frontiers | Frontiers in Sustainable Cities

TYPE Original Research
PUBLISHED 22 January 2025
DOI 10.3389/frsc.2024.1481932



OPEN ACCESS

EDITED BY
Gabriella Maselli,
University of Salerno, Italy

REVIEWED BY
Robert Home,
Anglia Ruskin University, United Kingdom
Maria Chiara Pastore,
Polytechnic University of Milan, Italy

*CORRESPONDENCE
Timothy O. Ogunbode
timothy.ogunbode@bowen.edu.ng

RECEIVED 16 August 2024
ACCEPTED 16 December 2024
PUBLISHED 22 January 2025

CITATION
Ogunbode TO, Oyebamiji VO, Sanni DO, Akinwale EO and Akinluyi FO (2025) Environmental impacts of urban growth and land use changes in tropical cities.
*Front. Sustain. Cities* 6:1481932.
doi: 10.3389/frsc.2024.1481932



# Environmental impacts of urban growth and land use changes in tropical cities

Timothy O. Ogunbode[1]*, Victor O. Oyebamiji[2], David O. Sanni[3], Emmanuel O. Akinwale[3] and Francis O. Akinluyi[3]

[1]Environmental Management Programme, College of Agriculture, Engineering and Science, Bowen University, Iwo, Nigeria, [2]Department of Geography, Obafemi Awolowo University, Ife, Nigeria, [3]Surveying and Geoinformatics Programme, College of Environmental Sciences, Bowen University, Iwo, Nigeria

Urban centers across the globe are undergoing rapid land use changes due to population growth, economic development, and urbanization. These changes have a profound impact on environmental dynamics and urban livelihoods. This study investigates land use changes and their environmental implications on urban livelihoods in Iwo, Nigeria. The research explores the patterns and drivers of land use changes over the past four decades and evaluates their effects on environmental quality and urban livelihoods. A combination of remote sensing and survey methods was employed. Landsat images from 1982 to 2023 were analyzed using supervised classification techniques to map changes in land cover categories such as built-up areas, vegetation, farmland, bare land, and water bodies. Additionally, a survey was conducted with 550 residents, selected through simple random sampling, to identify the key drivers of urban expansion from the residents' perspectives. Descriptive analysis revealed that most respondents had lived in Iwo for over 30 years, with many engaged in farming, trading, and civil service. Factor analysis was used to identify significant variables driving urban growth. The results indicate a substantial increase in built-up areas, from 9.30 $km^2$ in 1982 to 30.69 $km^2$ in 2023, alongside a significant decrease in vegetation cover. Farmland area showed an increasing trend, while bare land decreased. Key drivers of urban growth identified include religious activities, availability of land resources, small-scale businesses, government initiatives, and educational institutions. The environmental implications include deforestation, reduced green spaces, increased surface runoff, and pollution, which affect air quality, water resources, and biodiversity. This study highlights the importance of sustainable urban planning to balance growth with environmental preservation and social equity. The implementation of green infrastructure, effective waste management, and comprehensive urban planning policies is crucial to enhancing resilience and quality of life in Iwo.

KEYWORDS

**land use changes, urban expansion, environmental implications, urban livelihood, Iwo (Nigeria)**

## Introduction

A sustainable environment is crucial for meaningful development (Moallemi et al., 2020; Adedeji, 2023). Recognizing this, the United Nations (UN) has included sustainable cities as a key target within the 17 Sustainable Development Goals (SDGs), specifically in SDG 11. SDG 11 aims to make cities inclusive, safe, resilient, and sustainable, addressing the challenges

posed by rapid urbanization, particularly in developing countries. In these regions, the growing demand for land for industrial, residential, commercial, educational, and agricultural purposes has often resulted in degraded urban quality (Ogunbode and Oyebamiji, 2022; Zhou et al., 2024). Effective land management is essential to ensure access to adequate housing, basic services, sustainable transport systems, and inclusive urbanization (Bah et al., 2018; Fouad and Abbas, 2021; Adedibu, 2023). Moreover, protecting cultural and natural heritage and minimizing environmental impacts are also key components of effective land management (Wang and Zhang, 2024). This includes the implementation of green infrastructure, the enhancement of public transportation, the safeguarding of natural resources, and the promotion of inclusive participation in urban development. Addressing these issues can drive economic growth, create jobs, and improve services while mitigating the negative impacts of urbanization (Aram et al., 2019; Giliberto and Labadi, 2021).

The demand for land for various purposes, such as industrial, residential, commercial, educational, and agricultural developments, has led to complex challenges, particularly in developing countries where urban quality has been compromised (Fouad and Abbas, 2021; Atisa and Racelis, 2022). The allocation of land for essential human activities and its timely execution is crucial for sustaining urban livelihoods (Aram et al., 2019; Abdulai et al., 2022; Gao et al., 2023). Urban centers worldwide are experiencing rapid land use changes driven by population growth, economic development, and urbanization, which significantly impact environmental dynamics and the livelihoods of urban residents (Nuissl and Siedentop, 2021; Patra et al., 2018; Rana and Sarkar, 2021; Zhou et al., 2024). In developing countries like Nigeria, land use changes present both challenges and opportunities (Wu et al., 2011; Izakovičová et al., 2017; Nuissl and Siedentop, 2021).

Urbanization in Nigeria often leads to significant land use changes (Aliyu and Amadu, 2017; Onilude and Vaz, 2020). Essien (2023) and Aram et al. (2019) highlight that agricultural lands, forests, and open spaces are frequently converted into residential, commercial, and industrial areas to accommodate growing urban populations and stimulate economic activities (Fasona et al., 2018; Herrmann et al., 2020). In Iwo, these changes are evident as the city expands and modernizes, with traditional land use patterns being replaced by increased built-up areas and reduced green spaces. This conversion of land for urban purposes has led to a proliferation of residential buildings and shopping centers. However, this rapid urbanization brings consequences such as threats to food security due to reduced agricultural land and environmental degradation, including impacts on air quality, water resources, and biodiversity.

Urban expansion drives a wide array of land use changes. Residential areas have proliferated, often in a haphazard manner without comprehensive urban planning in developing countries (Marondedze and Schütt, 2019; Li C. et al., 2022; Li G. et al., 2022; Li Y. et al., 2022). Commercial establishments, ranging from small shops to larger markets, have spread across many cities in response to growing demand (Tomeldan et al., 2014; Nuissl and Siedentop, 2021; Tong et al., 2022). Although industrial activities are less prominent, they are emerging and contributing to the economic landscape of cities. However, the environmental consequences of land use changes are significant and multifaceted (Zuo et al., 2022). Deforestation and the loss of green spaces are among the most visible impacts (Fasona et al., 2018). As urban areas encroach on previously forested land, the ecological balance is disrupted, leading to a decline in biodiversity (Li C. et al., 2022; Li G. et al., 2022; Li Y. et al., 2022; Xie et al., 2024). The reduction of green spaces also exacerbates the urban heat island effect, making the city hotter and less comfortable, particularly during peak temperatures (Murtinová et al., 2022; Zhou et al., 2023).

Water resources in Iwo have also been impacted. The increase in impervious surfaces, such as roads and buildings, has led to higher surface runoff (Kim et al., 2016; Li C. et al., 2022; Li G. et al., 2022; Li Y. et al., 2022; Ogunbode and Oyebamiji, 2022). This has contributed to more frequent and severe flooding, posing risks to both property and lives. Additionally, water bodies in and around many cities have become increasingly polluted due to industrial discharges and inadequate waste management systems, further straining water supplies (McGrane, 2016; Li et al., 2021). Air quality has similarly deteriorated because of urbanization (Liang and Gong, 2020). The rise in vehicular emissions, industrial activities, and the use of generators due to unreliable power supply has led to higher levels of air pollutants (Zhou et al., 2018; Guo et al., 2020; Ganguly et al., 2021), which pose serious health risks to residents, contributing to various health challenges such as respiratory and cardiovascular diseases (Ganguly et al., 2021). These changes in land use also have profound socio-economic implications for Iwo's residents. On the one hand, urbanization can drive economic growth, create jobs, and improve access to services and infrastructure. On the other hand, it can also lead to increased inequality and displacement.

Addressing the environmental and socio-economic challenges associated with land use changes in Iwo requires comprehensive and forward-thinking urban planning and policy interventions. Sustainable urban development must balance growth with environmental preservation and social equity. This includes implementing green infrastructure, such as parks and urban forests, to mitigate the urban heat island effect and improve air quality, and establishing effective waste management systems to reduce pollution and protect water resources.

Osun State, the focus of this research, is renowned for its polycentric urban structure, distinguishing it from many other states in Nigeria. According to Olabamiji and Ajala (2024), Osun state does not have a single dominant urban center; instead, it features several mid-sized towns that collectively define its urban landscape. Key urban centers such as Ile-Ife, Ilesa, Ijebu-Jesha, Ede, Ikirun, Iwo, Ikire, and Osogbo (the state capital) each play significant roles in the state's socio-economic and cultural development. The creation of Osun State has further transformed these towns through the establishment of government offices, educational institutions, and other public infrastructure aimed at promoting balanced development across the state, rather than concentrating resources solely in Osogbo (Oladehinde et al., 2019). This decentralized approach makes the research particularly relevant and timely, as it addresses the dynamics of urban development and governance in a state with a uniquely dispersed urban system.

Over the past 30 years, Iwo has experienced significant growth due to various developmental initiatives. In the first instance is the establishment of the Osun State Agricultural Development Programme headquarters (OSSADEP) in the town. Also, the establishment and ongoing expansion of Bowen University, a private institution under the Nigerian Baptist Convention, has played a crucial role in this transformation. The university has attracted a diverse population to the town, including staff, researchers, business owners, and contractors. Additionally, the increased activity in the five-day periodic Odo-Ori

market has contributed to the town's rising population, drawing buyers and sellers from nearby cities and communities such as Osogbo, Ibadan, Ejigbo, Ede, Lagos, Ife-Odan, Lalupon, and Bode-osi (Ogunbode et al., 2022). The opening of the Federal College of Education in Iwo in 2022 is expected to further fuel the town's growth as the institution expands in terms of student and staff numbers. Other factors contributing to Iwo's urban growth include the rise in the number of primary and secondary schools and various business ventures, which have attracted people from neighboring communities. This ongoing expansion is anticipated to encroach on different urban land uses, affecting local resources and human livelihoods.

This research focuses on the patterns and drivers of land use changes in Iwo and their impact on environmental quality and the well-being of the town's residents. By examining the relationship between land use changes and their environmental consequences, the study is expected to offer insights for sustainable urban planning and policy-making to improve resilience and quality of life in urban centers like Iwo. The aim of the research is to examine environmental impacts of urban growth and land use changes in the tropical city of Iwo, Nigeria. Specific objectives are to: (i) analyze the patterns of land use changes in Iwo over the past two decades; (ii) identify the key drivers of land use changes in Iwo based on the perceptions of its inhabitants over the past four decades; and (iii) assess the impact of land use changes on urban quality and their potential effects on urban livelihoods.

## Theoretical basis for the investigation

Urbanization is a multifaceted process influenced by various theoretical frameworks that explain the patterns of spatial development, socio-economic dynamics, and environmental impacts in expanding cities. This research on land use changes and their environmental implications in Iwo, Nigeria, leverages several key theories and frameworks to provide a holistic understanding of the city's development and its sustainability challenges.

To begin with, the study draws on urbanization theories, including Burgess' Concentric Zone Model (Singh, 2022; Carcia, 2024). This model offers a perspective on how cities expand outward from their centers, forming distinct zones with varying land use patterns (McManamay et al., 2024). In Iwo's context, these models help analyze the evolution of the city's spatial structure, shaped by factors like population growth, economic activities, and infrastructure development. The Concentric Zone Model, for example, describes a series of concentric rings emanating from the central business district, each representing different socio-economic functions. Applying this model to Iwo allows for an exploration of the core-periphery dynamics and the impact of urban growth on land use changes. Additionally, the Urban Transition Theory provides a broader context for understanding urbanization processes in developing countries like Nigeria (Fox et al., 2018; McManamay et al., 2024). This theory suggests that cities undergo predictable stages of growth and transformation as they transition from agrarian to industrial and service-based economies (Jian et al., 2022; Natarajan et al., 2022). For Iwo, a city undergoing rapid urbanization, this theory frames its development stages, marked by shifting demographics, changing economic activities, and evolving land use patterns.

The research also incorporates concepts from land use change theory to examine the economic, social, and environmental drivers that contribute to shifts in land cover within Iwo (Gupta et al., 2020; Troian et al., 2021). The Land Use Transition Theory for instance, explains how rural landscapes transform into urbanized areas, driven by factors such as population growth, agricultural practices, and infrastructure development (Feike et al., 2015; Surya et al., 2020; Jellason et al., 2021). By applying this theory, the study aims to identify and analyze specific land use changes over time—from agricultural to residential, commercial, and other uses—and their implications for environmental sustainability (Mahtta et al., 2022; Leal and Marques, 2022). Environmental impact assessment frameworks are also crucial in this study for understanding the effects of urbanization and land use changes on the natural environment and community well-being. The DPSIR (Driving forces-Pressures-State-Impact-Response) framework, widely used in environmental assessments, offers a structured approach to analyzing how human activities exert pressures on the environment, leading to changes in environmental quality and socio-economic impacts (Jellason et al., 2021). Applying the DPSIR framework to Iwo helps identify key environmental pressures, such as deforestation, soil degradation, and pollution, and their socio-economic consequences for local communities (Long, 2022). Moreover, concepts like the Environmental Kuznets Curve (EKC) and the Sustainable Livelihoods Framework (SLF) provide insights into the relationship between economic development, environmental quality, and livelihood outcomes in urban areas (Leal and Marques, 2022; Long et al., 2021). The EKC suggests that environmental degradation initially worsens with economic growth but eventually improves as societies reach higher income levels and prioritize environmental protection. In Iwo, where rapid economic development accompanies urbanization, this theory helps anticipate environmental challenges and opportunities for sustainable development (Natarajan et al., 2022).

The SLF offers a comprehensive approach to understanding how urbanization and land use changes impact livelihood strategies and resilience among local communities. By examining how changes in land use affect access to natural resources, employment opportunities, and social capital in Iwo, this research aims to identify pathways for promoting sustainable livelihoods and enhancing community well-being amidst urban growth.

By integrating these theoretical frameworks and environmental concepts, this research seeks to provide a thorough analysis of the dynamics of urbanization, land use change, and environmental management in Iwo, Nigeria. It emphasizes the need for sustainable urban planning practices that balance economic development with environmental conservation and social equity, ultimately fostering resilient and livable cities for current and future generations.

# Method of study

## Study area

This study was conducted in Iwo Township, located at coordinates 7°38'N and 4°11'E, covering an area of 245 km$^2$ (Figure 1). Iwo serves as the administrative center of the Iwo Local Government Area (LGA) in Osun State, Southwestern Nigeria. The town has experienced a significant population increase in recent years, which has put a strain on the Aiba reservoir, the primary water source, making it increasingly difficult to meet the water demands of the growing population. According to the National Population Commission (NPC), Iwo's population was 191,348 in

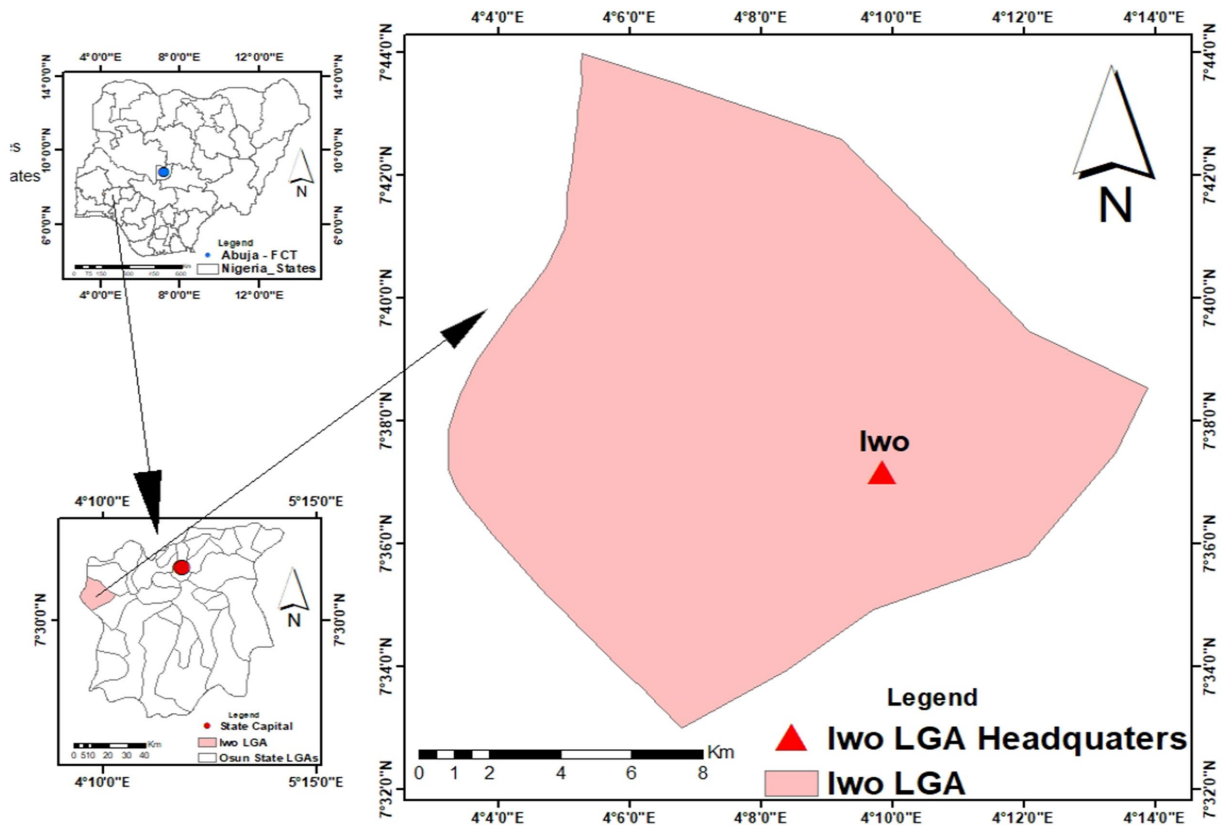


FIGURE 1
Map of Iwo in Osun state, Nigeria.

2006, with an annual growth rate of 2.6%. By 2012, this number had risen to 223,206, and by 2018, it had reached 262,817. The population growth in Iwo is driven not only by natural increase but also by key factors such as the establishment of Bowen University in 2002 and the growing popularity of Odo-Ori Market, both of which have attracted people from nearby cities, rural areas, and new settlers. Abanyam et al. (2020) highlighted the correlation between educational institutions and economic development over time and space, reinforcing the significant role Bowen University has played in Iwo's growth. Bowen University has emerged as a key catalyst for development in Iwo, spurring the growth of allied businesses and entrepreneurial ventures that have transformed the town into a significant regional hub. In addition, the Odo-Ori Market has become a major driver of Iwo's economic expansion. The market attracts a diverse range of buyers and sellers from major cities such as Ibadan, Osogbo, Ejigbo, Ogbomoso, and Oyo, as well as surrounding rural communities. It is renowned for its large-scale trade in agricultural products including yam, maize, plantain, yam flour, garri, palm oil, and more, further solidifying its role as a vital economic center in the region. In addition rural–urban migration has further contributed to Iwo's expansion. Migrants from neighboring rural communities, such as Bode-Osi, Ife-Odan, Obamoro, Telemu, and Ogbaagba, have increasingly settled in Iwo, making it their new home. This influx has accelerated urbanization, reshaping the town's socio-economic landscape and enhancing its status as a growing urban center.

The rapid urbanization resulting from this population boom has led to the development of the town's outskirts, increasing the demand for housing and infrastructure. However, the existing piped water network from the Aiba dam has not kept pace with this expansion, leaving many of the newly developed areas without access to piped water. As a result, a significant portion of Iwo's residents now rely on groundwater sources to meet their household water needs, using dug wells, deep boreholes, and motorized boreholes provided by individuals, religious organizations, philanthropists, and various government bodies. This reliance on groundwater is further influenced by the region's tropical climate, which experiences about 8 months of rainfall annually, from March to October (Figure 1).

## Data collection and analysis

Landsat images were obtained from the medium-resolution satellite data available at [USGS Earth Explorer][1] for the period between 1982 and 2023. For the years 1982 to 2002, Landsat TM (Thematic Mapper) and ETM (Enhanced Thematic Mapper) images were used, specifically employing bands 2 (green), 3 (red), and 4 (near-infrared) to create false color composite maps in ArcMap. For the Landsat 8/9 OLI (Operational Land Imager) data, bands 3 (green), 4 (red), and 5 (near-infrared) were utilized to generate similar false color composites. These maps were then used to select training samples representing different land cover types, such as built-up areas, vegetation, farmland, bare land, and water bodies,

1 https://earthexplorer.usgs.gov/

using a supervised classification technique. This process involved manually identifying features on the images and selecting corresponding training samples, which were then used for image classification. After classification, the images were reclassified and converted into polygons, enabling the calculation of the area covered by each land cover category. These areas were determined annually following the conversion process.

To identify the driving forces behind Iwo's urban expansion, a survey was conducted with 550 respondents in the town. The town was divided into four sections based on the two major roads: the Gbongan-Iwo-Oyo road and the Ibadan-Adeeke (Iwo)-Odo-Ori (Iwo)-Ife-Odan road. This division was intended to ensure comprehensive coverage of the town, rather than being based on population distribution. Respondents were selected using a simple random sampling method, with the criteria that they be at least 40 years old and long-term residents of Iwo. The age criterion was set to ensure that respondents had sufficient knowledge of the town's growth and development. However, potential biases were noted, such as respondents falsely claiming to have observed the town's trends despite having lived elsewhere or allowing others to complete the survey on their behalf. Falsification of age also posed a risk of bias in the survey results.

## Questionnaire content and administration

The questionnaire was divided into two sections. The first section gathered demographic data, including age, street name, length of residence in Iwo, and occupation. The second section featured a table with four columns: *Serial Number*, Va*riable Name*, and response options (*Strongly Agree*, *Agree*, *Disagree*, and *Strongly Disagree*) for each variable. Respondents were also encouraged to suggest additional factors they believed were relevant but not listed.

The survey was conducted over a 4-week period with the support of four fieldworkers, who operated during both morning and evening hours. This schedule was designed to accommodate respondents, primarily farmers and traders, by visiting them either in the mornings before they left for their farms or markets, or in the evenings after they returned home.

Participation in the survey was limited to residents who had lived in Iwo for a minimum of 30 years, as this was deemed a sufficient period to provide meaningful insights into the town's growth and expansion trends. The survey locations varied based on the convenience of willing respondents, ensuring flexibility and maximizing participation.

## Scope and limitations

While this study primarily focuses on the Aiba Dam in Iwo, Nigeria, its methodologies and findings can be applied to similar environments facing human encroachment globally. However, the study faced limitations such as data availability, scale considerations, and the need for continuous monitoring to validate long-term sustainability recommendations. Addressing human encroachment around dam areas is vital for ensuring water security, ecological balance, and sustainable development. By employing GIS techniques, this research offers valuable insights into the complex interactions between human activities and dam sustainability, promoting environmental stewardship and resilience in water resource management. Dams are not only engineering achievements but also complex socio-environmental systems that require a balanced approach to address their purposes, challenges, and sustainability. Sustainable dam management practices must integrate ecological conservation, community engagement, technological innovation, and governance reforms to optimize water resource utilization, minimize environmental impacts, and enhance resilience to climate change in the 21st century. Collaborative efforts among governments, stakeholders, and civil society are crucial for achieving water security, ecosystem integrity, and social well-being in regions affected by dams worldwide.

# Results

## Changes in land use pattern between 1982 and 2023 in Iwo

Figures 2–5 display the shifts in land use patterns in Iwo over a 51-year period, broken down by decade, with a summary provided in Table 1. Unfortunately, the land use data for 1992 could not be retrieved, but efforts were made to obtain data for 2023 to reflect the most current land use status in the study area. A close analysis of Table 1 reveals a consistent increase in urban expansion throughout the study period. In 1982, the built-up area occupied 9.30 km$^2$, which represented 3.10% of Iwo's total area of 299.64 km$^2$. A decade later, this increased by 0.42%, and by 2012, urban expansion had risen by 2.34%, reaching 5.86% of the total area. This growth marks a nearly 49% increase compared to 1982. By 2023, built-up areas had expanded to 30.69 km$^2$, or about 4.38% of the total area, reflecting a significant growth of 7.14% over the four decades studied.

Vegetation cover in Iwo, as shown in Table 1, has been on a downward trend over the study period. In 1982, 55.79% (167.16 km$^2$) of the total land area was covered by vegetation, which decreased to 48.24% (144.55 km$^2$) by 2002. By 2012 and 2023, vegetation cover had

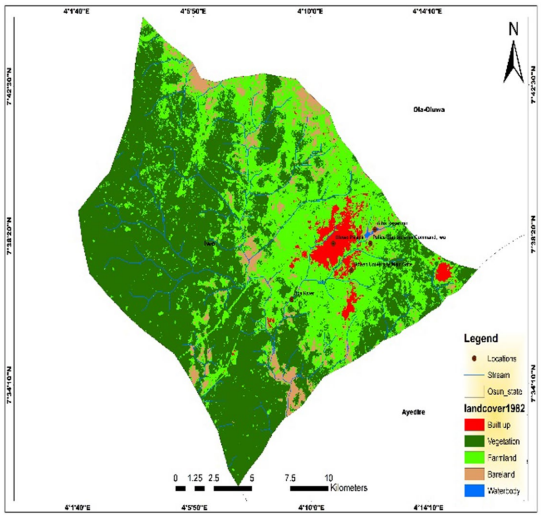


FIGURE 2
Changes in Land use as at 1982.

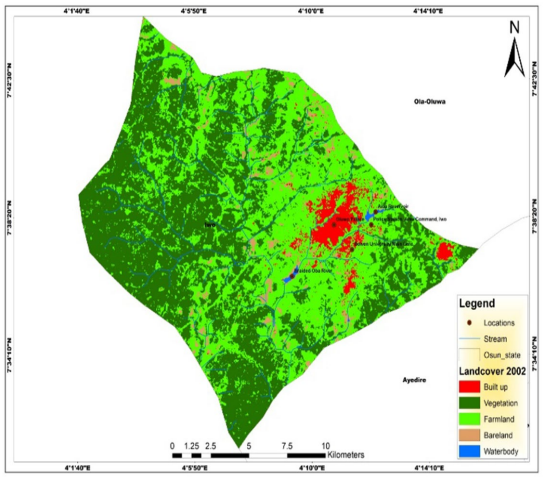


FIGURE 3
Changes in Land use as at 2002.

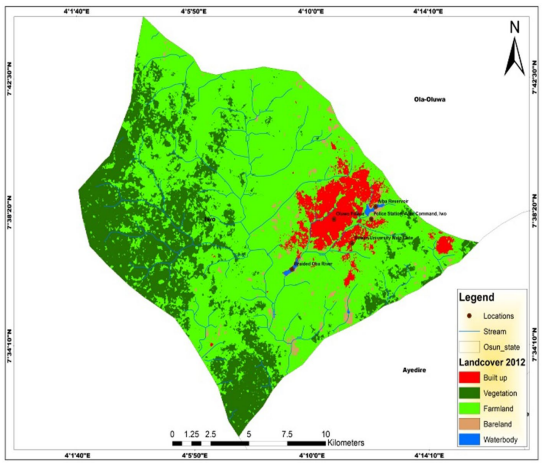


FIGURE 4
Changes in Land use as at 2012.

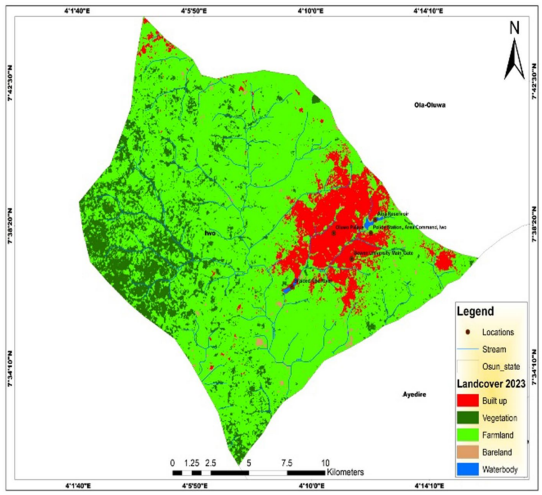


FIGURE 5
Changes in Land use as at 2023.

further reduced to 77.05 km$^2$ and 41.76 km$^2$, respectively. This sharp decline, particularly noticeable in the last decade, indicates a drastic reduction of 41.85% (125.4 km$^2$) from the initial coverage, likely due to deforestation driven by urbanization, agricultural expansion, and other developmental activities.

The area dedicated to farmland has shown an upward trend over the four decades studied, starting at 105.63 km$^2$ (35.25% of the total area) in 1982 and expanding to 224.45 km$^2$ by 2023, representing a 39.66% increase in land area coverage. In contrast, bare land has seen a decline over the study period, shrinking from 5.50% (17.39 km$^2$) in 1982 to 0.74% (2.23 km$^2$) by 2023, making it the most heavily utilized land use type by the end of the period studied. The proportion of water bodies in the study area increased until the last decade ending in 2023, when it slightly declined. In 1982, water features covered 0.05% (0.16 km$^2$) of the area, rising to 0.21% (0.62 km$^2$) by 2012, before decreasing to 0.17% (0.50 km$^2$) by 2023.

## Exploring Iwo growth driving factors from residents' perspectives

### Basic demographic attributes of the respondents

Table 2 presents a summary of the respondents' key characteristics, showcasing a range of diversity in terms of gender, education, length of residency in Iwo, age, occupation, and religious affiliation. The majority of respondents are male (63.2%), a result that is incidental and not tied to the study's design. Additionally, 66.2% of the participants have attained education beyond the primary level. To streamline the survey process, respondents who were able to read and comprehend the questionnaire were chosen, provided they met the other participation criteria. Notably, 95.8% of respondents have lived in Iwo for more than 30 years, and 96.9% are aged 40 or older. The respondents represent a variety of occupations: 45.6% are involved in farming, 20.4% in trading, 17.1% work in civil service, and the remaining 16.7% are engaged in occupations such as commercial transportation, ironworking, vehicle repair, bricklaying, and butchery. Religious affiliation was also considered to reduce bias, with 42% identifying as Christian, 41.3% as Muslim, and 2.9% as traditionalists. There was no data provided for the remaining 13.8%. Potential sources of bias in the survey include possible misreporting of age and length of residency, the exclusion of individuals unable to read or understand the questionnaire, and religious affiliation, which could affect the data on education, occupation, and religious representation.

A detailed analysis was conducted to identify the key factors driving the growth of Iwo from the perspective of its residents. The dataset underwent a factorability test, which confirmed its suitability for factor analysis (FA), with a KMO value of 69.97%, significant at $p < 0.005$. The FA process revealed five significant variables that

TABLE 1 Changes in land use in Iwo between 1982 and 2023.

| Land use type | 1982 | | 2002 | | 2012 | | 2023 | |
|---|---|---|---|---|---|---|---|---|
| | $Km^2$ | % | $Km^2$ | % | $Km^2$ | % | $Km^2$ | % |
| Built up | 9.30 | 3.10 | 10.54 | 3.52 | 17.55 | 5.86 | 30.68 | 10.24 |
| Vegetation | 167.16 | 55.79 | 144.55 | 48.24 | 77.05 | 25.71 | 41.76 | 13.94 |
| Farmland | 105.63 | 35.25 | 135.75 | 45.30 | 199.82 | 66.69 | 224.45 | 74.91 |
| Bare land | 17.39 | 5.80 | 8.24 | 2.75 | 4.60 | 1.54 | 2.23 | 0.74 |
| Waterbody | 0.16 | 0.05 | 0.55 | 0.18 | 0.62 | 0.21 | 0.50 | 0.17 |

TABLE 2 Some demographic attributes of the respondents.

| Categorization | | Distribution | |
|---|---|---|---|
| Category no | Attributes | Sample size | % of total in the category |
| A | Gender distribution | | |
| | Male | 347 | 63.2 |
| | Female | 203 | 36.8 |
| B | Level of education | | |
| | Post-secondary | 207 | 37.5 |
| | Post-primary | 304 | 66.2 |
| | No formal education | 40 | 7.3 |
| C | Length of stay | | |
| | >50 years | 247 | 44.9 |
| | 41–50 years | 198 | 36.0 |
| | 31–40 years | 82 | 14.9 |
| | Null | 23 | 4.2 |
| D | Age distribution | | |
| | >59 years | 243 | 44.2 |
| | 50–59 years | 127 | 23.1 |
| | 40–49 years | 163 | 29.6 |
| | 30–39 years | 17 | 3.1 |
| E | Occupational distribution | | |
| | Farming | 252 | 45.8 |
| | Trading | 112 | 20.4 |
| | Civil servants | 94 | 17.1 |
| | Others | 92 | 16.7 |
| F | Religious affiliations | | |
| | Christianity | 231 | 42.0 |
| | Islam | 227 | 41.3 |
| | Traditional | 16 | 2.9 |
| | Null | 76 | 13.8 |

contributed notably to the town's growth, out of the 11 variables analyzed. These 11 variables included: (i) small-scale businesses, (ii) livestock keeping, (iii) Bowen University, (iv) periodic markets, (v) religious activities, (vi) government activities, (vii) an increase in both primary and secondary schools, (viii) favorable weather, (ix) federal institutions, (x) availability of land resources, and (xi) improvements in social infrastructure.

## Urban growth drivers from the residents' perspectives

The data collected from the questionnaire survey underwent Factor Analysis (FA) to identify key factors influencing urban growth in Iwo, as perceived by the residents. Initially, the dataset was assessed using the Kaiser-Meyer-Olkin (KMO) measure and Bartlett's test to determine its suitability for FA. The results indicated

TABLE 3 Extracted variables and their respective features.

| S/No | Variable name | RCM | Eigen value | % variance | % cumulative variance |
|---|---|---|---|---|---|
| 1 | Religious activities | 85.6 | 2.502 | 20.847 | 20.847 |
| 2 | Availability of land resources | 84.4 | 2.048 | 17.064 | 37.911 |
| 3 | Small scale businesses | 89.8 | 1.964 | 16.364 | 54.275 |
| 4 | Government activities | 80.2 | 1.825 | 15.209 | 69.483 |
| 5 | Tertiary institutions (Bowen University) | 87.9 | 1.697 | 14.144 | 83.627 |

RCM, rotated component matrix.

a KMO value of 69.7%, which was statistically significant at $p < 0.005$, confirming the dataset's appropriateness for the analysis. FA then identified and extracted five significant factors out of the 11 variables analyzed. The summary of these results is presented in Table 3.

## Results

Factor analysis (FA) identified five key variables that significantly contribute to the growth of Iwo township. These variables, listed by their respective weights as shown in Table 1, are: (i) Religious activities; (ii) Availability of land for development; (iii) Growth of small and medium-sized enterprises (SMEs); (iv) Government initiatives in urban development; and (v) Expansion of educational institutions. Collectively, these variables account for 83.527% of the total factors driving urban growth in Iwo during the study period.

The most influential variable, which explains roughly one-quarter of the overall impact, is religious activities. This factor has an eigenvalue of 2.602, contributing 20.847% to the total explanation. The next significant factor is the availability of land for development, with an eigenvalue of 2.048, accounting for 17.084% of the total. Following closely is the increase in SMEs, ranked third with an eigenvalue of 1.964, representing 16.364% of the total. Government involvement in urban development ranks fourth, with an eigenvalue of 1.825 and a contribution of 15.209%. The final variable, the growth of educational institutions, has the smallest eigenvalue of 1.697 and contributes 14.144% to the overall explanation of Iwo's urban growth.

A detailed examination reveals that religious activities stand out among the five factors. The percentage difference between this and the next variable is significant at 18.146%. In contrast, the percentage differences between subsequent variables are 4.102, 7.077, and 7.014%, respectively. These variations are further explored in the Discussion section.

## Discussion

The identification and prioritization of religious activities as the most significant factor highlights the crucial role that religious groups, particularly Christian and Islamic communities, have played in the growth of Iwo township. Often referred to as a stronghold of Islam in Yorubaland, southwestern Nigeria, Iwo is known for its widespread Islamic faith, with mosques present throughout the town. However, the religious landscape began to shift in the 1970s with the arrival and expansion of Christianity, leading to the establishment of numerous churches, including Catholic, Baptist, Anglican, and Pentecostal denominations. Educational institutions founded by religious groups, such as Baptist High School and Bowen University, have also contributed significantly to the town's growth. This finding aligns with research by Odunola et al. (2021) and Ogunbode and Oyekan (2023), who emphasize the impact of religious organizations on urban development in southwestern Nigeria.

The availability of land for development, as highlighted by the FA, is supported by the town's extensive arable land, suitable for agriculture and urban expansion. Iwo covers an area of 264.94 $km^2$, primarily composed of lowland terrain, which facilitates agricultural activities and urban growth. This has attracted both individuals and businesses, contributing to the town's expansion. The presence of fertile land has also led to the settlement of agricultural produce buyers, further stimulating economic development. These findings are consistent with research by Owolabi (2018), who noted the influence of agricultural land on the development of cities like Ibadan, Ondo, and Akure. The growth of small and medium-sized enterprises (SMEs), particularly among the youth seeking sustainable livelihoods, has also played a significant role in Iwo's urban growth. SMEs are prevalent throughout the town, contributing to its economic vibrancy. This trend is supported by studies from Ogunbode et al. (2022) and Adeola and Aziakpono (2022), which highlight the importance of SMEs in the development of urban centers in developing countries.

Government intervention at various levels has further contributed to Iwo's growth, particularly through infrastructure development and the establishment of educational institutions. Notable examples include the Federal College of Education and state-funded road maintenance projects, which have attracted migrants and stimulated urban development. The role of government in urban growth is well-documented by Ayedun et al. (2011) and Farrell (2018), who emphasize the importance of infrastructure and social services in attracting people to urban centers.

Lastly, the expansion of educational institutions, both private and public, has been a significant driver of Iwo's growth. The establishment of Bowen University in 2002, in particular, has led to a marked increase in the town's population, attracting students, staff, and related businesses. This trend is consistent with findings from Turok and McGranahan (2013) and Adeniyi et al. (2021), who have

documented the role of educational institutions in the growth of cities across West Africa.

## Environmental implications of the findings

The growth of Iwo township, spurred by religious activities, educational institutions, the rise of small and medium-sized businesses, and government interventions, has considerable environmental consequences. As the town expands, changes in land use can lead to habitat destruction, a decrease in biodiversity, soil degradation, and disruptions in natural water cycles. Intensive agricultural practices may deplete soil nutrients and contaminate water sources, while increased waste generation and energy consumption contribute to pollution and higher greenhouse gas emissions. The surge in transportation needs can further deteriorate air quality, and the pace of urbanization may intensify issues of social and environmental inequality. To address these challenges, it is crucial to implement integrated urban planning and sustainable development strategies. This includes promoting green infrastructure, adopting sustainable agricultural practices, enhancing waste management, and developing affordable housing initiatives.

## Policy implications of the findings

The expansion of Iwo township calls for robust policy frameworks to guide sustainable development. Urban planning and zoning regulations should be enforced to manage land use effectively, preserve green spaces, and control urban sprawl. Environmental conservation policies must focus on protecting natural habitats, encouraging sustainable agriculture, and preventing water pollution. The development of efficient waste management systems and the promotion of renewable energy are essential to reducing pollution and minimizing greenhouse gas emissions. Improving public transportation infrastructure and promoting non-motorized transportation options can help alleviate traffic congestion and improve air quality. Policies should also aim to address social and environmental equity, ensuring that all communities benefit from urban growth and are shielded from environmental risks. Additionally, supporting educational institutions and fostering collaborations between the public and private sectors can drive sustainable development initiatives.

# Conclusion and recommendation

The study highlights the main drivers of growth in Iwo township, including religious activities, the availability of arable land, the expansion of small and medium-sized enterprises, government initiatives, and the presence of educational institutions. However, this growth brings about environmental challenges such as habitat destruction, pollution, water resource management issues, and concerns regarding social equity. To mitigate these impacts, it is recommended to adopt comprehensive urban planning and zoning regulations, promote environmental conservation through the establishment of protected areas and sustainable farming practices, and improve water resource management with techniques like rainwater harvesting and wastewater treatment. Enhancing waste management systems, adopting renewable energy sources, developing sustainable transportation options, and ensuring social and environmental equity are also vital. Furthermore, supporting educational institutions in integrating green practices and encouraging public-private partnerships for sustainable development are crucial for aligning growth with environmental sustainability and securing a healthy, thriving future for Iwo township and its inhabitants.

# Data availability statement

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author.

# Ethics statement

Ethical review and approval was not required for the study on human participants in accordance with the local legislation and institutional requirements. Written informed consent from the [patients/participants OR patients/participants legal guardian/next of kin] was not required to participate in this study in accordance with the national legislation and the institutional requirements.

# Author contributions

TO: Conceptualization, Data curation, Formal analysis, Methodology, Project administration, Resources, Supervision, Validation, Visualization, Writing – original draft, Writing – review & editing. VO: Formal Analysis, Investigation, Methodology, Project administration, Writing – original draft, Writing – review & editing. DS: Formal analysis, Investigation, Methodology, Software, Writing – original draft, Writing – review & editing. EA: Methodology, Project administration, Software, Writing – original draft, Writing – review & editing. FA: Conceptualization, Formal analysis, Investigation, Methodology, Validation, Writing – original draft, Writing – review & editing.

# Funding

The author(s) declare that no financial support was received for the research, authorship, and/or publication of this article.

# Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

## Publisher's note



## References

Abanyam, N. L., David, F., and Ibrahim, Y. D. (2020). The role of higher education in sustainable economic development in Nigeria: a functionalist theoretical perspective analysis. *Sapientia Global J. Arts Human. Develop. Stud.* 3, 276–284.

Abdulai, I. A., Ahmed, A., and Kuusaana, E. D. (2022). Secondary cities under siege: examining peri-urbanisation and farmer households' livelihood diversification practices in Ghana. *Heliyon* 8:e10540. doi: 10.1016/j.heliyon.2022.e10540

Adedeji, I. (2023). Nigerian urbanization and the significance of affordable housing. *J. Serv. Sci. Manag.* 16, 351–368. doi: 10.4236/jssm.2023.163020

Adedibu, B. A. (2023). Nigerian Pentecostal megachurches and development: a diaconal analysis of the redeemed Christian Church of god. *Religions* 14:70. doi: 10.3390/rel14010070

Adeniyi, O., Ajayi, P. I., and Adedeji, A. A. (2021). Education and inclusive growth in West Africa. *Journal of Economics and Development* 23, 163–183. doi: 10.1108/JED-04-2020-0036

Adeola, O. O., and Aziakpono, M. J. (2022). Unlocking the relationship between capital flows and economic growth in a small open economy of Kenya: an empirical investigation. *Cogent Econ. Finance* 10:2085608. doi: 10.1080/23322039.2022.2085608

Aliyu, A. A., and Amadu, L. (2017). Urbanization, cities, and health: the challenges to Nigeria - a review. *Ann. Afr. Med.* 16, 149–158. doi: 10.4103/aam.aam_1_17

Aram, F., Higueras García, E., Solgi, E., and Mansournia, S. (2019). Urban green space cooling effect in cities. *Heliyon* 5:e01339. doi: 10.1016/j.heliyon.2019.e01339

Atisa, G., and Racelis, A. E. (2022). Analysis of urbanization and climate change effects on community resilience in the Rio Grande Valley, South Texas. *Sustainability* 14:9049. doi: 10.3390/su14159049

Ayedun, C. A., Durodola, O. D., and Akinjare, O. A. (2011). Towards ensuring sustainable urban growth and development in Nigeria: challenges and strategies. *Business Manag. Dynamics* 1, 99–104.

Bah, E. M., Faye, I., and Geh, Z. F. (2018). "Unlocking land markets and infrastructure provision" in eds. E. M. Bah, I. Faye and Z. F. Geh Housing market dynamics in Africa (London: Palgrave Macmillan).

Carcia, D. (2024) Understanding burgess concentric zone model in urban geography. Sociomindscape. Available at: https://sociomindscape.com/burgess-concentric-zone-model-ap-human-geography/ (Accessed July 1, 2024)

Essien, E. (2023). Urban theories and urbanization perspectives in cities across Nigeria. *Environ. Res. Commun.* 5:085008. doi: 10.1088/2515-7620/acefb4

Farrell, K. (2018). An inquiry into the nature and causes of Nigeria's rapid urban transition. *Urban Forum* 29, 277–298. doi: 10.1007/s12132-018-9335-6

Fasona, M., Adeonipekun, P. A., Agboola, O., Akintuyi, A., Bello, A., Ogundipe, O., et al. (2018). "Drivers of deforestation and land-use change in Southwest Nigeria" in Handbook of climate change resilience. ed. W. Leal Filho (Cham: Springer).

Feike, T., Mamitimin, Y., Li, L., and Doluschitz, R. (2015). Development of agricultural land and water use and its driving forces along the Aksu and Tarim River, P.R. China. *Environ. Earth Sci.* 73, 517–531. doi: 10.1007/s12665-014-3108-x

Fouad, Z., and Abbas, S. S. (2021). The role of urban land management on the informal settlements. *Earth Environment. Sci.* 754:012014. doi: 10.1088/1755-1315/754/1/012014

Fox, S., Bloch, R., and Monroy, J. (2018). Understanding the dynamics of Nigeria's urban transition: a refutation of the 'stalled urbanisation' hypothesis. *Urban Stud.* 55, 947–964.

Ganguly, R., Sharma, D., and Kumar, P. (2021). Short-term impacts of air pollutants in three megacities of India during COVID-19 lockdown. *Environ. Dev. Sustain.* 23, 18204–18231. doi: 10.1007/s10668-021-01434-9

Gao, W., Lyu, W., and Liu, B. (2023). Integrating system spatial archetypes and archetypical evolutionary patterns of human settlements: towards place-based sustainable development. *Land* 12:2164. doi: 10.3390/land12122164

Giliberto, F., and Labadi, S. (2021). Harnessing cultural heritage for sustainable development: an analysis of three internationally funded projects in MENA countries. *Int. J. Herit. Stud.* 28, 133–146. doi: 10.1080/13527258.2021.1950026

Guo, Y., Zhang, Q., Lai, K. K., Zhang, Y., Wang, S., and Zhang, W. (2020). The impact of urban transportation infrastructure on air quality. *Sustain. For.* 12:5626. doi: 10.3390/su12145626

Gupta, J., Scholtens, J., Perch, L., Dankelman, I., Seager, J., Sánder, F., et al. (2020). (2020) re-imagining the driver–pressure–state–impact–response framework from an equity and inclusive development perspective. *Sustain. Sci.* 15, 503–520. doi: 10.1007/s11625-019-00708-6

Herrmann, S. M., Brandt, M., Rasmussen, K., and Fensholt, R. (2020). Accelerating land cover change in West Africa over four decades as population pressure increased. *Commun. Earth Environ.* 1:53. doi: 10.1038/s43247-020-00053-y

Izakovičová, Z., Mederly, P., and Petrovič, F. (2017). Long-term land use changes driven by urbanisation and their environmental effects (example of Trnava City, Slovakia). *Sustain. For.* 9:1553. doi: 10.3390/su9091553

Jellason, N. P., Robinson, E. J. Z., Chapman, A. S. A., Neina, D., Devenish, A. J. M., Po, J. Y. T., et al. (2021). Systematic review of drivers and constraints on agricultural expansion in sub-Saharan Africa. *Land* 10:332. doi: 10.3390/land10030332

Jian, L., Chuimin, K., Jijian, Z., Yusheng, K., and Ntarmah, A. (2022). The relationship between economic growth and environmental degradation: could west African countries benefit from EKC hypothesis? *Environ. Sci. Pollut. Res.* 29, 73052–73070. doi: 10.1007/s11356-022-21043-x

Kim, H., Hanseok, J., Jihye, J., and Seungjong, B. (2016). The impact of impervious surface on water quality and its threshold in Korea. *Water* 8:111. doi: 10.3390/w8040111

Leal, P. H., and Marques, A. C. (2022). The evolution of the environmental Kuznets curve hypothesis assessment: a literature review under a critical analysis perspective. *Heliyon* 8:e11521. doi: 10.1016/j.heliyon.2022.e11521

Li, G., Fang, C., Li, Y., Wang, Z., Sun, S., He, S., et al. (2022). Global impacts of future urban expansion on terrestrial vertebrate diversity. *Nat. Commun.* 13:1628. doi: 10.1038/s41467-022-29324-2

Li, Y., Li, J., and Chum, J. (2022). Research on land-use evolution and ecosystem services value response in mountainous counties based on the SD-PLUS model. *Ecol. Evol.* 10:e9431. doi: 10.1002/ece3.9431

Li, C., Lu, L., Fu, Z., Sun, R., Pan, L., Han, L., et al. (2022). Diverse cooling effects of green space on urban heat island in tropical megacities. *Front. Environ. Sci.* 10:1073914. doi: 10.3389/fenvs.2022.1073914

Li, L., Yu, Q., Gao, L., Yu, B., and Lu, Z. (2021). The effect of urban land-use change on runoff water quality: a case study in Hangzhou City. *Int. J. Environ. Res. Public Health* 18:10748. doi: 10.3390/ijerph182010748

Liang, L., and Gong, P. (2020). Urban and air pollution: a multi-city study of long-term effects of urban landscape patterns on air quality trends. *Sci. Rep.* 10:18618. doi: 10.1038/s41598-020-74524-9

Long, H. (2022). Theorizing land use transitions: a human geography perspective. *Habitat Int.* 128:102669. doi: 10.1016/j.habitatint.2022.102669

Long, H., Zhang, Y., Ma, L., and Tu, S. (2021). Land use transitions: Progress, challenges and prospects. *Land* 10:903. doi: 10.3390/land10090903

Mahtta, R., Fragkias, M., Güneralp, B., Mahendra, A., Reba, M., Wentz, E., et al. (2022). Urban land expansion: the role of population and economic growth for 300+ cities. *NPJ Urban Sustain* 2:5. doi: 10.1038/s42949-022-00048-y

Marondedze, A. K., and Schütt, B. (2019). Dynamics of land use and land cover changes in Harare, Zimbabwe: a case study on the linkage between drivers and the Axis of urban expansion. *Land* 8:155. doi: 10.3390/land8100155

McGrane, S. J. (2016). Impacts of urbanisation on hydrological and water quality dynamics, and urban water management: a review. *Hydrol. Sci. J.* 61, 2295–2311. doi: 10.1080/02626667.2015.1128084

McManamay, R. A., Vernon, C. R., Chen, M., Thompson, I., Khan, Z., and Narayan, K. (2024). (2024) dynamic urban land extensification is projected to lead to imbalances in the global land-carbon equilibrium. *Commun. Earth Environ.* 5:70. doi: 10.1038/s43247-024-01231-y

Moallemi, E. A., Malekpour, S., Hadjikakou, M., Raven, R., Szetey, K., Ningrum, D., et al. (2020). Achieving the sustainable development goals requires transdisciplinary innovation at the local scale. *One Earth* 3, 300–313. doi: 10.1016/j.oneear.2020.08.006

Murtinová, V., Igor, G., and Branislav, O. (2022). Mitigating effect of urban green spaces on surface urban Heat Island during summer period on an example of a medium size town of Zvolen, Slovakia. *Remote Sens.* 14:4492. doi: 10.3390/rs14184492

Natarajan, N., Newsham, A., Rigg, J., and Suhardiman, D. (2022). A sustainable livelihoods framework for the 21st century. *World Dev.* 155:105898. doi: 10.1016/j.worlddev.2022.105898

Nuissl, H., and Siedentop, S. (2021). "Urbanisation and land use change" in Sustainable land Management in a European Context. Human-environment interactions. eds. T. Weith, T. Barkmann, N. Gaasch, S. Rogga, C. Strauß and J. Zscheischler, vol. *8* (Cham: Springer).

Odunola, O. O., Odufuwa, B. O., Odunsi, O. M., and Morenikeji, T. O. (2021). Evaluation of locational and environmental effects of religious Centres on adjoining development in Ibadan, Nigeria. *LAUTECH J. Civil Environ. Stud.* 7, 76–87. doi: 10.36108/laujoces/1202.70.0180

Ogunbode, T. O., and Oyebamiji, V. O. (2022). Towards a Sustainable City environment: resolving the challenge of flooding in a growing Tropical City in Osun state, Nigeria- a review. *Aswan University J. Environ. Stud.* 3, 346–356. doi: 10.21608/aujes.2022.145259.1074

Ogunbode, T. O., and Oyekan, F. E. (2023). Religious practices and its impacts on a sustainable urban environment in Nigeria: the way forward. *Sci. World J.* 2023:8080235. doi: 10.1155/2023/8080235

Ogunbode, T. O., Oyelude, O., and Oyebamiji, V. O. (2022). Evaluation of the impacts of micro-business operations on the quality of urban environment: a case study of Iwo, southwestern Nigeria. *Front. Sustain. Cities.* 4:1027450. doi: 10.3389/frsc.2022.1027450

Ogunbode, T. O., Oyelude, O., and Oyebamiji, V. O. (2022). Impact of Home water provision burdens on Women educational attainment in Iwo, Nigeria, Bahria University. *J. Humanities. Soc. Sci* 5, 14–30.

Olabamiji, A., and Ajala, O. (2024). (2024) spatial suitability of urban land use models for poverty alleviation in the cities of Nigeria. *Discov. Sustain.* 5:374. doi: 10.1007/s43621-024-00579-7

Oladehinde, G. O., Fatusin, A. F., and Ojo, V. A. (2019). Urban expansion and loss of agricultural land in Osogbo, Osun state Nigeria, using multi-temporal imageries. *J. African Real Estate Res.* 4, 139–156. doi: 10.15641/jarer.v4i1.735

Onilude, O., and Vaz, E. (2020). Data analysis of land use change and urban and rural impacts in Lagos state, Nigeria. *Data* 5:72. doi: 10.3390/data5030072

Owolabi, B. O. (2018). Assessment of agricultural practices on residential land use in Ondo state, Nigeria. *Environ. Analysis Ecol. Stud.* 4, 386–399. doi: 10.31031/EAES.2018.04.000590

Patra, S., Sahoo, S., Mishra, P., and Mahapatra, S. C. (2018). Impacts of urbanization on land use/cover changes and its probable implications on local climate and groundwater level. *J. Urban Manag.* 7, 70–84. doi: 10.1016/j.jum.2018.04.006

Rana, M. S., and Sarkar, S. (2021). Prediction of urban expansion by using land cover change detection approach. *Heliyon* 7:e08437. doi: 10.1016/j.heliyon.2021.e08437

Singh, K. (2022) Concentric zone theory by E.W. Burgess. Available at: https://pangeography.com/concentric-zone-model-by-e-w-burgess/ (Accessed July 1, 2024)

Surya, B., Ahmad, D. N. A., Sakti, H. H., and Sahban, H. (2020). land use change, spatial interaction, and sustainable development in the metropolitan urban areas, South Sulawesi Province, Indonesia. *Land* 9:95. doi: 10.3390/land9030095

Tomeldan, M. V., Antonio, M., Arcenas, J., Beltran, K. M., and Cacalda, P. A. (2014). "Shared growth" urban renewal initiatives in Makati City, metro Manila, Philippines. *J. Urban Manag.* 3, 45–65. doi: 10.1016/S2226-5856(18)30083-9

Tong, D., Chu, J., Han, Q., and Liu, X. (2022). How land finance drives urban expansion under fiscal pressure: evidence from Chinese cities. *Land* 11:253. doi: 10.3390/land11020253

Troian, A., Gomes, M. C., Tiecher, T., Berbel, J., and Gutiérrez-Martín, C. (2021). The drivers-pressures-state-impact-response model to structure cause–effect relationships between agriculture and aquatic ecosystems. *Sustain. For.* 13:9365. doi: 10.3390/su13169365

Turok, I., and McGranahan, G. (2013). Urbanization and economic growth: the arguments and evidence for Africa and Asia. *Environ. Urban.* 25, 465–482. doi: 10.1177/0956247813490908

Wang, Y., and Zhang, J. (2024). Research on cultural diversity and sustainable land-use management assessment model. *Front. Environ. Sci.* 12:1359521. doi: 10.3389/fenvs.2024.1359521

Wu, Y., Zhang, X., and Shen, L. (2011). The impact of urbanization policy on land use change: a scenario analysis. *Cities* 28, 147–159. doi: 10.1016/j.cities.2010.11.002

Xie, H., Sun, Q., and Song, W. (2024). Exploring the ecological effects of rural land use changes: a bibliometric overview. *Land* 13:303. doi: 10.3390/land13030303

Zhou, X., Chu, Z., and Ji, X. (2024). Changes in the land-use landscape pattern and ecological network of Xuzhou planning area. *Sci. Rep.* 14:8854. doi: 10.1038/s41598-024-59572-9

Zhou, C., Li, S., and Wang, S. (2018). Examining the impacts of urban form on air pollution in developing countries: a case study of China's megacities. *Int. J. Environ. Res. Public Health* 15:1565. doi: 10.3390/ijerph15081565

Zhou, W., Yu, W., Zhang, Z., Cao, W., and Wu, T. (2023). How can urban green spaces be planned to mitigate urban heat island effect under different climatic backgrounds? A threshold-based perspective. *Sci. Total Environ.* 890:164422. doi: 10.1016/j.scitotenv.2023.164422

Zuo, Q., Zhou, Y., Wang, L., Li, Q., and Liu, J. (2022). Impacts of future land use changes on land use conflicts based on multiple scenarios in the central mountain region, China. *Ecol. Indic.* 137:108743. doi: 10.1016/j.ecolind.2022.108743