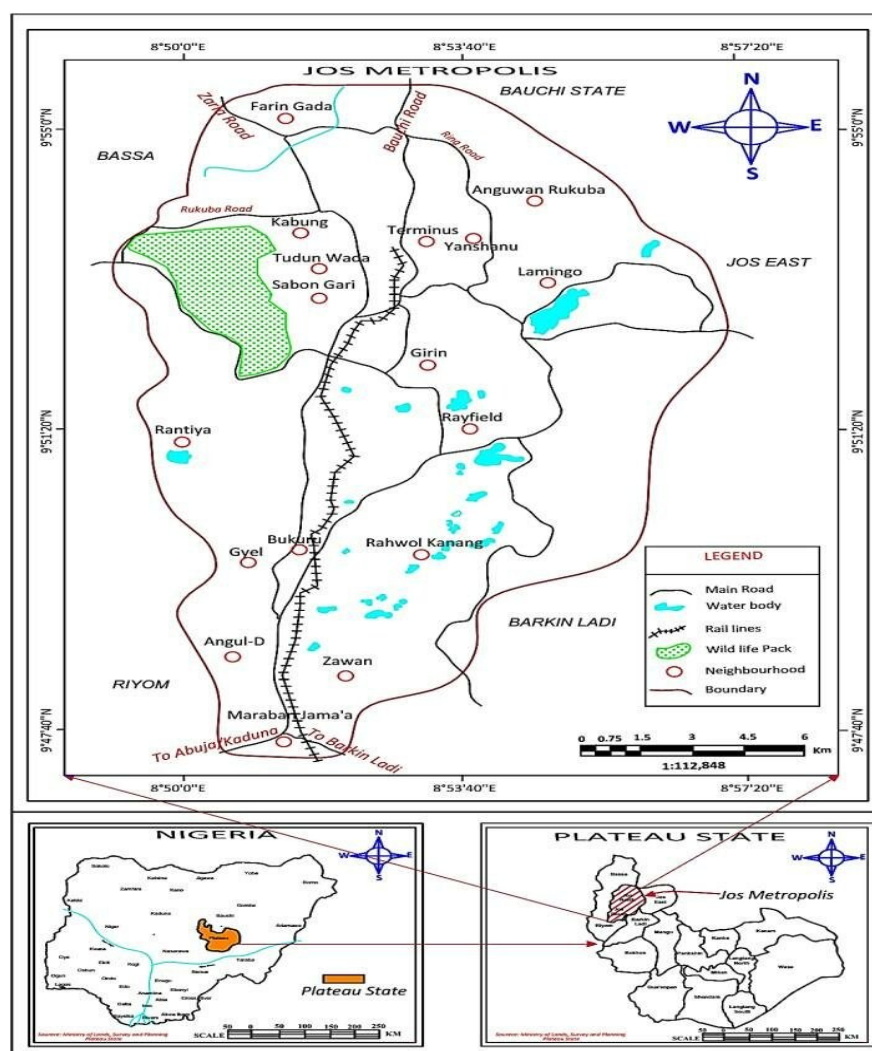


Fig 1. Jos Metropolitan

Source: Plateau State Geographic Information Service 2013

Study Population, Research Design and Sampling

The target population comprised urban farmers and residents of Jos Metropolitan. A mixed-method research design was employed, combining experimental and survey approaches. The survey used a two-stage sampling technique: snowball sampling was applied in the first stage to identify urban farmers through peer referrals within their networks; simple random sampling was applied in the second stage, where the study area was divided into wards, and in each ward the tenth household was surveyed. Neighbourhoods were randomly drawn by ballot. A total of 397 respondents were sampled using Yamane (1967) formula at a 5% margin of error, comprising 50 urban farmers and 347 households.

Experimental Yield Trials

The experimental component evaluated three farming systems hydroponics, sack farming, and conventional open-field cultivation each established on a standardized plot of 0.002 hectares. The test crops were yam (*Dioscorea* spp.) and bell pepper (*Capsicum annuum*), selected as the most economically significant crops in each system category. Identical standard input allocations were applied across all three systems to enable direct yield comparisons.

The hydroponic system employed a nutrient film technique (NFT) configuration. The nutrient solution was composed of nitrogen (N: 200 mg/L), phosphorus (P: 50 mg/L), potassium (K: 300 mg/L), calcium (Ca: 200 mg/L), and magnesium (Mg: 50 mg/L), with trace micronutrients (iron, manganese, zinc, copper, and boron) supplied at standard concentrations following Hoagland's formulation. Solution pH was maintained between 5.8 and 6.2, and electrical conductivity (EC) was held at 2.0–2.5 mS/cm throughout the growth cycle. The sack farming system used 50 litre polypropylene sacks filled with a growing medium composed of 60% topsoil, 30% composted cow manure, and 10% coarse sand, providing adequate drainage, aeration, and nutrient availability for root crop development (Gallaher et al., 2015). These specifications are provided to ensure experimental reproducibility.

Data Collection

Primary data were collected through field measurements and semi-structured questionnaires administered to respondents over a seven-month period spanning both the rainy and dry seasons of 2024–2025. Data items included farm size, farm type, crop type, years of farming experience, and income generation from urban agriculture.

Data Analysis

Descriptive statistics were computed using the Statistical Package for the Social Sciences (SPSS). Geospatial data were analyzed using ArcGIS to map the distribution of farm sites. Yield comparisons between the urban farming systems and conventional open-field farming were based on measured produce weights at harvest. A micro-economic analysis was conducted to assess the financial viability of each farming system and inform investment decisions, using net present value (NPV), internal rate of return (IRR), and payback period as indicators, computed over a one-year projection at a 26.25% lending rate (Central Bank of Nigeria rate)..

Results

Spatial Distribution of Urban Agricultural Practices

The spatial distribution of urban agricultural practices in Jos Metropolis is depicted in Figures 2, 3, and 4, which show the geographic clustering of greenhouse farming, dispersion of sack farming, and hydroponics respectively. Greenhouse farming predominates at 76% of all mapped practices, concentrated in the peri-urban areas of Jos South where land is more accessible. Sack farming accounts for 18% of practices, while hydroponics represents only 6%, indicating limited adoption of technology intensive systems. (Table 1)

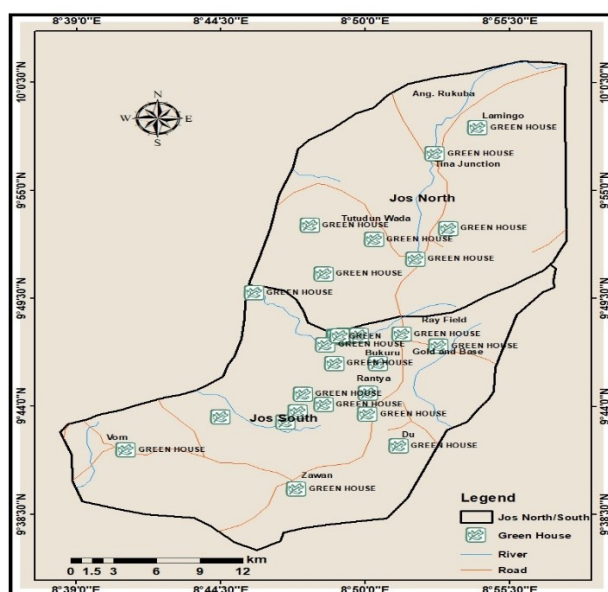


Fig 2. Green house practices in Jos Metropolis
Source: field data (2025)

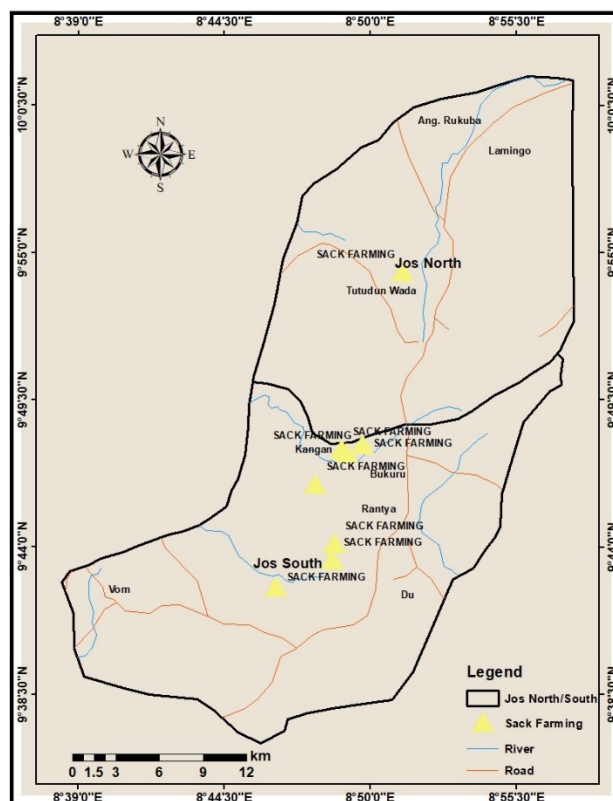


Fig 3. Sack farm in Jos Metropolis
Source: field data (2025)

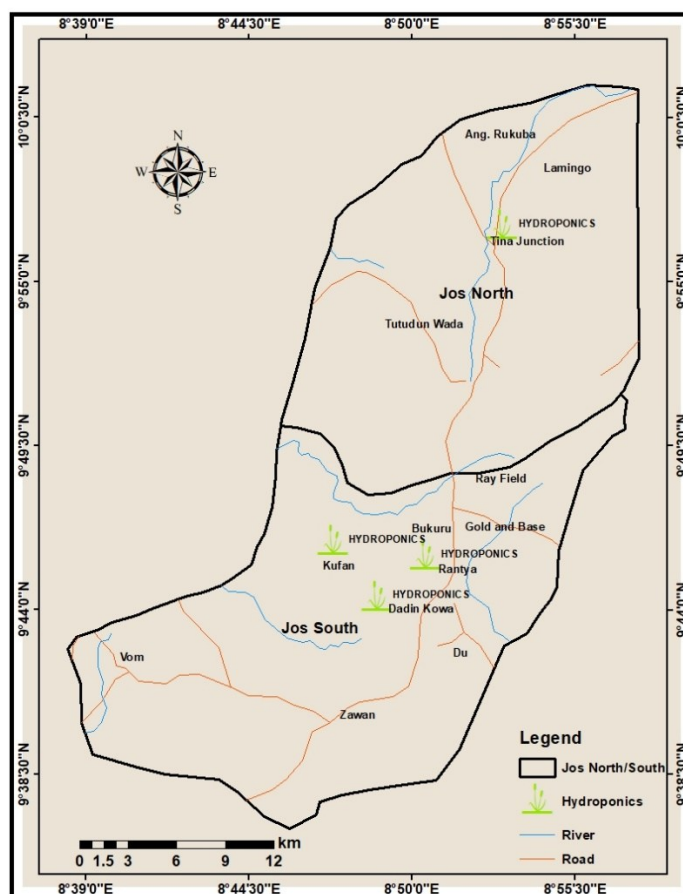


Fig 4. Hydroponic farm in Jos Metropolis

Source: field data (2025)

Table 1. Urban Agricultural Practices in Jos

Sn	Urban agriculture practice	Frequency	Percent
1	Green house	37	76%
2	Hydroponics/aquaponics	3	6%
3	sack farming	9	18%
Total		50	100%

Source: Field Data (2025)

Farmers Experience

Table 2 shows the experience by years for urban, the majority of urban farmers are relatively inexperienced: 44% had 1–3 years of experience and 36% had 4–6 years. Only 16% were veterans with more than six years of experience, and 4% had less than one year experience indicating a young and growing sector in the study area.

Table 2. Urban Farmer Experience in the Study Area

Sn	Years	Frequency	Percent
1	1-3 years	22	44%
2	4-6 years	18	36%
3	Less than 1 year	2	4%
4	More than 6 years	8	16%
	Total	50	100%

Distribution of Farm Size

The majority of urban farms (44%) operate on plots of 0.01–0.05 ha, suitable for greenhouse cultivation. Farms on 0.05–0.1 ha account for 36%, while 16% operate on plots smaller than 0.01 ha typical of sack and hydroponic systems. Only 4% of farms exceeded 0.1 ha, confirming the predominantly small-scale character of urban agriculture in the study area (Table 3).

Table 3. Farm size Distribution in the study area

Sn	Land size (hectare)	Frequency	Percentage
1	0.01 – 0.05	22	44%
2	0.05- 0.1	18	36%
3	Less than 0.01	8	16%
4	More than 0.1	2	4%
	Total	50	100

Agricultural Produce

Vegetables dominated urban agricultural produce at 72%, followed by Irish potatoes and yam at 14% each (Table 4), reflecting urban farmers' preference for high-value, short-cycle perishable crops.

Table 4. Urban agriculture produces in the study area

Sn	Produce	Frequency	Percent
1	Irish potatoes	7	14%
2	Vegetable	36	72%
3	Yam	7	14%
	Total	50	100

Evaluation of Urban Agricultural Practices

Yield trials comparing hydroponic, sack, and conventional open-field systems demonstrated a clear advantage for the urban farming methods (Table 5). The hydroponic system yielded 900 kg of bell peppers compared to 210 kg from conventional open-field farming a 4.3-fold increase. Sack-farmed yam yielded 90 kg compared to 29 kg from the open-field plot a 3.1-fold increase.

Table 5. Crop Yield Urban Farming Systems vs. Conventional Open Field Farming

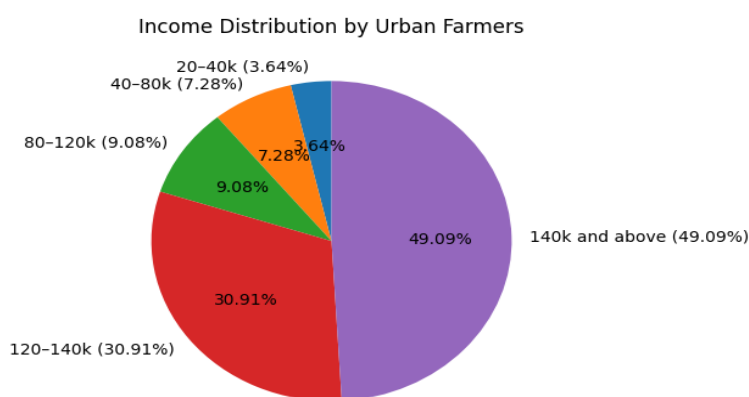
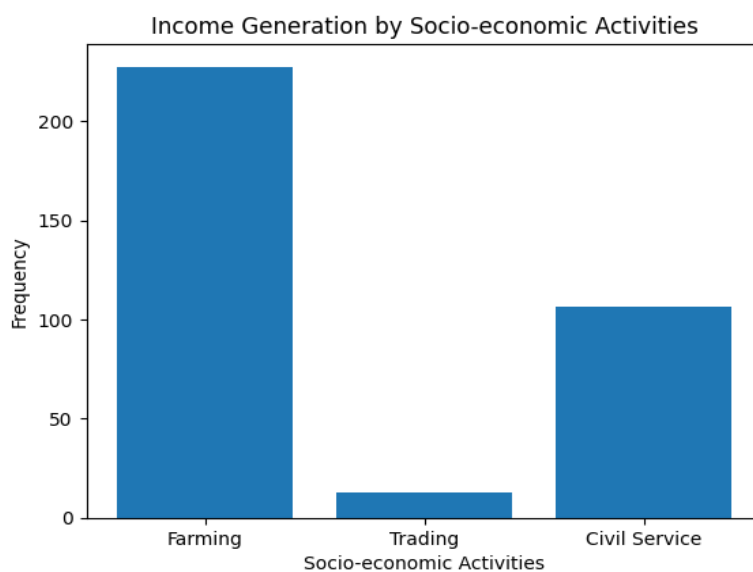
Crop	Yield from urban agric practice	Yield from conventional agric practice
Yam	90 kg	29 kg
Bell peppers	900kg	210kg

Socio-Economic Impact of Urban Agriculture

Income Generation

Income data from the 50 urban farmers surveyed show that 49.09% earned ₦140,000 and above monthly, while only 3.64% earned between ₦20,000–₦40,000 (fig 5).

When disaggregated by source, farming accounted for 65.72% of respondents' total income exceeding civil service employment (30.64%) and trading (3.64%), (fig 6).

**Figure 5.** Income distribution**Fig 6.** Income generation by Socio-economic activity

Cost-Benefit Analysis

Capital expenditure and revenue data (Table 8) show that while hydroponics requires a higher initial investment, it generates significantly greater gross revenue. Bell pepper hydroponics produced a gross margin of ₦597,000 (₦810,000 revenue less ₦213,000 CAPEX); sack-farmed yam yielded a gross margin of ₦59,000; open-field bell pepper returned a modest ₦52,500; and open-field yam recorded a loss of approximately -₦89,950.

Table 6: Capital Cost and Revenue for Urban Farming vs. Conventional Open-Field Farming

Farming Type	Yield	Unit price (₦)	Revenue (₦)	CAPEX (₦)	Gross Margin (₦)
Yam – Sack Farming	90 kg	₦2,000	₦194,000	₦135,000	+59,000
Yam – Open Land	29 kg	₦2,000	₦56,000	₦145,950	-89,950
Bell Pepper Hydroponic	900 kg	₦900/kg	₦810,000	₦213,000	+597,000
Bell Pepper – Open Land	210 kg	₦900/kg	₦189,000	₦136,500	+52,500

Financial Viability

The one-year micro-economic analysis at a 26.25% lending rate (Table 9) confirmed that hydroponics is the most financially viable system, with an NPV of ₦428,584, IRR of 280.28%, and a payback period of just 0.26 years. Sack farming also yielded positive returns. By contrast, open-field yam farming recorded a negative NPV of -₦101,594 and an IRR of -61.63%, indicating it is not financially viable in a space-constrained urban context.

**Table 7 Financial Analysis for Urban Agriculture Practices
(1-Year, Lending Rate @ 26.25%)**

Project	CAPEX (₦)	Revenue (₦)	NPV (₦)	IRR (%)	Payback (years)	Period	Break-even
Bell Pepper Hydroponic	213,000	810,000	428,584	280.28	0.26		☑ Yes
Yam Sack Farming	135,000	194,000	18,663	43.70	0.70		☑ Yes
Bell Pepper Open Land	136,500	189,000	13,203	38.46	0.72		☑ Yes
Yam Open Land	145,950	56,000	-101,594	-61.63	2.61		✗ No

Discussion

Spatial Distribution of Urban Agriculture

The predominance of greenhouse farming at 76% of mapped practices, concentrated in the peri-urban zones of Jos South, is consistent with patterns reported in the literature: building integrated and protected farming systems tend to cluster where land access, infrastructure, and market proximity are favourable (Thomaier et al., 2015; Orsini et al., 2013). Jos South's lower

population density and available land contrast sharply with the built-up, space-constrained character of Jos North, which limits opportunities for open or protected cultivation.

The low adoption of hydroponics (6%) and the still emerging uptake of sack farming (18%) reflect well documented barriers in developing urban contexts, principally high capital costs, limited technical knowledge, and inadequate extension services tailored to urban producers (Mok et al., 2014; Sanyé-Mengual et al., 2015). The prevalence of small farm plots (44% on 0.01–0.05 ha) aligns with the realities of land constrained cities, where modular and space efficient systems such as sack gardens and small greenhouses offer the best fit per unit area (Gallaher et al., 2015; Thomaier et al., 2015). This is comparable to findings by Drechsel and Dongus (2010) in Dar es Salaam, where mid-sized peri-urban plots similarly supported greenhouse and protected cultivation.

The dominance of young, relatively inexperienced farmers with 44% having only 1–3 years of experience is consistent with broader observations from rapidly urbanizing West African cities, where livelihood diversification draws in first generation producers (Ayambire et al., 2019). This contrasts with urban food systems in cities with longer-established UA traditions, where farming knowledge is typically embedded across generations (Kiribou, 2024).

Agricultural Produce

The dominance of vegetables at 72% of produce is consistent with the established preference for short-cycle, high turnover crops in West African urban markets (Akinmoladun & Adejumo, 2011; Kiribou, 2024). The secondary position of yam and Irish potatoes (14% each) reflects urban farmers' orientation towards high value perishable crops that offer quicker returns on investment a pattern well documented in West African urban food systems (Akinbamiyo et al., 2002).

Evaluation of Urban Agricultural Practices

The 4.3-fold yield advantage of the hydroponic system over conventional open-field cultivation for bell peppers, and the 3.1-fold advantage of sack farming for yam, are consistent with findings from controlled-environment and modular system reviews that consistently demonstrate greater land and water use efficiency compared to traditional methods (Orsini et al., 2013; Sanyé-Mengual et al., 2015; Benis & Ferrão, 2017). Water savings in soilless systems have been well documented in recent hydroponic systems research (Velazquez-Gonzalez et al., 2022). For sack farming specifically, evidence from Nairobi's Kibera informal settlement demonstrates feasibility in densely populated urban contexts, with measurable contributions to household food access (Gallaher et al., 2015).

These results reinforce the argument that controlled environment and modular urban farming systems offer a practical response to the twin constraints of space scarcity and low agricultural productivity that characterize urban areas in sub-Saharan Africa.

Socio-Economic Impact of Urban Agriculture

The high earning potential observed with 49.09% of urban farmers earning above ₦140,000 monthly and farming accounting for 65.72% of respondents' total income underscores urban

agriculture's viability as a primary livelihood strategy rather than merely a supplementary activity. This aligns with Mougeot's (2005) finding that urban agriculture can account for a substantial share of household income in developing countries, and with Zezza and Tasciotti's (2010) cross country evidence linking UA engagement to improved food security and poverty reduction in informal urban settings.

The cost benefit analysis confirms that hydroponics and sack farming offer superior returns per unit of capital invested compared to conventional open-field farming. This is consistent with Drechsel and Keraita (2014), who documented returns on investment in urban farming systems that were two to four times higher than conventional equivalents. Benis and Ferrão (2017) similarly reported IRRs exceeding 200% in compact urban hydroponic systems, closely mirroring the 280.28% IRR recorded in this study.

The one-year financial projection further validates these findings. The hydroponic system's payback period of 0.26 years (approximately three months) is shorter than the 6–12-month range reported by Specht et al. (2014) for urban hydroponic systems, suggesting that the Jos context with its relatively low CAPEX and favorable produce prices may offer particularly attractive conditions for hydroponic investment. Sack farming also demonstrated positive financial indicators within the first year. By contrast, open-field yam farming returned a negative NPV (–₦101,594) and an IRR of –61.63%, confirming that conventional open-field agriculture is not economically viable in urban, space constrained settings where capital costs per unit area are high relative to achievable yields. Thomaier et al. (2015) similarly highlighted that sack-based systems minimize land dependency, reinforcing their suitability in land-constrained urban environments.

Taken together, these findings affirm that climate-smart urban farming systems particularly hydroponics and sack farming offer a financially viable, food-secure, and income generating pathway for urban households in Jos Metropolis and comparable Nigerian cities.

Limitations and Unexpected Findings

Several limitations warrant acknowledgement. First, the sample of urban farmers ($n = 50$) was purposively identified through snowball sampling, which, while appropriate for a hard-to-enumerate population, may not fully represent the diversity of urban farming practices across the entire metropolis. Second, the financial projections are based on a single growing year (2024–2025), and longer-term viability will need to be assessed over multiple seasons, accounting for fluctuations in input costs, produce prices, and climatic variability.

A notable and unexpected finding is the apparent paradox between hydroponic viability and adoption. Despite offering the strongest financial indicators an IRR of 280.28% and a payback period of less than three months hydroponics accounts for only 6% of mapped urban farm practices. This disconnect between financial attractiveness and actual adoption suggests that economic returns alone are insufficient drivers of technology uptake. Access barriers including the capital required for initial NFT infrastructure, limited availability of nutrient solution inputs in local markets, and a lack of trained extension workers familiar with soilless systems appear to constrain adoption far more than economic disincentive. This finding underscores the need

for targeted extension services, demonstration programmes, and input subsidies to translate hydroponics' financial potential into widespread practice.

CONCLUSION

Urban agriculture in Jos Metropolis demonstrates considerable potential for enhancing urban food production and livelihoods. This study revealed that greenhouse farming is the dominant practice, concentrated in peri-urban Jos South where land availability is greater, while sack farming is emerging and hydroponics remains at low adoption levels due to high initial investment requirements and limited technical knowledge. Vegetables constitute the principal produce at 72%, with Irish potatoes and yam each at 14%, reflecting urban farmers' preference for short-cycle, high value perishable crops. Farm operations are predominantly small-scale, with most plots between 0.01 and 0.05 hectares, and the urban farming population is relatively young and inexperienced, with 44% having only 1–3 years of experience and only 16% classified as veterans (Ayambire et al., 2019).

Experimental yield trials clearly favored the urban farming systems over conventional open-field cultivation. The hydroponic system produced a 4.3-fold yield advantage for bell peppers, while sack farming produced a 3.1-fold yield advantage for yam, confirming that these systems offer superior productivity and more efficient resource utilization per unit area (Orsini et al., 2013; Benis & Ferrão, 2017).

Urban agricultural practices particularly hydroponics and sack farming proved instrumental in enhancing income stability in low-income urban settings, serving not only as a food security strategy but also as a viable income-generating enterprise (Mougeot, 2005). Based on the one-year micro-economic financial projection, the hydroponic system stood out as a highly profitable, low-risk investment with a payback period of approximately three months shorter than the 6–12 months reported by Specht et al. (2014) in comparable urban contexts. Sack farming also yielded positive financial indicators within the first year. Conversely, conventional open-field farming proved economically unsustainable in the urban setting, returning a negative NPV of –N101,594 and an IRR of –61.63%, attributable to high capital expenditure relative to low yields.

while the experimental plots were standardized at 0.002 hectares with identical input allocations, variability in microclimate, plot drainage, and operator skill between systems may have influenced yield outcomes. Future studies should replicate the yield trials across multiple sites and seasons, and incorporate soil and water quality analyses to further validate the findings. Overall, the findings affirm that climate-smart urban farming systems are a financially viable, food-secure, and income-generating pathway for urban households in Jos Metropolis, with broader applicability to similarly space constrained Nigerian and West African cities.

Recommendations

Based on the findings of this study, the following recommendations were made:

1. **Awareness and community engagement:** State and local government departments of agriculture should initiate public sensitization programmes to promote the benefits of urban agriculture, foster behavioral change among residents, and build community

ownership. This will enhance food access, utilization, and food security outcomes in urban settings.

2. **Policy incentives for urban farmers:** Government at all levels should introduce targeted incentives such as subsidized inputs, access to credit, and tax relief to make urban agriculture more attractive to a broader range of participants, thereby increasing the volume of food available to urban dwellers.
3. **Integration into national agricultural research:** Urban farming should be formally incorporated into Nigeria's national agricultural research agenda so that technologies can be developed, tested, and refined to keep pace with global trends and improve productivity in space constrained environments.
4. **Integration into land use planning:** Urban agriculture should be embedded in the land use planning frameworks of all major Nigerian cities. One practical mechanism is the designation of greenbelt zones within urban master plans dedicated to food production, ensuring that land is legally protected and accessible for urban farming.
5. **Support for context-specific innovation:** Academic institutions and research bodies should be encouraged and resourced to develop innovations specifically suited to low income, space constrained urban settings, ensuring that technologies such as hydroponics and sack farming are made accessible and affordable for smallholder urban producers.

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