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Geospatial Dynamics of Urban Irrigation Agricultural Land Use for Sustainable Income Generation on the Jos Plateau

Dr. Emmanuel Omomoh, Dr. Sunday Nannim, Dr. Rogers Rengje Danlami Gujahar, Moses Omitunde Omirinde, Gwamzhi Ponsah Emmanuel

Information and Communications Technology, Zonal Advanced Space Technology Application Laboratory, Nigeria

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ABSTRACT

Urban agriculture has become increasingly significant in African cities as a strategy for food security, income generation, and sustainable urban development. This study employed geospatial techniques, anchored in the Sustainable Livelihoods Framework (SLF), to map and analyze market gardening activities and land use changes in Jos South Metropolis, Nigeria, over a ten-year period (2014–2024). The research addresses critical knowledge gaps regarding the spatio-temporal dynamics and sustainability challenges of urban agriculture in Jos Metropolis, where comprehensive data on arable farming activities had been lacking despite extensive crop cultivation. High-resolution satellite imagery with 15 cm spatial resolution was acquired from the National Space Research and Development Agency (NASRDA) for both time periods and processed using ArcGIS 10.8 software. Through systematic on-screen digitization, spatial analysis, and change-detection algorithms, the study quantified changes in agricultural land use, settlements, and water bodies. Extensive fieldwork involved systematic reconnaissance of Jos South Local Government Area (LGA) to identify active market gardening sites, establish ground control points, and conduct interviews with local farmers and agricultural extension agents. Results revealed that market gardens covered 9.59 km² in 2014, declining to 9.03 km² in 2024, representing a 5.84% reduction. Conversely, settlements expanded dramatically from 43.82 km² to 79.32 km², a 34.76% increase, while water bodies decreased marginally from 4.57 km² to 4.46 km², highlighting increasing pressure on water resources driven by urbanization. The study identified key constraints to sustainable urban agriculture including land tenure insecurity, with 63% of dry-season farmers being landless; limited access to irrigation water; pest and disease pressure; inadequate fertilizer supply; and increasing competition for land from urban development. Field surveys documented diverse cropping systems, with farmers cultivating temperate vegetables such as tomatoes, lettuce, cabbage, carrots, and Irish potatoes throughout the year using fadama lands along river channels and mine ponds. The intensive cropping systems documented included plots undergoing three cropping cycles per year, demonstrating both the productivity potential and sustainability challenges. The findings align with global evidence that urban agriculture persists in the face of urbanization, serving multiple livelihood, ecological, and social functions. The research demonstrates the capability of remote sensing and GIS in monitoring urban agricultural dynamics and provides baseline data for urban planning and agricultural policy formulation. The study recommends establishing agricultural zones in fadama areas, strengthening extension services, enacting secure land tenure policies, and fostering rural–urban production synergies to sustain this vital economic sector in the face of rapid urbanization.

Keywords: Urban agriculture, market gardening, geospatial analysis, land use change, remote sensing, GIS, sustainable livelihoods, Jos Plateau

INTRODUCTION

Urban agriculture is not a novel phenomenon; it is likely as old as the earliest urban settlements, with an estimated 800 million urban residents involved in commercial and subsistence agriculture in or around cities globally (WFP, 2022; Mwaijande, 2024). Over the past two decades, urban agriculture has gained increasing recognition as a viable intervention strategy enabling urban residents to sustain themselves and earn supplementary income (Matamanda & Chirisa, 2024). Several scholars have documented that urban agricultural

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practice is increasingly becoming a means of livelihood for urban and peri-urban inhabitants globally, particularly in African cities (Teklemariam & Cochrane, 2021; Khumalo et al., 2024; Kiribou et al., 2024; Yan et al., 2022; Kwiringira et al., 2024).

Urban agriculture has historically been an essential element of the Jos urban economy. The commercial mining of tin and associated minerals, which started in the region around 1904, brought about the introduction of irrigated or dry-season agriculture (Fadama) to the Jos Plateau in the 1940s by Hausa and Kanuri miners (Phillips-Howard et al., 1990). The replacement of the ancient Shadoof irrigation system by mechanical pumps enabled irrigated farming to spread further upslope towards watersheds wherever water was available. Large-scale tin mining greatly modified the landscape over several decades, creating 316 km² of spoil heaps, open-cast pits, and tailings (Phillips-Howard et al., 1992). The open-cast pits, when filled with water, became mine ponds now used for irrigation, domestic and industrial water supply, fish farming, and recreation. As mining activity widened many valleys, it helped to create more fadama land, which is highly suitable for dry-season farming.

Adepetu (1985) noted that irrigated agriculture expanded rapidly on the Jos Plateau from the early 1980s, driven by growing vegetable markets, mechanical pumps, and artificial fertilizers. The near-temperate climate makes Jos City unique in Nigeria and the West African sub-region, permitting sound horticultural practices and enabling the cultivation of temperate vegetables not producible elsewhere in the country. There is great potential for further expansion, with sufficient water to irrigate over 600,000 ha of the Plateau (Phillips-Howard & Schoeneich, 1991).

Rainfed and dry-season farming take place throughout the year within heterogeneous, multiple-resource utilization situations in Jos. Urban agriculture enhances food supply and provides employment for urban dwellers (Tessema et al., 2025). According to Kiribou et al. (2024), urban areas also provide market access and significant potential for agricultural produce. However, despite extensive crop cultivation in Jos Metropolis, there is a dearth of information on this activity. Comprehensive data regarding the changes, trends, nature, and status of arable farming activities in Jos are still lacking, and urban farming remains relatively invisible to policymakers and unrecognized by urban planning authorities.

Since 2008, the world's urban population has outnumbered its rural population for the first time in history (UNDESA, 2022). Urban food insecurity is often overlooked because, at the aggregate level, economic and social conditions in urban areas appear better than in rural areas (FAO et al., 2023). FAO et al. (2023) suggested that urban food security has become one of the greatest humanitarian challenges of this century, yet it is scarcely recognized in contemporary political debate. Wegerif & Wessels (2024) argued that the lack of attention by African governments to urban food security may be due to policymakers' perception of food security as a household-level responsibility.

In the case of Jos Metropolitan Area, the impact arising from inadequate food supply stretches far beyond its physical boundaries. Considerable areas of hinterland that the city depends upon for food supplies have been under severe pressure, not because of large population alone, but because the environment has been devastated and local resources greatly restricted by historical open-cast mining. Because of the uniqueness of Jos in the production and supply of agricultural products, there is a growing need to generate relevant data that can reveal the nature and character of urban agriculture in the metropolis. The aim of this study is to demonstrate the capability of space technology in mapping and generating comprehensive data on market gardening activities in Jos Metropolis. The specific objectives are to: (i) determine the extent of urban agricultural land use between 2014 and 2024; (ii) examine the ways farmers gain access to land; (iii) identify the types of crops grown; (iv) explain the farming practices involved in urban cultivation; and (v) examine the constraints to urban agricultural land use. The study is limited to dry-season arable farming within the continuously built-up area of Jos South Metropolitan Area, focusing on small-, medium-, and large-scale arable farmers cultivating plots along river channels, around mine ponds, and on flood plains.

Theoretical Framework

This study is anchored in the Sustainable Livelihoods Framework (SLF), developed by the UK Department for International Development (DFID, 1999) and subsequently adapted by scholars to contexts of urban poverty and

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urban agriculture (Ellis, 2000; Teklemariam & Cochrane, 2021). The SLF posits that livelihoods are shaped by access to five categories of capital assets, natural, physical, financial, human, and social, operating within a vulnerability context defined by trends, shocks, and seasonality. In the urban agriculture context of Jos South, these capitals correspond to: access to fadama land and mine pond water (natural capital); mechanical pumps and irrigation infrastructure (physical capital); micro-credit and market networks (financial capital); farming knowledge and extension services (human capital); and farmer cooperatives and community water-management arrangements (social capital).

The vulnerability context in Jos is defined by competing land uses driven by rapid urbanization (a structural trend), seasonal water scarcity (seasonality), and the decline of the tin mining economy (a historical shock). The SLF enables analytical traction on why some farmers sustain livelihoods despite these pressures, while others are marginalized, and provides a normative basis for the policy recommendations in this study. Complementary insights are drawn from Urban Resilience Theory (Meerow et al., 2016), which emphasizes the capacity of urban systems, including informal food production systems, to absorb disturbance and reorganize while undergoing change. The persistence of 9.03 km² of market gardens in 2024, despite a 34.76% expansion in settlement area, is interpreted here as evidence of urban agricultural resilience, consistent with findings by Sacks et al. (2023) and Yan et al. (2022) in other African and global contexts.

LITERATURE REVIEW

The role of urban and peri-urban agriculture in sustaining livelihoods has been extensively documented in the literature, particularly in sub-Saharan Africa. Kwiringira et al. (2024) demonstrated that urban agriculture in Kampala, Uganda, functions as an evolved livelihood strategy rather than a transitional activity, providing food security and social networks for low-income households. Similarly, Khumalo et al. (2024) found, through systematic review across sub-Saharan Africa, that climate-smart urban agriculture significantly contributes to household food and income security. These findings are consistent with earlier arguments by Teklemariam & Cochrane (2021) in peri-urban Ethiopia, where land rights and tenure security were identified as the foremost determinants of whether urban agriculture could be sustained.

The intersection of geospatial technologies and urban agriculture monitoring represents a growing research frontier. Remote sensing and GIS have been deployed to map urban agricultural land use in cities such as Lagos (Gilbert & Shi, 2023), Kaduna (Musa & Abubakar, 2024), Onitsha (Inam et al., 2023), and Addis Ababa (Tessema et al., 2025). These studies consistently highlight the tension between settlement expansion and agricultural land retention, a dynamic also identified by Frontiers in Environmental Science (2025) using Land Change Modeler (LCM) approaches. However, there remains a critical gap in spatially explicit, high-resolution studies of urban agriculture in Jos, Nigeria, a city with a unique climatic and historical context that warrants dedicated investigation.

Land tenure insecurity is one of the most pervasive constraints documented across the urban agriculture literature in Africa. Kidido & Ajabuin (2022) reported that smallholder farmers in peri-urban Tamale, Ghana, face tenure insecurity driven by customary land allocation practices that exclude non-indigenous residents. Naab et al. (2023) confirmed that land tenure, food security, and gender are deeply interlinked in northern Ghana, with women and migrants disproportionately affected by insecure tenure. Matamanda et al. (2022) documented similar patterns in Harare, Zimbabwe, where spatial injustice in land allocation systematically disadvantages urban farmers. The 63% landlessness rate documented among dry-season farmers in this study resonates with these findings and underscores the need for policy interventions that transcend local specificity.

Globally, urban agriculture serves multiple functions beyond food production, including ecological services, social cohesion, and economic diversification. Yan et al. (2022) conducted a global bibliometric analysis demonstrating that urban agriculture research is increasingly framed around urban resilience and sustainability, with a growing emphasis on multifunctional land use and green infrastructure. Wegerif & Wessels (2024) showed that urban agriculture in growing African cities contributes significantly to urban food flows and dietary diversity. However, the literature also cautions that the persistence of urban agriculture should not mask its structural vulnerabilities: Matamanda & Chirisa (2024) emphasized that without formal recognition in urban

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planning frameworks, urban agriculture in African cities risks marginalization and eventual displacement by competing urban land uses.

The present study builds on this body of knowledge by providing a high-resolution, temporally comparative geospatial analysis of urban agriculture in Jos South, situated within the SLF analytical framework. It contributes to the literature by combining remote sensing outputs with primary socioeconomic data and by comparing findings with global and African urban agriculture trends.

Study Area

Location, Position, and Size

Jos Metropolis is geographically unique in many respects, including its location, altitude, and weather conditions. It has an average elevation of approximately 1,250 m above sea level and stands about 600 m above the surrounding plains. The capital of Plateau State, Jos city lies between latitudes 9°36′ and 10°01′16″N and longitudes 8°38′32″ and 8°59′14″E, approximately 300 km from the Federal Capital Territory, Abuja. Jos Metropolis comprises Jos North LGA (291 km²) and Jos South LGA (510 km²), bounded by the Bauchi plains to the north, Barki Ladi to the south, the Bassa/Rukuba complex to the west, and Jarawa to the east.

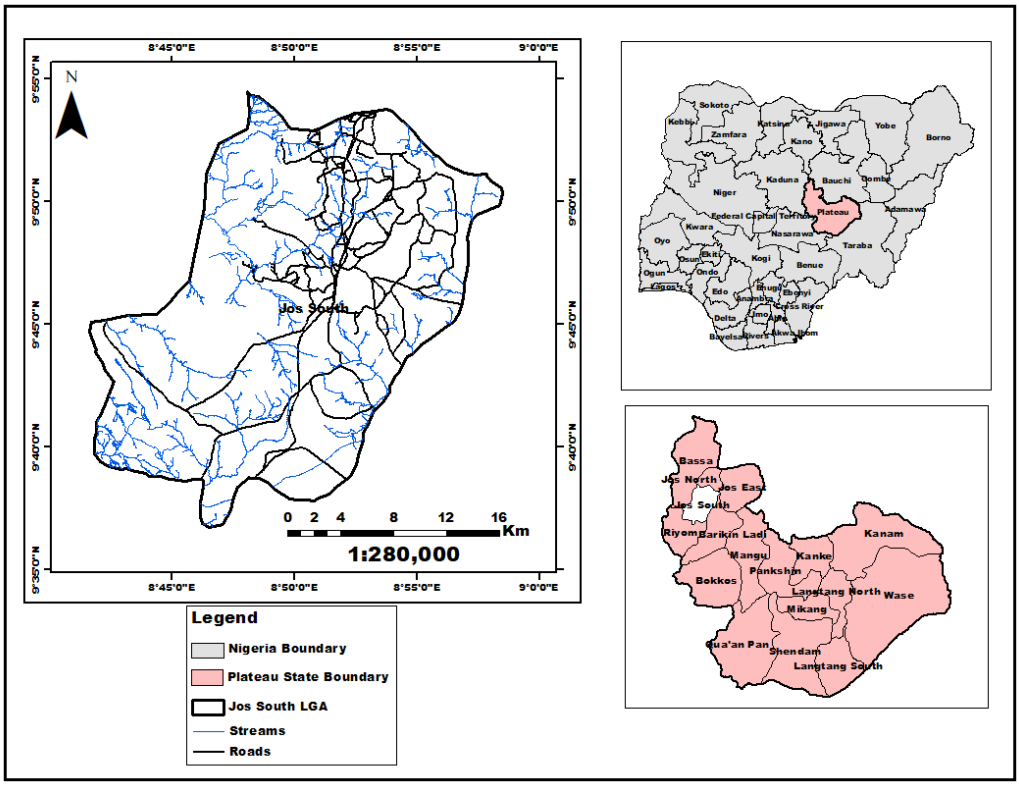

Figure 1: Study Area Map, Jos South, Plateau State, Nigeria

Climatic Characteristics

The climate of Jos Plateau is influenced by its altitude and the seasonal migration of the Inter-Tropical Convergence Zone (ITCZ). Altitude lowers temperatures and induces orographic rainfall (Eziashi, 1995; Olowolafe et al., 2000). The mean annual temperature is approximately 22°C; mean monthly maxima range from about 27°C to 31°C (March/April), while mean monthly minima range from about 12°C to 18°C (December/January) (Alford & Tuley, 1974; Hill & Rackham, 1974). During exceptionally cold harmattan periods, temperatures may drop well below 10°C. Mean annual rainfall is approximately 1,465 mm, varying from about 1,800 mm in the southwest to about 1,000 mm in the southeast rain-shadow zone (Ajaegbu et al., 1989). The hydrological peak of the rainy season is generally in August. Rainwater accumulates in numerous mine ponds that provide irrigation water for dry-season cultivation. Land preparation for rainfed crops begins in late April to May; for dry-season crops, from October.

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Tables 1 and 2 present meteorological records from the University of Jos station (2000–2010). As shown in Table 1, mean monthly temperatures fluctuate moderately throughout the year, with the hottest months recorded in May (28.2°C average) and the coolest in August (19.3°C average), reflecting the plateau's temperate influence. Table 2 reveals a strongly bimodal rainfall pattern: precipitation is negligible from November to February, rises sharply from April, peaks in August (averaging 285.6 mm), and recedes from October. This seasonal pattern creates a well-defined dry season from November to March, during which irrigation agriculture becomes essential for year-round food production and farmer income.

Table 1: Mean Monthly Temperature (°C) of Jos Metropolis

Year/Month	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	Ave
Jan	19.6	19.1	19.1	19.7	19.7	18.9	18.1	19.3	19.3	19.9	19.9	17.54
Feb	22.0	25.2	25.2	25.2	24.4	24.4	21.0	21.0	21.6	24.7	24.7	23.3
Mar	25.2	29.1	29.1	27.4	27.4	26.6	26.6	25.9	25.9	21.4	21.4	26.4
Apr	25.0	26.1	26.1	25.0	25.0	27.3	27.3	27.1	27.1	28.0	28.0	26.55
May	27.0	29.6	29.6	31.3	31.2	28.0	27.0	25.8	26.8	26.3	25.3	28.2
Jun	29.5	27.3	24.1	22.9	23.5	21.3	21.2	20.9	20.4	19.9	19.5	23.1
Jul	29.9	22.5	21.3	21.2	20.9	20.4	19.9	20.5	19.6	20.2	19.6	21.5
Aug	19.7	18.9	18.2	18.4	18.3	18.9	17.9	17.6	17.3	22.5	24.9	19.3
Sep	22.1	21.2	21.0	19.4	19.5	18.3	21.3	22.3	25.1	26.3	27.3	22.5
Oct	28.9	28.3	27.2	23.6	21.8	20.8	20.2	21.3	20.7	20.5	20.2	23.95
Nov	19.1	18.7	18.7	18.8	20.7	25.3	26.8	27.7	28.7	29.2	29.7	23.95
Dec	27.6	27.4	26.6	23.8	21.0	19.5	18.8	17.7	17.3	16.6	16.7	21.18

Source: University of Jos Meteorological Station, Jos

Table 2: Average Monthly Rainfall (mm) of Jos Metropolis

Year/Month	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Jan	0	0	0	0	0	0	0	0	0	0	0
Feb	0	0	0	0	1	0	35	0	0	0	0
Mar	10.8	0	9	0	14.1	0	0	11.1	3	0	48.4
Apr	52.7	99.2	155.9	199.9	216.7	88.2	51.1	82.5	69.2	87.6	76.6
May	191.2	202.2	81.9	185.2	223.8	123.9	222.9	176.6	244	135.8	142.1
Jun	234.8	105	365.4	183.7	246.3	310.6	146.6	310	117.1	100.4	218.1
Jul	169.3	301.5	406.2	160.9	249.4	223.8	168.2	303.5	272.7	167.8	245.3
Aug	297.8	264.6	266	283.1	129	263.4	307.9	286	307.6	299.4	345.4
Sep	165	263.1	209.3	257.5	41	138.1	245.6	184.1	195.2	190.3	263.5
Oct	38.4	11.8	91	36.3	0	55.9	67.9	1.8	93.6	176	93.2
Nov	0	0	0	1.8	0	0	0	0	0	30.4	0
Dec	0	0	0	0	0	0	0	0	24.7	0	0
Ave	**96.667**	**103.95**	**131.9**	**109.03**	**100.97**	**100.32**	**103.8**	**112.966**	**108.7**	**98.97**	**119.383**

Source: University of Jos Meteorological Station, Jos

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Landform, Drainage, and Soils

The land surface of the Jos Plateau consists of plains, hills, and depressions formed during the Miocene and Pliocene periods (Ajaegbu et al., 1989). Jos Metropolis forms the most important watershed in the region, dividing drainage basins into the Lake Chad Basin (northeast), the Sokoto-Rima Basin (northwest), and the Rivers Niger and Benue Basins (southwest and southeast respectively). The study area has a network of numerous streams, including River Delimi and River Gyel, and is dotted with mine ponds serving as vital irrigation water sources.

The soils of the Jos Plateau have been characterized at various levels (Grove, 1952; Hill & Rackham, 1974; Ajakpo, 1986). D'Hoore (1964) identified three principal soil groups: (i) Lithosols, which are weakly developed soils on ferruginous crusts; (ii) Ferruginous Tropical Soils, common on sandy parent materials and suitable for groundnut production and mechanized agriculture; and (iii) Eutropic Brown Soils, found on ferro-magnesium mineral-rich rocks, which are very fertile and well distributed in the Jos-Bukuru metropolis, forming the basis of fadama agriculture. Soils derived from biotite granites are characterized by low total nitrogen, phosphorus deficiency, and low calcium status (Macleod et al., 1971; Olowolafe & Dung, 2000), making fertilizer application critical for sustained productivity.

Population and Human Activities

The growth of Jos was closely linked to tin mining. The population grew from approximately 8,000 in 1920 to 11,000 by 1931 (Bingel, 1978), increasing from about 40,000 in 1960 to 594,955 in 1991 and 736,016 in 2006 (NPC, 1992; 2006). The city's population is ethnically heterogeneous, comprising indigenous Berom, Jarawa (Afusare), Anaguta, and Rukuba groups alongside Hausa, Igbo, Yoruba, and other communities. The Hausas are predominantly involved in dry-season farming. After the decline of tin mining, abandoned mine ponds, huge spoil dumps, and excavated pits now characterize significant portions of the area, while the agricultural economy has absorbed many former mining workers and their families.

MATERIALS AND METHODS

Primary Data Collection and Fieldwork

Extensive fieldwork was carried out to locate and document existing gardens engaged in dry-season irrigation farming within Jos South LGA. The field survey involved systematic reconnaissance of the entire study area to identify active market gardening sites and establish ground control points for subsequent remote sensing analysis. GPS coordinates were recorded for each garden location, with detailed observations on farming practices, irrigation systems, crop types, and seasonal variations. Structured and semi-structured interviews were conducted with local farmers and agricultural extension agents to gather information on crops, cropping systems, changes in cultivation patterns, and challenges faced by market gardeners.

Satellite Data Acquisition and Preprocessing

High-resolution satellite imagery with 15 cm spatial resolution was acquired from the National Space Research and Development Agency (NASRDA) for 2014 and 2024. The ten-year temporal window was sufficient to capture significant changes in market gardening patterns while ensuring data availability and quality. The 15 cm resolution was particularly important as it enabled identification and mapping of small-scale agricultural features, including individual plots, irrigation channels, and farm boundaries. The imagery underwent rigorous preprocessing: geometric correction, radiometric calibration, atmospheric correction, and reprojection to a common coordinate system for accurate temporal comparison.

Digital Image Analysis and Feature Extraction

The satellite images were processed using ArcGIS 10.8 desktop software. Systematic on-screen digitization and manual vectorization were employed to delineate market gardens based on spectral characteristics, geometric patterns, and spatial context. Drainages, water bodies, settlements, and major roads were also digitized as separate vector layers. Each feature class underwent multiple quality-control checks to ensure accuracy and

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consistency in boundary delineation across both time periods. Change-detection algorithms were subsequently applied to quantify the magnitude and direction of land use changes, generating total area coverage, percentage changes, and spatial distribution patterns for all mapped features.

RESULTS AND DISCUSSION

Spatial Distribution and Temporal Changes in Land Use

The geospatial analysis revealed significant changes in land use patterns within Jos South Metropolis between 2014 and 2024. Table 3 summarizes the area coverage for all land use classes, with percentage changes calculated to facilitate temporal comparison. Figures 2–5 illustrate the spatial distributions of land use in both periods.

Table 3: Area Coverage of Land Use Classes in Jos South (2014 vs. 2024)

Land Use Class	2014 Area (km²)	2024 Area (km²)	Change (%)
Settlements	43.82	79.32	+34.76%
Water Bodies	4.57	4.46	−2.41%
Market Gardens	9.59	9.03	−5.84%

Source: Authors' geospatial analysis (2024*)*

As shown in Table 3, irrigated agriculture in Jos South covered 9.59 km² in 2014, declining to 9.03 km² in 2024, a reduction of 0.56 km² (5.84%). This marginal decline in the absolute area of market gardens, despite the dramatic expansion of settlements, signals the remarkable resilience of urban agriculture under intense urbanization pressure. Within the same period, settlements increased from 43.82 km² to 79.32 km², representing an increase of 35.50 km² (34.76%). This rate of settlement expansion is consistent with trends documented in other rapidly growing Nigerian cities: Musa & Abubakar (2024) recorded settlement expansion rates of 25–40% in Kaduna between 2000 and 2020, while Inam et al. (2023) documented a 38% expansion of built-up area in Onitsha over a comparable period. The explosive settlement growth in Jos South reflects national urbanization trends driven by rural-to-urban migration, natural population growth, and the concentration of economic activities in the metropolis. Water bodies declined from 4.57 km² to 4.46 km², a reduction of 0.11 km² (2.41%). Although modest in absolute terms, this decline is ecologically significant given the critical role of mine ponds and river channels in sustaining irrigated agriculture. The convergence of settlement expansion and water body reduction suggests increasing competition among urban land uses, residential development, agriculture, and water supply, that must be addressed through integrated urban water resource management, as recommended by the Sustainable Livelihoods Framework's emphasis on natural capital preservation.

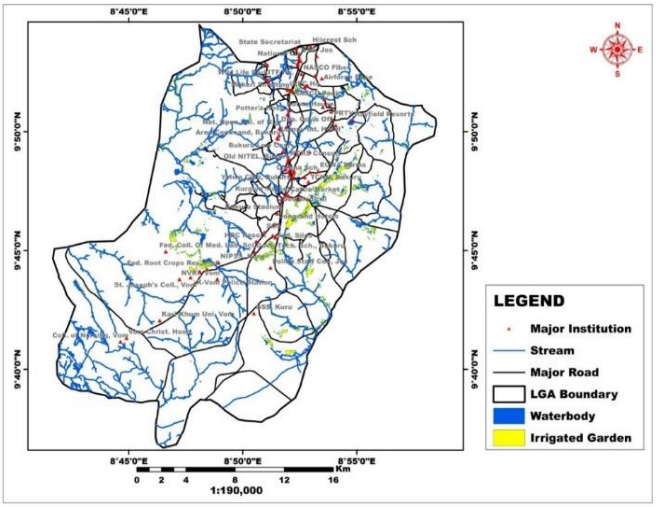

Figure 2: Urban Irrigated Agriculture and Potential Water Sources in Jos South (2024)

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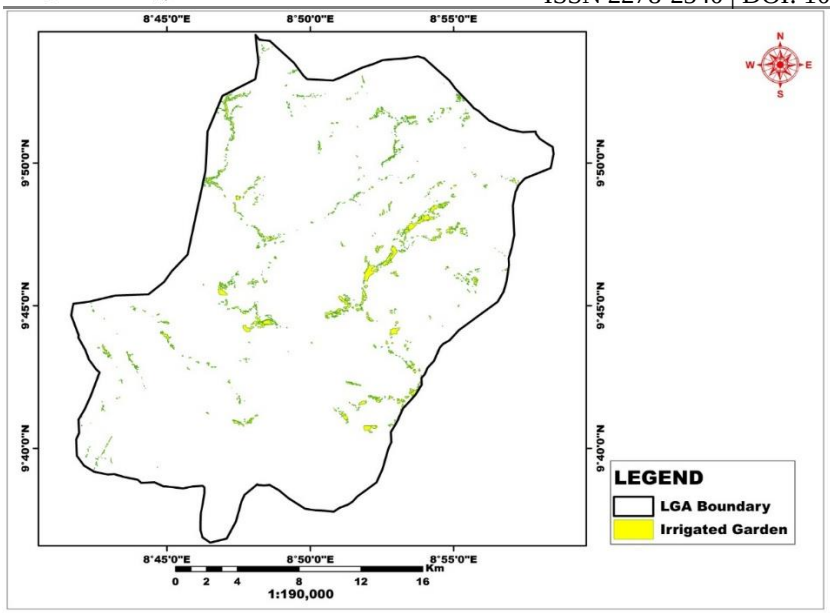

Figure 3: Urban Irrigated Agriculture in Jos South (2024)

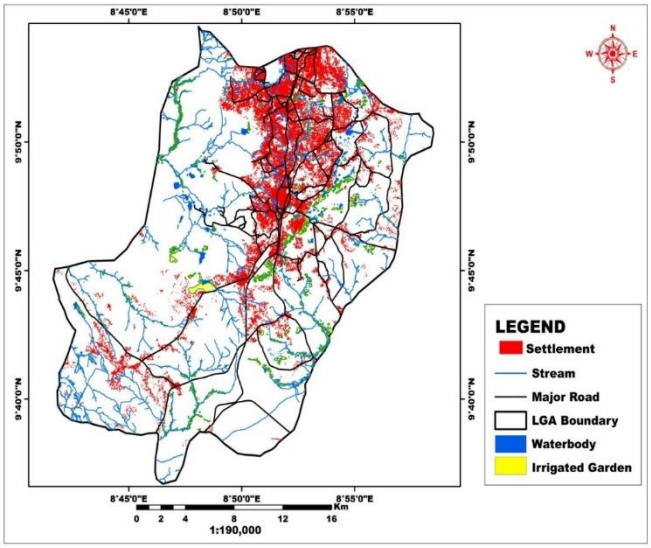

Figure 4: Urban Growth and Irrigated Agriculture in Jos South (2014)

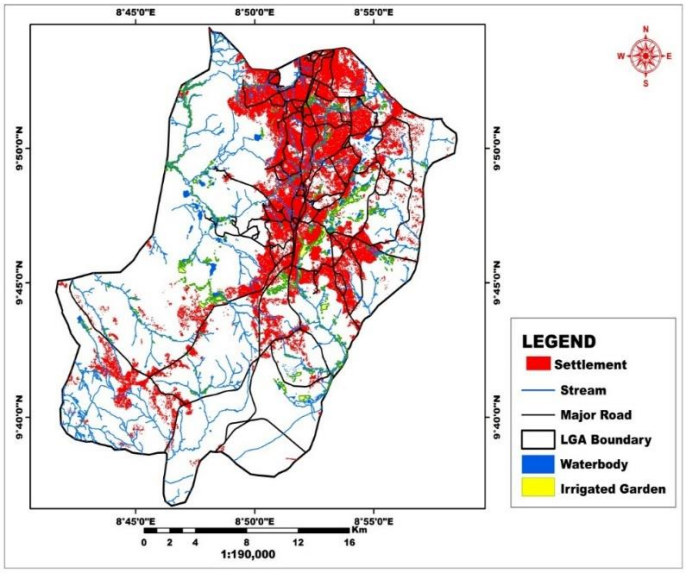

Figure 5: Urban Growth and Irrigated Agriculture in Jos South (2024)

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Comparing Figures 4 and 5, the spatial footprint of settlements has expanded substantially southward and eastward between 2014 and 2024, with new residential areas encroaching upon previously agricultural fringe zones. In contrast, market gardens have retained their spatial concentration along river channels and mine pond margins, reflecting the indispensability of water access for irrigated agriculture. This spatial pattern confirms that natural capital, particularly water, functions as the primary determinant of urban agricultural persistence in Jos, consistent with the SLF's analytical logic.

The 34.76% settlement expansion juxtaposed with only a 5.84% reduction in market gardens reflects the growing pressure of urbanization on agricultural land, yet also demonstrates urban agriculture's resilience. This finding aligns with similar studies: Kidido & Ajabuin (2022) reported that urban agricultural livelihoods in peri-urban Ghana are threatened by tenure insecurity and encroaching development, while Musa & Abubakar (2024) noted that urban growth in Nigeria continues to diminish land available for agriculture through landscape fragmentation. Globally, Yan et al. (2022) identified settlement encroachment as the foremost driver of urban agricultural land loss in rapidly urbanizing cities of the Global South. Despite these pressures, the persistence of 9.03 km² of market gardens in 2024 demonstrates the resilience of urban agriculture in Jos, corroborating Sacks et al. (2023), who observed that urban agriculture is integrated into the urban economic and ecological system and serves multiple functions beyond food production, including employment, ecosystem services, and social cohesion.

Methods of Acquisition of Farmlands

Farmland along river channels and around mine ponds (flood plains) is cultivated year-round. Key fadama areas in Jos South include the stretch from behind the Nasco Company in Anglo Jos southward to Zaramangada and parts of Rayfield, and those on the city edges at Raho Kana in Bukuru, extending to behind Grand Cereal.

Land is a costly commodity within the city. The study revealed that approximately 63% of dry-season respondents were landless, they did not own the land they farmed. Many urban residents were willing to farm but lacked access to land. Farmers interviewed reported farming on land where they did not know the owner, which is common in new development areas where plots are sold but await construction. The demand for agricultural land is typically met through short-term, informal tenancy agreements, creating insecurity of tenure and considerable difficulties, particularly for dry-season farmers.

It was also found that some migrant farmers from northern states and from Plateau State communities (Barki Ladi, Mangu, Bokkos, Bassa), even those who have lived in Jos for several years, still lack formal land rights. Such seasonal migrants cultivate rainfed crops in their home villages and then travel to Jos to seek viable fadama land for dry-season cultivation, attracted by access to irrigation water throughout the farming season and by the ready urban markets for fruits and vegetables.

This land tenure situation reflects a systemic challenge documented across African urban centres. Matamanda et al. (2022) documented similar patterns of spatial injustice in land allocation in Harare, Zimbabwe, where urban farmers are systematically excluded from formal tenure arrangements. Kwiringira et al. (2024) found that informal tenure agreements in Kampala undermined farmers' ability to invest in land improvements, thereby reducing long-term productivity. Naab et al. (2023) highlighted how land tenure, food security, and gender intersect in northern Ghanaian cities, with women and non-indigenous migrants most affected. These convergent findings across diverse African contexts underscore the need for deliberate policy interventions that provide secure land tenure for urban farmers in Jos and beyond.

Crops Cultivated and Cropping Systems

A wide variety of crops are cultivated year-round in Jos South Metropolis. Dry-season crops include tomatoes, lettuce, cabbage, carrots, cucumber, green peas, green pepper, celery, cauliflower, beetroot, strawberry, and garden egg. Maize, tomatoes, cucumber, cabbage, pepper, ugu (pumpkin leaf), and spinach are grown in both rainy and dry seasons. The availability of fadama land along stream channels and numerous mine ponds creates a unique opportunity for irrigated agriculture, while the near-temperate climate enables production of temperate

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vegetables that Jos can supply to markets across southern Nigeria during periods when production elsewhere is not possible.

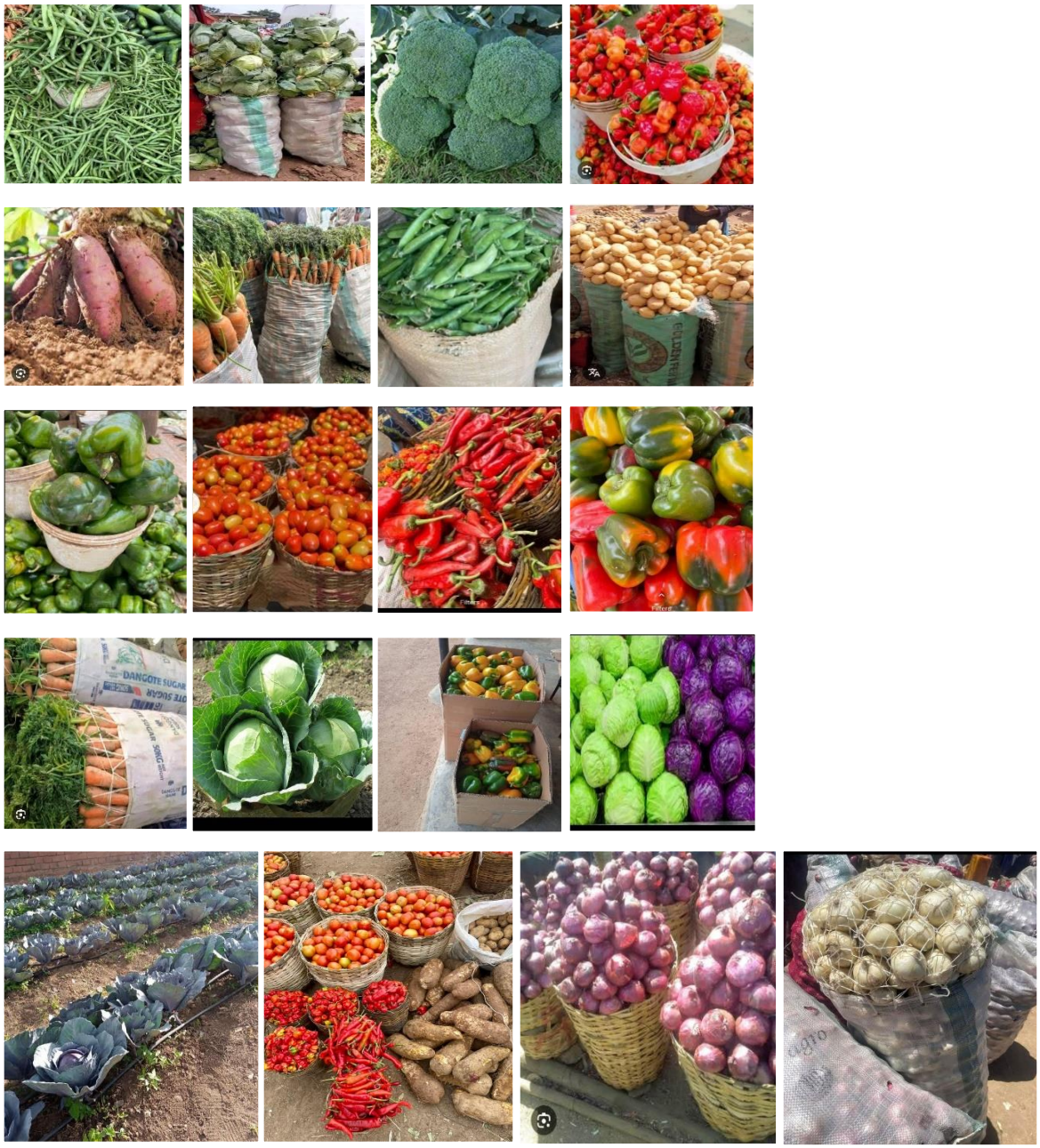

Figure 6: Photographic Collage of Crop Types and Market Garden Produce in Jos South

As illustrated in Figure 6, the diversity of crops cultivated reflects the productive capacity and market orientation of urban farmers in Jos. The presence of high-value temperate crops such as strawberries, lettuce, and cauliflower, which cannot be grown under the hot, humid conditions prevalent in southern Nigeria, represents a competitive advantage unique to the Jos Plateau. This specialization enables Jos farmers to serve niche urban markets in cities such as Lagos, Enugu, and Port Harcourt, contributing to national food system resilience.

Cropping intensity is remarkably high. Because urban land pressure precludes traditional bush-fallow fertility restoration, some plots undergo three cropping cycles per year: a first dry-season cycle (tomatoes, lettuce, cabbage, green beans, green peas) from mid-September to December, timed for the Christmas market; a second dry-season cycle from January to April; and a rainy-season cycle (maize or Irish potatoes) from May to September. This intensity of year-round cultivation, without adequate fallow periods, places tremendous pressure on soil fertility, explaining the critical dependence on inorganic fertilizers, particularly given the inherently low nitrogen and phosphorus status of Jos Plateau soils derived from biotite granites (Olowolafe & Dung, 2000). Globally, similar patterns of intensive urban cultivation without adequate nutrient cycling have

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been documented by Kiribou et al. (2024) in Burkina Faso, and by Tessema et al. (2025) in Addis Ababa, reinforcing the need for integrated soil fertility management as a component of sustainable urban agriculture policy.

Irrigation Practices and Water Management

The frequency and volume of irrigation water applied depend on crop type, stage of crop development, soil texture, and water availability. Clay soils hold more moisture than sandy soils, while leaf canopies help keep the soil surface moist longer by limiting direct solar exposure. At the peak of the dry season (January–April), when irrigation water is scarce, farmers in fadama locations such as Zaramangada and behind Nasco in Anglo Jos cooperatively construct earth dams along river channels and develop water-use scheduling calendars. This collective water management practice reflects both the strength of social capital (within the SLF framework) and the intensity of water demand, which intensifies as the dry season progresses.

The decline in water body area from 4.57 km² to 4.46 km² (Table 3) suggests that some mine ponds have been partially infilled or encroached upon by urban development, further reducing the natural capital available for irrigation. This trend, if unaddressed, threatens the medium-term viability of fadama agriculture in Jos South and reinforces the case for protective legislation governing mine pond areas.

Harvesting and Marketing

Harvesting of crops during dry-season cultivation relies largely on communal labour involving family members, friends, buyers, and neighbouring farmers. Farmers organize collective harvesting, hire trucks, and transport produce to markets in Enugu, Aba, Onitsha, Calabar, Port Harcourt, Benin, Warri, and Lagos. For local markets within Jos-Bukuru Metropolis, harvesting is timed to weekly market days: Mondays for the Tuesday market at the Building Material Market, and Wednesdays for the Thursday Faringada market. During festive seasons, particularly Christmas, buyers from across southern Nigeria converge on Jos, transforming weekly markets into daily ones and significantly boosting farm incomes. This market integration demonstrates how urban agriculture in Jos contributes to inter-regional food flows, consistent with the findings of Hannah et al. (2022), who documented the critical role of secondary cities in bridging rural–urban food systems in sub-Saharan Africa.

Constraints to Urban Agriculture

Farmers in Jos Metropolis encounter numerous constraints: pests and diseases (the most commonly reported and most severe), inadequate fertilizer supply, lack of capital, poor soil fertility, restricted farmland access, pollution and shortage of irrigation water, shortage of agricultural labour, crop theft, absence of storage facilities, and exploitation by middlemen. The intensity of these problems differs between cropping seasons and between locations.

The demand for urban land is high and highly competitive. Accessibility to farmland is especially critical for dry-season farmers, who are at greatest risk from the informal nature of tenure arrangements. Only those who own land through inheritance or purchase enjoy security of tenure. Kidido & Ajabuin (2022) and Naab et al. (2023) have noted that arguments about farming as a non-lucrative use of high-value urban land frequently exclude farming interests from planning decisions, further marginalizing urban farmers. This exclusion is particularly consequential in Jos, where the planning framework has not yet formally recognized the role of urban agriculture in the urban economy.

Comparative Perspectives: Jos in Global Context

The findings of this study reflect broader patterns documented in urban agriculture research globally, while also revealing the distinctive character of market gardening on the Jos Plateau. Table 4 situates the Jos findings within a comparative global framework.

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Table 4: Comparative Overview of Urban Agriculture Dynamics in Selected African and Global Cities

City / Country	AG Land Change	Settlement Expansion	Key Constraint
Jos South, Nigeria (this study)	−5.84% (2014–2024)	+34.76%	Land tenure insecurity; water scarcity
Kaduna, Nigeria (Musa & Abubakar, 2024)	Landscape fragmentation	~25–40%	Rapid urban sprawl
Tamale, Ghana (Kidido & Ajabuin, 2022)	Tenure insecurity	Significant	Customary land systems; migrant exclusion
Harare, Zimbabwe (Matamanda et al., 2022)	Spatial injustice	High	Policy exclusion of urban farmers
Kampala, Uganda (Kwiringira et al., 2024)	Stable; evolved livelihood	High	Informal tenure; limited investment
Addis Ababa, Ethiopia (Tessema et al., 2025)	Positive contribution to food security	Very high	Peri-urbanization; smallholder marginality

Source: Compiled by authors from reviewed literature

As Table 4 illustrates, urban agricultural land loss in the context of settlement expansion is a near-universal phenomenon in rapidly urbanizing African cities. The 5.84% decline in Jos South's market garden area is relatively modest compared with the severe landscape fragmentation reported in Kaduna, suggesting that the unique ecological endowments of the Jos Plateau, particularly its mine pond irrigation infrastructure and temperate climate, have buffered urban agriculture from more severe contraction. This resilience parallels findings by Yan et al. (2022), who observed globally that cities with distinctive ecological assets (water bodies, favourable microclimates) tend to sustain larger proportions of urban agricultural land in the face of urbanization.

Nonetheless, the convergence of challenges documented across these cities, tenure insecurity, water competition, policy neglect, points to systemic governance failures that cannot be addressed through farmer ingenuity alone. The inclusion of urban agriculture in formal planning frameworks, as recommended in this study and corroborated by Matamanda & Chirisa (2024) in a multi-country African study, emerges as the critical missing ingredient for long-term sustainability.

CONCLUSION

Urban agriculture has, over the years, become a significant and indispensable feature of Jos Metropolis that can no longer be ignored by planning authorities. The moderate climate of the Jos Plateau and the availability of fadama land and mine ponds provide unique assets for sustained agricultural production. Grounded in the Sustainable Livelihoods Framework, this study has demonstrated the multidimensional nature of urban agriculture in Jos South, encompassing natural, social, physical, financial, and human capital assets and vulnerabilities.

The geospatial analysis successfully demonstrated the capability of remote sensing and GIS technology in monitoring and mapping urban agricultural land use dynamics over a decade. Between 2014 and 2024, market garden areas declined marginally by 5.84% (from 9.59 km² to 9.03 km²), while settlements expanded dramatically by 34.76% (from 43.82 km² to 79.32 km²), indicating intense competition for urban land. Water bodies declined from 4.57 km² to 4.46 km², reflecting growing pressure on natural irrigation resources.

Despite these pressures, the persistence of 9.03 km² of market gardens in 2024 underscores the resilience and economic importance of this activity to Jos residents. The study documented significant challenges facing urban

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farmers: land tenure insecurity affecting 63% of dry-season farmers, inadequate irrigation water supply, pest and disease pressures, limited fertilizer access, and encroachment from urban development. These constraints threaten the sustainability of this vital economic sector unless deliberate policy interventions are implemented.

Comparatively, the Jos case aligns with documented urban agriculture dynamics across African cities while also exhibiting distinctive resilience attributable to the plateau's unique ecological endowments. There is a pressing need to integrate urban agriculture formally into the Greater Jos Master Plan to ensure its continued contribution to food security, employment generation, and sustainable urban development.

RECOMMENDATIONS

Based on the findings and guided by the Sustainable Livelihoods Framework, the following recommendations are proposed:

1. Integration into Urban Planning: Agriculture should be recognized as an integral component of the urban ecosystem in Jos-Bukuru Metropolis. Specific agricultural activity zones should be designated in the Jos Master Plan. Practical steps should protect and preserve key fadama areas at Raho Kana in Bukuru, adjacent to the University of Jos permanent site, and around the Seminary along Zaria Road. The fadama behind Nasco and Coca-Cola, stretching to Zaramangada, requires rationalization, as industrial and agricultural land uses are incompatible in that corridor.

2. Strengthening Extension Services: The activities of the Agricultural Services Training Centre (ASTC) in Vom should be intensified, including regular training programs, improved access to mechanized services, and enhanced provision of quality inputs, improved seeds, fertilizers, and pesticides, at affordable prices. Digital extension tools should be explored to broaden reach to peri-urban communities.

3. Land Tenure Security: Government should develop policies providing secure, long-term land tenure for urban farmers, including formal agricultural leasing arrangements that protect farmers from arbitrary displacement while accommodating legitimate urban development needs. Community land trusts could serve as a viable model for collective tenure arrangements.

4. Water Resource Management: Existing mine ponds must be legally protected from encroachment, water-use efficiency must be improved through drip and trickle irrigation technologies, and alternative irrigation sources must be explored. Integrated water resource management strategies are needed to balance agricultural and other urban demands, particularly in the context of ongoing climate variability.

5. Rural–Urban Production Synergies: Policies should support value chains connecting rural production areas with urban markets and processing facilities in Jos, strengthening overall food system resilience across the region. Investment in post-harvest storage and cold chain infrastructure would significantly reduce food losses and improve farmer incomes.

6. Farmer Organizations and Continuous Monitoring: The formation and strengthening of farmer cooperatives and associations should be encouraged to improve bargaining power and political voice in planning processes. Continuous geospatial monitoring of urban agricultural land use should be institutionalized to supply timely data for planning and policy formulation. Further research should focus on sustainable intensification, integrated pest management, and organic farming systems suited to urban environments.

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