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Safeguarding rural-urban linkages: modeling drivers of peri-urban sprawl and impacts on ecosystem services

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Africa is experiencing unparalleled urbanization, with projections suggesting that by 2030, more than 50% of its inhabitants will live in urban areas. Uncontrolled spatial expansion threatens sustainability, especially in megacities like Lagos. Urban sprawl in peri-urban areas has led to the loss of valuable agricultural lands, food security risks, and breaking the link between rural and metropolitan regions. This study investigates the proximate factors driving urban sprawl on statutory agricultural lands in peri-urban areas of Lagos. An interdisciplinary methodology that employs remote sensing, land change analysis, field surveys, and structural equation modeling was adopted. The findings revealed that built-up areas in the Ikorodu municipality increased by 127% over 32 years, leading to fragmented and uncontrolled development in statutory agricultural zones. The structural equation modeling for 322 homeowners sampled shows a lack of policy awareness and weak development control as major underlying drivers, explaining 37% of peri-urban expansion. Also, declining per capita arable lands indicate risks to regional food self-sufficiency. A strategic land management approach is needed to leverage rural−urban linkages that safeguard food provisioning services and achieve resilient African megacities. Also, rapidly growing African cities should adopt spatial planning incorporating agroecological perspectives and collaborative governance of urban and rural lands for a sustainable future.

KEYWORDS

urban sprawl, peri-urban area, agricultural lands, fractal analysis, land cover change, structural equation modeling

1 Introduction

Urbanization is a worldwide trend that reshapes the twenty-first century's landscapes, economies, and communities. According to the United Nations (2018), by 2050, 68% of the world's population is projected to live in urban areas, with almost 90% of the growth occurring in Africa and Asia. Also, India, China, and Nigeria alone will account for 35% of the world's population growth between now and 2050. Nigeria will be the 3rd most populous country in the world, at par with the United States of America, with a population of 375 million (United Nations, 2018, 2022). However, the urbanization rate in these regions presents significant

global and local sustainability challenges (Bhatta, 2010; Seto et al., 2011; Verburg et al., 2013; van Vliet, 2019).
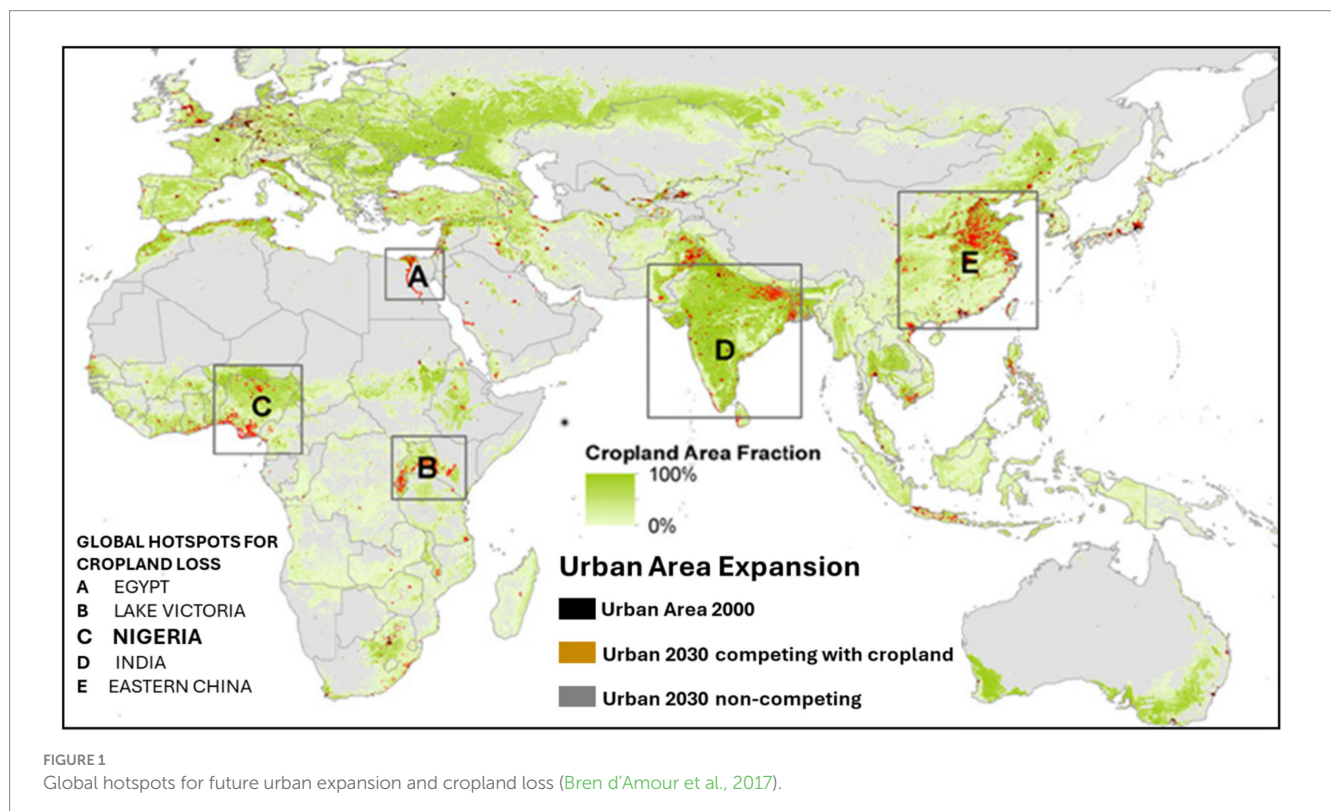
In African cities, the sustainability challenges come from the spatial expansion of cities related to informal land use, environmental degradation, loss of agricultural land, and diminution of forest and high-biodiversity wetlands (Lambin et al., 2001; Huang et al., 2020; Simkin et al., 2022). Furthermore, some researchers have linked these sustainability challenges in sub-Saharan African cities to a sprawling peri-urbanization process (Mbiba and Huchzermeyer, 2002; Agbola and Agunbiade, 2009; Cobbinah and Amoako, 2012; Amoateng et al., 2013; Areola et al., 2014). Sub-Saharan Africa's sustainability challenge of shrinking provisioning ecosystem services has been associated with converting farmlands and forest land to urban land uses in peri-urban areas (Appiah et al., 2014; Pullanikkatil et al., 2016) (see Figure 1).

Nigeria's rapid population growth and corresponding decline in agricultural lands pose substantial risks to urban development and food security. The World Development Indicator shows that Nigeria's total population grew from 49.9 million in 1965 to 208.3 million in 2020. However, arable land per person in Nigeria dwindled from 0.49 hectares in 1965 to 0.17 hectares in 2020, with a decline rate of approximately 2% (World Bank, 2024). This trend is greater than the global and sub-Saharan Africa (SSA) average, with decline rates of 1.15 and 1.88%, respectively. Agricultural land loss in PUAs of African cities could exceed 2% yearly (Lasisi et al., 2017; Coulibaly and Li, 2020; Molla et al., 2024), thus creating serious food security problems. According to land use policies and ineffective urban planning have exacerbated the loss of agricultural land in peri-urban areas of a rapidly growing megacity like Lagos.

The Lagos Megacity in Nigeria typifies the global urbanization trends. It is one of the world's fastest-growing cities, with a population exceeding 20 million. It typifies the complexities of the African city and its sustainability capabilities. Like some African cities, Lagos has sprawled into peri-urban areas, transforming agricultural and forest landscapes, thereby exerting pressure on available ecosystem services (Dekolo et al., 2015; van Vliet, 2019). In research investigating future urban expansion and the implications on global croplands, Bren d'Amour et al. (2017) identified the Lagos Megacity Region as one of the hotspots for rapid global cropland loss. The research predicted that by 2030, Nigeria would lose 2.1 Mha of its croplands to urban expansion, equivalent to 6% of the global croplands. Another study by Abiodun et al. (2017) predicts a 56% increase in urban expansion of the Lagos Megacity Region by 2030 due to rapid urban growth, implying more loss of agricultural land that provides ecosystem services. Another example is the PUA study of Greater Cairo, which investigated the impact of uncontrolled urban sprawl for 20 years, leading to agricultural land fragmentation and loss (Salem and Tsurusaki, 2024). Ecosystem services (ES) are natural benefits that directly or indirectly contribute to human well-being (Powledge, 2006; van Oudenhoven, 2015). Naeem et al. (2003) identified four types of ES; these include provisioning services (food, water, raw materials, medicinal resources), regulatory services (climate regulation, flood control, air, and water quality), cultural (tourism. Aesthetics, spiritual) and supporting services (biodiversity, soil formation). Due to continuous expansion into peri-urban areas in Lagos, these services are threatened, often leading to habitat degradation, biodiversity diminution, and agricultural land loss, thereby compromising the ability of these areas to provide essential ES (Braimoh and Onishi, 2007).

The need for promoting mutual interdependence between rural and urban areas, especially in peri-urban areas (PUAs) through linked ecosystem services, has been emphasized in literature (Feng et al., 2021; Gebre and Gebremedhin, 2019; Tacoli, 2003, 1998; Wu

FIGURE 1
Global hotspots for future urban expansion and cropland loss (Bren d'Amour et al., 2017).

et al., 2017). Also, previous studies have focused on quantifying peri-urban land use change and the effect of urban sprawl on agricultural land and ecosystem services. These studies have predominantly applied remote sensing spatial metrics to quantify the extent of change and the underlying drivers like the economy, population growth, urbanization, and agro-ecological factors (Ingwani et al., 2024; Molla et al., 2024). However, the proximate factors, such as behavior, perception, and socio-demographic inclinations, which are more elusive, have often been overlooked, especially in the Lagos context and other SSA countries. Understanding the complex relationships between human decisions and land use change requires robust models that transcend existing spatial and statistical models, which often do not account for these proximate factors in the form of latent variables. The study aims to fill this gap using Structural Equation Modelling (SEM) to understand the proximate drivers of urban sprawl on statutory agricultural lands in Lagos' PUA, Ikorodu.

This research aims to detect urban sprawl from land cover transitions in Ikorodu between 1984, 2000, and 2016 and to determine the proximate drivers of sprawl in agricultural lands by applying SEM. The longitudinal study was limited to 2016 because another subregional master plan will be operational from 2016 to 2036. The statutory agricultural lands were based on the Lagos State Regional Plan 1980–2000 and the revised edition effective till 2016. The study integrates geospatial techniques and field survey data to understand the urban expansion dynamics and motives that drive land use change decisions using SEM, thereby providing valuable insight for effective land resource planning and management in rapidly growing cities of Africa in comparable contexts. This study suggests the need for integrated urban planning approaches that contemplate both spatial and human dimensions of land use change decisions. The findings from this study inform policymakers on effective strategies for sustainable urban growth management in Lagos and contribute to the broader debate of sustainable development in rapidly growing cities.

2 Methodology

2.1 The study area: Ikorodu, Lagos State, Nigeria

Ikorodu is a municipality (Local Government Area) in the peri-urban area of Lagos, the fastest-growing megacity in sub-Saharan Africa. The study area is found at the northeastern fringe of the Lagos megacity, approximately 36 km Northeast of Lagos Central Business District, and lies between longitude 3.43°W and 3.7°W and latitude 6.68°N and 6.53°N. Ikorodu is approximately 396.5 square kilometers. The existence of perennial rivers and streams, abundant wetlands, and closeness to the Lagos Lagoon endeared the Lagos State Government to zone 66% of its landmass for agriculture, forestry, and conservation land uses in the 1980–2000 Lagos State Regional Plan. Ikorodu was predominantly rural, but the expansion of Lagos stimulated its growth into a significant secondary city (see Figure 2).

Historically, the primary livelihood sources of the locals are farming, fishing, and trading. Ikorodu recorded a 186% population increase between the 1991 and 2006 census years (i.e., from 184,674 to 527,917), and its present population estimate is over a million, ranking 13th among Nigeria's 20 largest urban agglomerations shown
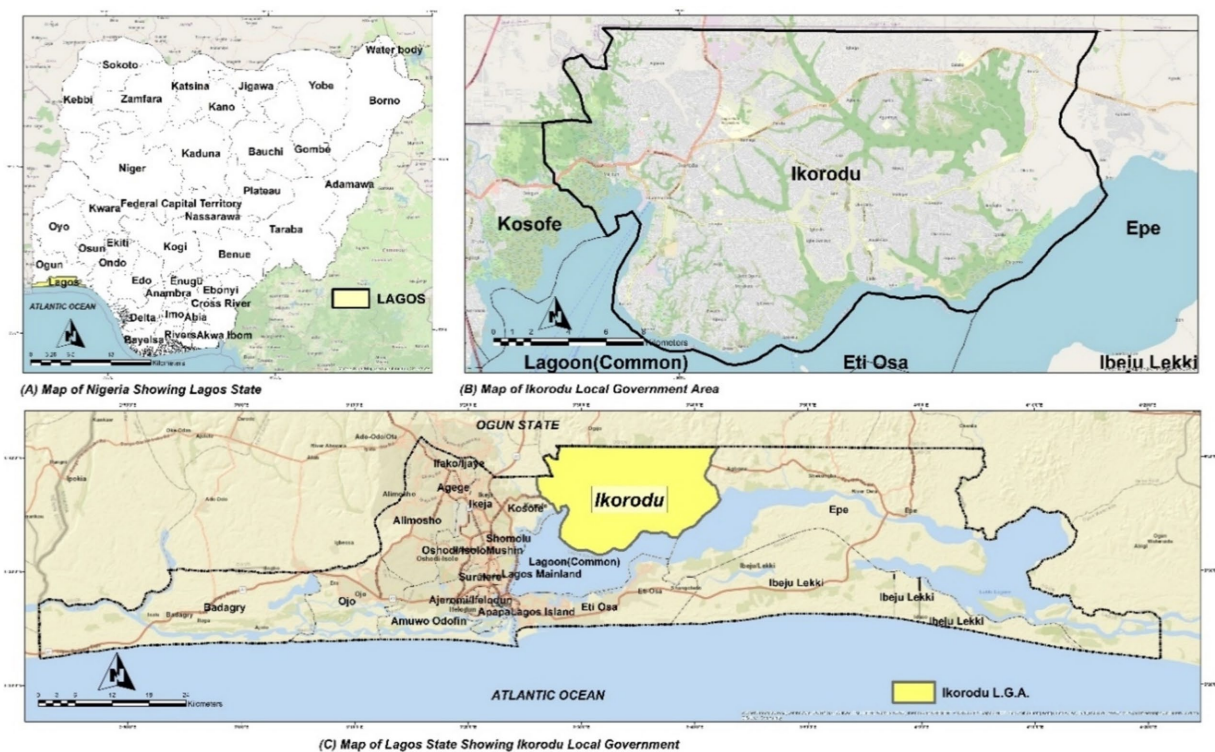

FIGURE 2
The study area: Ikorodu, Lagos, Nigeria.

in Table 1. Ikorodu has a light port and Nigeria's most significant industrial estate, with 1,582.27 hectares, attracting population growth.

2.2 Data collection and analysis

2.2.1 Land use and land cover change analysis

2.2.1.1 Spatial and temporal resolutions

The study utilized Landsat imagery from 1984, 2000, and 2016 to analyze land cover changes (see Table 2). These specific years aligned with significant policy changes and developmental milestones in Lagos State, where the state adopted a new master plan for the Ikorodu subregion in 2016. A 30 m spatial resolution was adopted for the study.

2.2.1.2 Classification process

Land cover classification was done using an unsupervised cluster algorithm and post-classification method. Geospatial analysis and modeling Software (i.e., ArcGIS 10.2.1 and Idrisi Terrset Modeling Software) were used for land change modeling. To simplify urban sprawl detection and land use change modeling in this research, urban/built-up, forested land, agricultural land, and water bodies created four classes of land cover. Level 1 of classes will produce change statistics, while level 2 will describe various land uses and land cover classes. Post-classification accuracy assessment was done using the Percentage Correct method by selecting 60 random GPS points across the entire study area, and clusters were compared with high-resolution imageries from Google Earth historical archives. The overall correctness of sampled points was 96% (see Table 3).

2.2.2 Fractal analysis for sprawl detection

Fractal analysis was used to assess the growth pattern. Few studies have used fractal analysis to measure sub-Saharan African urban sprawl (Bonsu and Bonin, 2023; Dekolo et al., 2015; Mundia and Murayama, 2010). Fractal analysis offers a quantitative sprawl measurement, distinguishing between dispersed and compact growth. Highly patchy built-up areas signify a sprawling pattern with few fractal dimensions, while compaction and regularity attract a higher figure (Frankhauser and Tannier, 2005; Tannier and Pumain, 2005). Urban areas for the three periods (1984, 2000, and 2016) were extracted from the land cover maps of Ikorodu using a Boolean operation, and rasters were analyzed with Fractalyse Software (version 2.4.1) to measure the fractal dimension. The results from the fractal analysis were interpreted in the context of the land use policies and implications, linking sprawl patterns to potential impacts on ecosystem services.

2.2.3 Ecosystem service assessment

The study focuses on the provisioning services of agricultural land, that is, the ability of the agricultural landscape to supply food, thereby evaluating how land use and land cover changes affect the capacity for providing a critical ES like food. By correlating land cover changes with population growth, the study assesses the sustainability of local food production and the broader implications for food security in a rapidly urbanizing area. This method differs from previous economic valuation-based approaches used in ES existing research in sub-Saharan Africa (Nelson et al., 2010; Egoh et al., 2012; Adekola et al., 2015). The challenges of applying economic valuation in ES assessment in sub-Saharan Africa include a lack of consistency

TABLE 1 Population of Nigeria's 20 largest cities (1990−2035) in thousands ('000).

	1990	1995	2000	2005	2010	2015	2020	2025	2030	2035
Lagos	4,764	5,983	7,281	8,859	0441	2,239	4,368	17,156	20,600	24,419
Kano	2095	2,339	2,602	2,895	3,221	3,583	3,999	4,645	5,551	6,579
Ibadan	1739	1993	2,236	2,509	2,814	3,157	3,552	4,144	4,956	5,874
Abuja	330	526	833	1,316	1814	2,442	3,278	4,210	5,119	6,071
Port harcourt	680	845	1,091	1,407	1816	2,344	3,020	3,794	4,595	5,449
Benin City	689	845	975	1,124	1,296	1,495	1727	2045	2,451	2,906
Onitsha	337	418	533	681	869	1,109	1,415	1767	2,138	2,536
Uyo	194	261	350	470	631	848	1,136	1,457	1771	2,101
Kaduna	785	832	881	933	988	1,046	1,113	1,260	1,499	1776
Aba	484	551	630	721	825	943	1,081	1,275	1,527	1810
Nnewi	160	219	300	411	562	770	1,051	1,362	1,659	1967
Ilorin	515	572	633	700	774	856	950	1,100	1,314	1,557
Ikorodu	**174**	**226**	**300**	**399**	**531**	**706**	**938**	**1,197**	**1,454**	**1,724**
Jos	493	547	604	666	734	809	895	1,035	1,236	1,465
Owerri	266	324	395	482	587	716	873	1,064	1,282	1,520
Warri	184	238	307	397	513	663	856	1,076	1,304	1,546
Maiduguri	499	538	580	625	674	727	786	899	1,071	1,269
Umuahia	136	181	243	324	434	580	774	990	1,204	1,427
Enugu	363	412	467	529	600	680	773	907	1,085	1,286
Zaria	592	625	643	662	682	702	726	810	961	1,138

Bold text highlights the study area, Ikorodu.

TABLE 2 Data sources.

Acquisition date	Satellite number	Sensor type	WRS path/row	UTM zone	Datum	Spatial resolution	Sources & year
26/12/2016	Landsat 8	OLI_TIRS	191/55	31 N	WGS84	30 M	USGS, 2016
06/02/2000	Landsat 7	ETM+	191/55	31 N	WGS84	30 M	USGS, 2000
18/12/1984	Landsat 5	TM	191/55	31 N	WGS84	30 M	USGS, 1984
Supporting spatial data/demographic data							
05/1963	Lagos map (1:250,000) NB 31–7, edition 1-AMS						Texas University Library
1980	The Lagos State regional plan (1980–2000)						Doxiadis associates
2006	Ikonos 1 m resolution imagery						LAMATA-LASG
1963–2006	National population census 1963, 1991, 2006						NPC 1991, 2006
17/10/2011	ASTER global digital elevation model (ASGDEMV2_0N06E002)						NASA/METI, 2011

TABLE 3 Land use land cover classification.

Level 1	Level 2 (description)
1. Urban or built-up land	Residential, commercial, industrial, institutional, transportation/communication/utilities, mixed uses
2. Agricultural land	Cropland, grazing, agricultural tree crop plantation, arable crop plantation
3. Forest land	Riparian forest, forest plantation, disturbed forest, mangrove forest, forested freshwater swamp, non-forested freshwater swamp
4. Water bodies	Ocean, rivers and streams, lakes, bays and estuaries, ponds

in the following datasets: prices per hectare, yield per hectare, measurements, exchange rates, and diverse socioeconomic value systems. The non-monetary approaches can overcome some of the challenges identified above (Burkhard et al., 2009; Verburg et al., 2009; Wolff et al., 2015; Haas and Ban, 2017).

In this case study, the effect of urban sprawl on the ES potentials of the PUAs surrounding Ikorodu town emerged by associating the SPUs and SBAs in the three periods (1984, 2000, and 2016). Agricultural landscapes are SPUs supplying food to urban areas, which are SBAs. SPU-SBA relationship may be in-situ, omnidirectional, directional, or decoupled (Burkhard et al., 2014). The United Nations Food and Agricultural Organisation specifies 2,360 Kcal/capita/day as sub-Saharan Africa's total food consumption requirement per capita per day in 2015 (Alexandratos and Bruinsma, 2012). The minimum land required per capita for a diversified diet is obtained in North America and Europe at 0.5 hectares. However, the global average is between 0.2 and 0.25 hectares, while the absolute minimum is 0.07 hectares (Myers, 1999; Goswami and Nishad, 2017). The study examines the relationship between the ES demanded by relating the population and food density with the spatial capacity of the agricultural land to supply per capita dietary requirements of the SBAs. This approach aims to uncover the intricate dynamics of urban sprawl in the study area and its implications for provisioning ES.

2.2.4 Field survey and data analysis

2.2.4.1 Questionnaire design

A structured questionnaire was developed to capture homeowners' perceptions, motivations for residential development in agricultural land, and land use and policy awareness levels. Additionally, the tool gathered socioeconomic data, such as income levels, migration patterns, and household size, which were incorporated to contextualize

the changes observed in land cover. Data was collected to determine the proximate drivers of homeowners' development decisions in PUAs.

2.2.4.2 Sampling technique

A stratified random sampling technique was adopted to ensure representation across different neighborhoods. Three hundred eighty-five owners of residential properties across 75 neighborhoods in the 6 Local Council Development Areas (LCDAs) of Ikorodu Municipality were given questionnaires with an overall response rate of 83.07% (see Table 4). Based on the building footprint count of 139,694 residential properties extracted from high-resolution satellite imageries in the study area, 383 was the recommended sample size, with a confidence level of 95% and a margin of error of 5% (see Figure 3).

2.2.4.3 Sample size suitability

The suitability of the data and sample size was examined by the use of the Kaiser-Meyer-Olkin Measure of Sample Adequacy (KMO) and Bartlett's test of sphericity, in which the KMO result obtained was 0.767, and Bartlett's significance value is 0. This result confirms the suitability of the data and sample size used for factor analysis (for adequate data, the KMO must be 0.6 minimum, and Bartlett's significance value must be 0.5 or less).

2.2.4.4 Data analysis

Responses to the field survey were analyzed using statistical software (Statistical Package for Social Sciences, SPSS) and AMOS to identify correlations and key drivers influencing land use decisions.

2.2.4.5 Exploratory factor analysis

EFA was employed as an initial step to reduce the dimensionality of the data and extract the key drivers of decisions for residential development in agricultural and forested lands. Principal Component Analysis (PCA) with varimax rotation was used to identify

TABLE 4 Sample size and ratio for local council development areas in Ikorodu.

LCDA	Size of LCDA (SQ. KM.)	Urban extents (SQ. KM.)	No. of neighborhoods/ density types	Enumeration areas (neighborhoods)	Sample size and no. of distributed questionnaires per LCDA	Response rate per LCDA (% of sample)
Ikorodu central	86.14 (17.89%)	32.43 (23.43%)	15 high/medium	Aga, Ijomu, Ikorodu, Isele, Ita-Elewa, Itamaga, Ladega, Lowa, Solomade, Benson, Eruwen, GRA, Mowo Kekere, Agunfoye 1, Agbele	80 (20.89%)	52 (65%)
Ikorodu north	58.48 (15.87%)	22.00 (16.03%)	22 high/medium	Ladegboye, Iseolu, Aribila, Ajebo, Idera, Adamo, Akaun, Agodo, Isiwu, Itunmaja, Ita Oluwo, Ita Oloja, Idafa, Odogunya, Odo Nla, Odo Kekere, Parafa, Maya, Laketu, Lambo- Lasuwon	76 (19.84%)	75 (98.68%)
Ikorodu west	61.01 (16.56%)	30.37 (22.13%)	10 high/medium	Okokoro, Ori-okuta, Agbede, Eyita, Ita-oluwo, Orimedu, Ebute, Isawo, Ogolonto, Owutu, Ajose	76 (19.84%)	73 (96.05%)
Igbogbo- Baiyeku	69.79 (18.92%)	35.09 (25.57%)	12 high/medium	Baiyeku, Ewu Elesin, Ibeshe, Oreta, Igbe, Igbogbo, Ijomu, Ofin, Balefun, Shoboliye, Olumo, Omotoro, Ajebo	76 (19.84%)	54 (71.05%)
Imota	86.14 (23.38%)	6.07 (4.43%)	6 medium/low	Imota, Isiwu, Gbokuta Oke-Odo, Oke-Agbo, Ojagemo	45 (11.65%)	39 (86.65%)
Ijede	27.20 (7.38%)	11.28 (8.22%)	10 low	Gberigbe, Ijede, Ewu-Elepe, Oke Eletu, Igbopa, Morekete, Igbalu, Oreyo, Ajebo, Agura	30 (7.83%)	29 (96.67%)
Ikorodu L.G.A.	368.51 (100%)	137.24 (100%)	75	75 out of 102 Residential Neighborhoods (74%)	383 (100%)	322 (84.07%)

FIGURE 3
(A) Map of Ikorodu municipality showing neighborhoods (source: Lagos map), sheet NB 31–7 (1963); (B) satellite imagery of Ikorodu showing six (6) LCDAs and sampled neighborhoods.
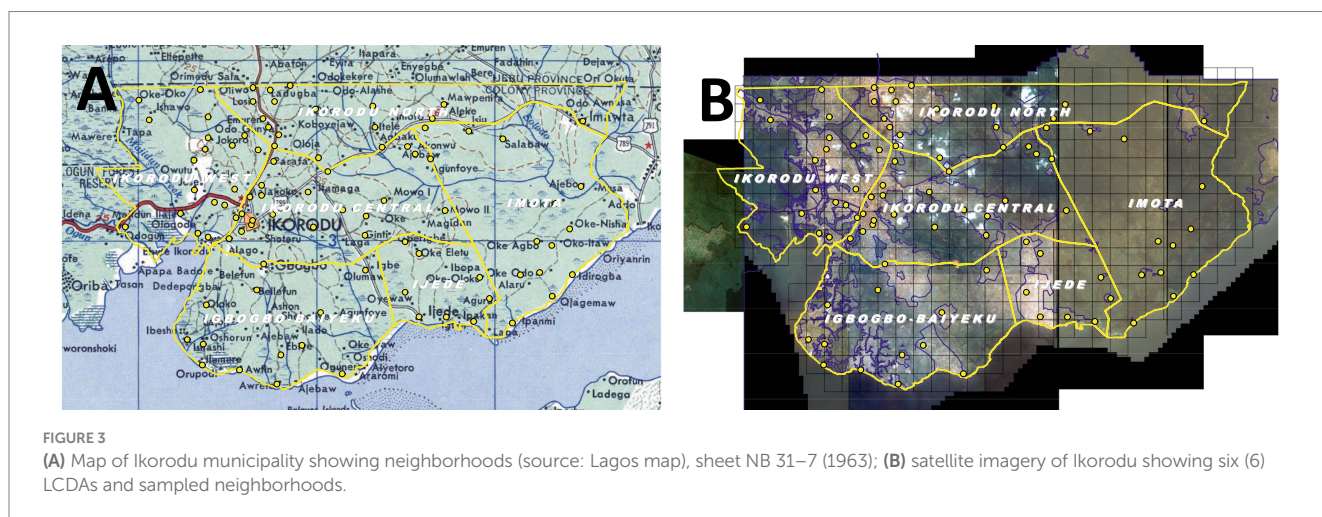
components or factors with eigenvalues exceeding 1.0, based on an initial pool of 50 variables from the questionnaire. Sixteen (16) factors initially accounted for 67.21% of the total variability in the data. However, the selection of the final components was guided by both statistical and theoretical considerations. A parallel analysis using Monte Carlo Simulation Software and a scree plot indicated that eight (8) components provided a more robust and interpretable solution. These eight components explained 63.69% of the total variance in the data, focusing on the 29 variables with factor loadings of 0.4 or higher (see Table 5). The decision to enforce eight components aligns with

TABLE 5 Exploratory factor analysis result showing total variance explained.

Component	Initial eigenvalues			Extraction sum of squared loadings			Rotation sum of squared loadings		
	Total	% of variance	Cumulative %	Total	% of variance	Cumulative %	Total	% of variance	Cumulative %
1	4.294	14.806	14.806	4.294	14.806	14.806	3.625	12.501	12.501
2	3.720	12.826	27.632	3.720	12.826	27.632	3.347	11.542	24.043
3	2.488	8.580	36.212	2.488	8.580	36.212	2.581	8.902	32.945
4	2.349	8.101	44.313	2.349	8.101	44.313	2.154	7.428	40.373
5	1.590	5.483	49.796	1.590	5.483	49.796	2.050	7.070	47.443
6	1.449	4.995	54.791	1.449	4.995	54.791	1.777	6.128	53.571
7	1.369	4.721	59.512	1.369	4.721	59.512	1.518	5.233	58.804
8	1.212	4.179	63.692	1.212	4.179	63.692	1.417	4.888	63.692
9	0.938	3.233	66.925						
10	0.917	3.161	70.086						
11	0.827	2.853	72.939						
12	0.807	2.783	75.722						
13	0.744	2.567	78.289						
14	0.694	2.392	80.681						
15	0.636	2.194	82.875						
16	0.604	2.083	84.959						
17	0.555	1.913	86.872						
18	0.540	1.863	88.735						
19	0.482	1.661	90.396						
20	0.455	1.569	91.965						
21	0.416	1.436	93.401						
22	0.375	1.292	94.693						
23	0.365	1.260	95.952						
24	0.359	1.237	97.189						
25	0.276	0.952	98.141						
26	0.255	0.880	99.021						
27	0.118	0.408	99.429						
28	0.096	0.333	99.762						
29	0.069	0.238	100.000						

Extraction method: principal component analysis.

theoretical constructs and domain relevance, ensuring the retained factors meaningfully represent the drivers of residential development.

2.2.4.6 Confirmatory factor analysis

The variable with the highest loadings was used in a CFA using SPSS Amos (version 23) to determine the relationships between the various variables that drive residential development on agricultural land use zones. A close assessment of the Rotated Component Matrix in the Table 6 indicates a cluster of variables with similarity in each of the eight (8) components or factors. These components are intangible or unobserved variables known as "latent variables" on which the theoretical constructs and hypothesis are hinged (e.g., Policy Awareness is a latent variable for indicators like awareness of Building Permits, Regional Plan 1980, etc.).

The role of the CFA is to measure the relationship between each variable in the model if they are consistent with existing theoretical models. Each component was named according to the dominant variables consistent with the theoretical constructs. The path model in Figure 4 shows the correlation estimates between each latent variable (in curved lines with arrows on each end) and Regression estimates between the latent and observed variables (unidirectional arrows).

2.2.4.7 Structural equation modelling

SEM was applied to determine the drivers of residential development in Ikorodu's agricultural and forest lands. While previous studies depended on statistical and econometric models to explain drivers of land use change, these models were limited in handling complex endogenous and exogenous variables associated with land use decisions. This limitation has motivated the application of SEMs in

TABLE 6 Rotated component matrix.

Variables	Components							
	1	2	3	4	5	6	7	8
Awareness of regional plan (1980)	0.842							
Awareness of building permit regulations	0.805							
Awareness of URP law (1992)	0.804							
Awareness of Lagos metro. Master plan (1980)	0.798							
Awareness of land policy (1980)	0.767							
Awareness of land use act (1978)	0.523							
Distance to work		0.947						
Transport cost to work		0.945						
Average time spent to work		0.923						
Work in Ikorodu		−0.767						
If born in Lagos State			0.926					
Lagos is state of origin			0.924					
If Indigene of Ikorodu			0.784					
Good health and less stress than in the Lagos city				0.789				
Lower cost of living than city				0.732				
Closeness to leisure and nature				0.637				
Affordable land				0.571				
Site access to transport infrastructure					0.766			
Adequate security of life and property					0.670			
Security of land tenure					0.652			
Proximity of site to urban infrastructure					0.636			
Lived in lagos metro before Ikorodu						−0.788		
Move from Ikorodu LGA						0.784		
If you have tenants						0.503		
Served contravention notice							0.838	
Inspection by planning agency							0.765	
Obtained by inheritance								0.727
Proximity to family and friends								0.677
Age of house owner								0.481

Extraction method: principal component analysis. Rotation method: varimax with Kaiser normalisation.

determining the drivers of agricultural land conversion in recent times (Azadi et al., 2015). SEM, or covariance structure analysis, is a statistical technique to quantitatively assess cause-effect relationships among variables. SEM measures the relationships between observed variables and unobserved (latent variables) and the relationship between latent variables (Hair et al., 2021). Latent variables are research constructs or abstractions, which may be impossible to directly measure but observed (e.g., Ethnic prejudice, travel behavior, user perceptions, etc.). SEM was applied using SPSS Amos version 23 Software. SEM requires five essential steps: model specification, identification, model estimation, model fitting, and interpretation of estimates. Lastly, model re-specification is used if it is poor or reporting is good (Teo et al., 2013; Kline, 2016). Based on the result of the CFA, the SEM developed for the study has one (1) dependent manifest variable (Y), eight exogenous independent latent variables (Z), and 29 endogenous independent manifest variables (X) (see Table 7).

2.2.5 Model specification

The "Model of Residential Growth" developed by Chapin and Weiss (1968) was modified for this research as follows:

$$\gamma = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \ldots\ldots\beta_n X_n + \varepsilon \qquad (1)$$

Using the model above, the dependent variable (γ) is *land use change from agricultural and forest land to residential,* and the explanatory variables $(X_1, X_2, X_3\ldots X_n)$ are factors responsible for change (e.g., proximate factors like socio-demographic, work-travel, etc.,) and regression coefficients are β, while the residual or random error term is ε. The multivariate regression model in Equation 1 is consistent with the structural level of the SEM in which the latent variable Z predicts the observed dependent variable Y. Moreover, $(Z_{1\ldots8})$ are the mediating variables between the observed $(X_{1\ldots29})$ and the dependent variable (Y).

FIGURE 4
Path model of the confirmatory factor analysis (CFA).
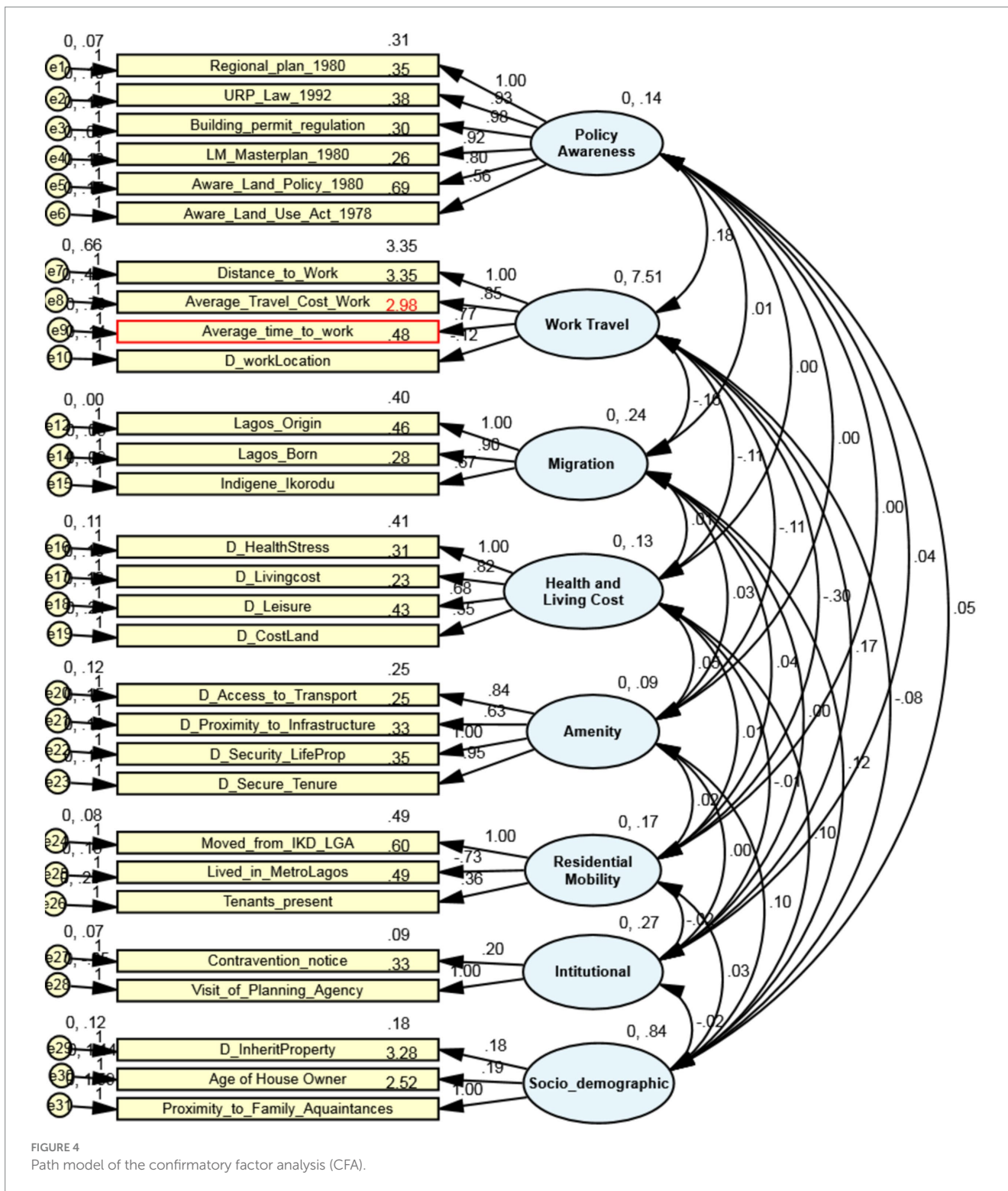
The residential growth model was adapted for this research as follows: Structural model:

$$y_i = \beta_0 + \beta_1 Z_{1i} + \beta_2 Z_{2i} + \beta_3 Z_{3i} + \ldots + \beta_p Z_{pi} + \varepsilon_i \quad (2)$$

Where, y = Residential Development in Agro-ecological Zone, β = coefficient of regression of Z predicting y, Z_1 = Policy Awareness, Z_2 = Work Travel, Z_3 = Migration, Z_4 = Health and Living Cost,

Z_5 = Amenity, Z_6 = Residential Mobility, Z_7 = Development Control, Z_8 = Socio-demographic

$$y_i = \beta_0 + \beta_1\left(\text{Policy Awareness}\right) + \beta_2\left(\text{Work Travel}\right) + \\ \beta_3\left(\text{Migration}\right) + \beta_4\left(\text{Health and Living Cost}\right) + \\ \beta_5\left(\text{Amenities}\right) + \beta_6\left(\text{Residential Mobility}\right) + \\ \beta_7\left(\text{Development Control}\right) + \beta_8\left(\text{Socio} - \text{Demographic}\right) + \varepsilon_i$$

$X_{1.0.29}$	Independent (observed) variables	Independent (latent) variables (Z_{1-8})	Dependent (observed) variable (Y)
1	Awareness of regional plan (1980)	Policy Awareness (Aware_1)	Residential Development in Agriculture Land Use Zone (ResDev_AgricZone)
2	Awareness of building permit regulations		
3	Awareness of URP law (1992)		
4	Awareness of Lagos metro. Master plan (1980)		
5	Awareness of land policy (1980)		
6	Awareness of land use act (1978)		
7	Transport cost to work	Work Travel (Travel_2)	
8	Distance to work		
9	Travel time to work		
10	Work in Ikorodu		
11	Lagos as state of origin	Migration (Migrate_3)	
12	If born in Lagos State		
13	If indigene of Ikorodu		
14	Good health and less stress than Lagos	Health and cost of living (Living_4)	
15	Lower cost of living than city		
16	Closeness to leisure and nature		
17	Affordable land		
18	Site access to transport infrastructure	Amenity (Infra_5)	
19	Security of land tenure		
20	Adequate security of life and property		
21	Proximity of site to urban infrastructure		
22	Lived in Lagos before Ikorodu	Migration (ResMobile_6)	
23	Move from Ikorodu LGA		
24	If you have tenants		
25	Served contravention notice	Development control (LUControl_7)	
26	Inspection by planning agency		
27	Age of house owner	Socio-demographic (Social_8)	
28	Obtained by inheritance		
29	Proximity to family and friends		

Measurement model:

$$Z_{1j} = \lambda_0 + \lambda_1 x_{1j} + \lambda_2 x_{2j} + \lambda_3 x_{3j} + \ldots + \lambda_p x_{pj} + e_{1j} \qquad (3)$$

Hence, the new structural equation model for residential development in the agricultural and forested land is proposed as follows:

$$y = X\beta + \varepsilon \qquad (4)$$

Where:

y = (n x 1) matrix or column vector of cases or sample size ($n = 322$).

X = (n x p) matrix, where p is the total number of observed variables ($p = 29$).

β = (p x 1) matrix of unknown parameters (coefficient) to be estimated.

ε = (nx1) matrix of residual or error.

$$y = \begin{bmatrix} y_1 \\ \vdots \\ y_n \end{bmatrix} X = \begin{bmatrix} x_{1,1} & \cdots & x_{1,p} \\ \vdots & \ddots & \vdots \\ x_{n,1} & \cdots & x_{n,p} \end{bmatrix} \beta = \begin{bmatrix} \beta_1 \\ \vdots \\ \beta_p \end{bmatrix} \varepsilon = \begin{bmatrix} \varepsilon_1 \\ \vdots \\ \varepsilon_n \end{bmatrix}$$

On model identification, the SEM model is over-identified, with 30 endogenous variables and 38 exogenous variables, totaling 68 parameters. It has positive degrees of freedom ($df = 370$), which is the measure for identification. Moreover, its Chi-Square test shows it is statistically significant ($X^2 = 552.351$, $p = 0.000$). Therefore, the model is suitable for hypothesis testing.

2.2.6 Model fitting and summary

The validity of the structural equation model (SEM) was assessed using a combination of global fit indices; while the Chi-Square test

TABLE 8 Model fit statistics.

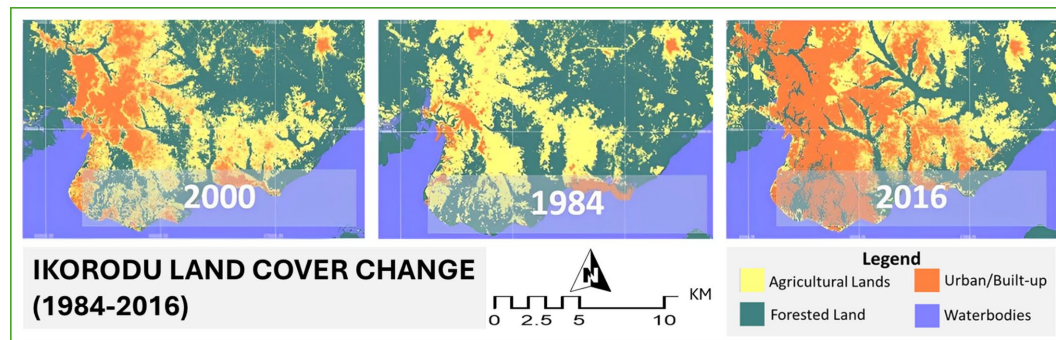| Global fit statistics	Acceptable range	Estimated value
Chi-square goodness of fit (X^2/df)	Acceptable <3 (N > 200)	1.49
Root mean square error of approximation (RMSEA)	Acceptable RMSEA <0.10 Good RMSEA <0.05	0.04
Non-significant Chi square value = X^2	$p > 0.05$	0.00
Normed fit index (NFI)	NFI >0.90	0.87
Comparative fix index (CFI)	CFI >0.90	0.95

Source: Azadi et al. (2015) and Kline (2016).

FIGURE 5
Ikorodu land cover change (1984–2016).

statistic ($X^2 = 552.351$, $p = 0.000$) indicates statistical significance, it is acknowledged that large sample sizes ($n = 322$) can inflate the Chi-Square value, potentially overestimating poor fit (Kline, 2016). Therefore, additional fit indices were employed to provide a more comprehensive evaluation of the model's goodness of fit, as shown in Table 8.

The model satisfies the five commonly recommended fit criteria. The ratio of the Chi-Square statistics to degrees of freedom (1.49) is below the recommended threshold of 3, indicating an acceptable fit for large sample sizes. Root Mean Square Error of Approximation (RMSEA) value of 0.04 is within the "good fit" range (<0.05). Although the p-value is 0.00, which is statistically significant, this is expected given the sample size and does not necessarily indicate poor model fit. Normed Fit Index (NFI) of 0.87, while slightly below the threshold of 0.90, is close to the acceptable range and consistent with other fit indices. A comparative Fit Index (CFI) value of 0.95 exceeds the recommended threshold of 0.90, indicating a strong comparative fit. By considering multiple indices beyond the Chi-Square statistic, the results demonstrate an overall acceptable fit for the model, balancing the limitations of individual measures with a holistic assessment of goodness-of-fit.

3 Results

This section presents the detailed analysis results of the impacts and proximate drivers of urban sprawl in Lagos' peri-urban areas, focusing on converting statutory agricultural land in Ikorodu. Results were derived from a multidisciplinary approach that combines spatial analysis of land use change patterns through the application of remote sensing and fractal analysis and modeling of the proximate behavioral and socioeconomic factors that drive the changes through the application of SEM.

3.1 Urban expansion and loss of agricultural lands

The land use and land cover change analysis of Ikorodu for 1984, 200, and 2016, as presented in Figure 5 and Table 9, reveals significant growth in urban land and diminution of agricultural and forested lands. On the one hand, Built-up areas increased from 1,819.26 hectares in 1984 to 14,580.72 hectares in 2016, about 127.46% over the 32-year study period, revealing an unambiguous transformation in the landscape. On the other hand, agricultural and forested lands lost 32.65 and 51.29% consecutively during the same period. The loss of agricultural and forested lands underscores the pressure of urban expansion on local food production and ecosystem service provisioning, which has implications for achieving SDG 2. Also, forested land loss inhibits biodiversity and ecological balance, having implications for achieving SDG 15. This study's result aligns with previous studies' findings, which have revealed similar trends of agricultural land loss due to peri-urban expansion in SSA. For example, in Uganda, 66.7% of Kampala's peri-urban agricultural lands were encroached upon by urban expansion between 1989 and 2015 (Williamson and Feeney, 2001; Muchelo et al., 2024). Similarly, the PUAs of Greater Cairo lost 51.7% of its agricultural land to urban encroachment between 2001 and 2021(Salem and Tsurusaki, 2024), revealing a common trend in the global south.

TABLE 9 Ikorodu land cover change (1984–2016).

Land cover	Area (Ha) 1984	%	Area (Ha) 2000	%	Area (Ha) 2016	%	Net change (Ha) 1984–2000	Net change (%) 1984–2000	Net change (Ha) 2000–2016	Net change (%) 2000–2016	Total change (%) 1984–2016
Waterbodies	13188.24	24.91	13306.77	25.14	12777.93	24.14	118.53	0.89	–528.8	–4.14	–3.25
Forested land	24491.7	46.26	20212.92	38.18	15534.45	29.34	–4278.8	–21.17	–4,678	–30.12	–51.29
Agricultural land	13441.5	25.39	12931.11	24.43	10047.6	18.98	–510.39	–3.95	–2,884	–28.7	–32.65
Urban/built-up	1819.26	3.44	6489.9	12.26	14580.72	27.54	4670.6	71.97	8090.8	55.49	127.46
Total	52940.7	100	52940.7	100	52940.7	100					

3.2 Sprawl detection through fractal analysis

Further investigation of the landscape pattern using fractal analysis shows fragmentation. This is evident from the patchy and scattered agricultural lands caused by the increasingly sprawling unplanned residential development. The fractal dimension for 1984 was 0.94 value, while the values for 2000 and 2016 were 0.96 and 1.56, respectively. Highly fragmented built-up areas have small fractal dimensions, while compaction and regularity will attract a higher figure (Thomas et al., 2008). Metastatic growth of settlement will have a fractal dimension value between 1.26 and 1.54, while values between 1.54 and 1.78 indicate rapid growth and metastatic consolidation. Fractal dimension values close to 1.0 or less show dispersed urban areas, while those close to 2.0 are consolidated compact settlements (Encarnação et al., 2012). This spatial pattern of development has far-reaching implications for the existing farmlands, which are fragmented and finally displaced. Such loss of valued cultivated lands to urban development has an enormous consequence on the ecosystem provisioning food production services in the study area (see Figure 6).

3.3 Agricultural land fragmentation and capacities for food security

In the study, the decline in agricultural land per capita was juxtaposed with the population increase, which paints a worrying picture for food security. Table 10 shows that agricultural land per capita declined from 0.08 to 0.01 hectares per capita, revealing how urban expansion diminishes land vital for food production, with potential long-term implications for the cities' sustainability.

The result also confirms a continuous decline in the potential of the available agricultural land to provide the daily dietary requirement per person for Service Benefiting Areas (SBAs). The food density of Ikorodu increased from 192,820 kcal/hectare/day to 275018.36 kcal/hectares/day while the agricultural land per capita (ALPC) fell below the absolute minimum, i.e., from 0.08 hectare per capita to 0.01 hectares per capita as seen in Table 10. The implication is that the minimum land required to feed a single person dropped from 0.08 in 1984 to 0.01 in 2016, which is far below the absolute minimum of 0.07 hectares specified (Myers, 1999; Goswami and Nishad, 2017), even though the food supply to Ikorodu could be omnidirectional, directional or decoupled, the fact remains that this an indication of food insecurity.

Fragmentation and displacement of agricultural land are rarely noticed without spatiotemporal analysis of land cover change. However, the magnitude of change is better understood when comparisons are made from local to global scales. Comparing the findings of this study with global trends shows that Ikorodu's experience resonates with broader land cover change patterns of PUAs from urban expansion, often at the expense of ecological and agricultural lands (Seto et al., 2011; Güneralp and Seto, 2013), as can be revealed in recent studies from Ghana, Uganda and Egypt (Muchelo et al., 2024; Salem and Tsurusaki, 2023; Sumbo et al., 2023).

Figure 7 shows the gradual decline of ALPC at global, continental, and national scales. The global decline is an aggregation of local, national, and regional land cover changes due to urban expansion.
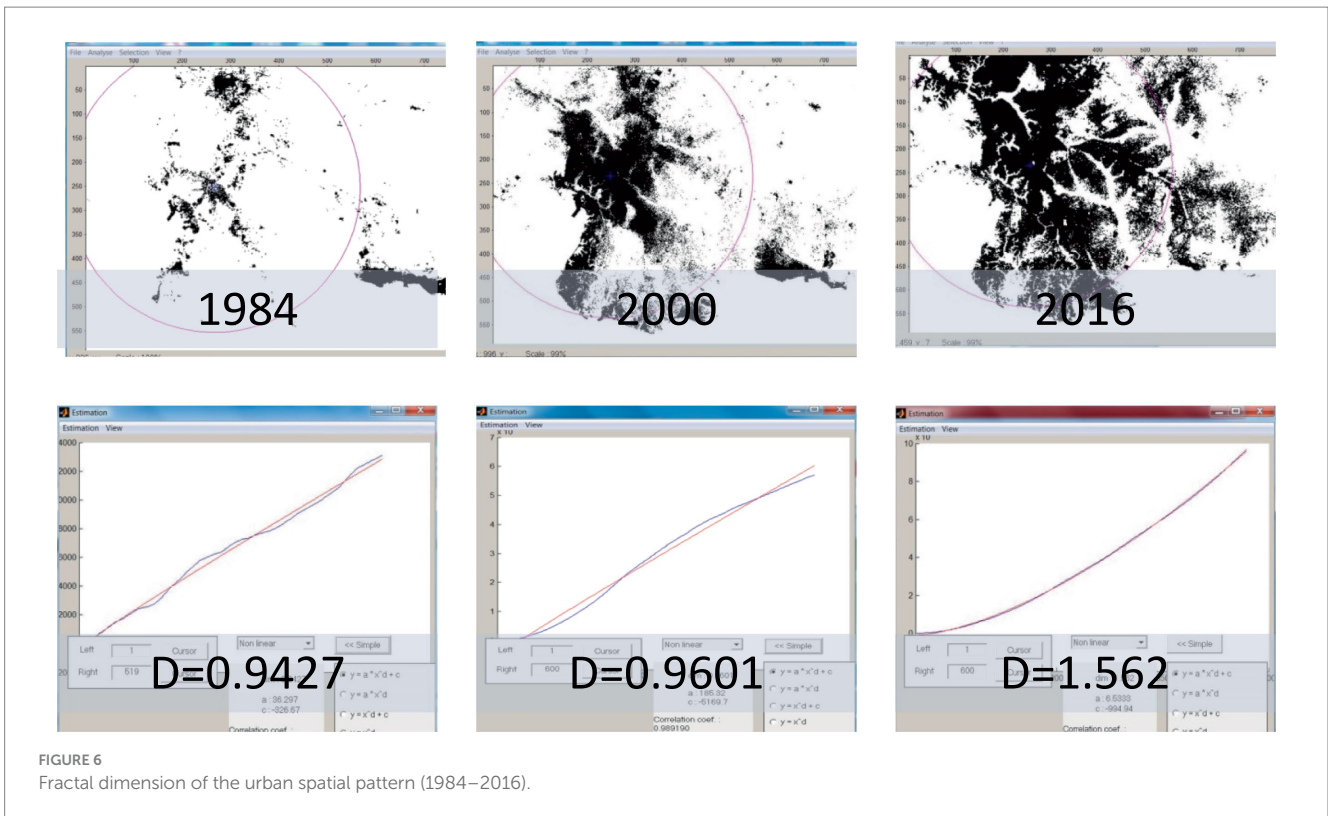
FIGURE 6
Fractal dimension of the urban spatial pattern (1984–2016).

Globally, ALPC decreased from 1.45 hectares in 1961 to 0.61 hectares in 2021, while Africa's ALPC reduced from 4.20 hectares to 0.83 hectares during the same period. At national levels, Nigeria's ALPC decreased significantly from 1.18 hectares in 1961 to 0.32 hectares in 2021 compared to South Africa's decrease from 5.96 hectares to 1.62 hectares. These decline trends across Africa are red flags for urgent action.

3.4 Modeling the drivers of residential development in agricultural lands

The SEM analysis presented in this section reveals the proximate drivers of urban sprawl in Lagos' peri-urban area. Table 11 shows the unstandardized and standardized regression scores of the manifest (observed) variables. The observed variables can be used to explain the underlying latent variables; the higher the standardized R^2 value of the observed variable, the stronger the association and representation of the latent factor.

However, Table 12 results give insights into the total effects (direct and indirect) of drivers influencing change from agricultural to residential land use. Four factors had a statistically significant relationship ($p < 0.05$) with the dependent variable (ResDev_AgricZone-Residential Development in Agricultural Zone); they included policy awareness, migration, health, cost of living, and socio-demographic factors as significant drivers (see Figure 8).

3.4.1 Structural model interpretation

The total effects of the eight (8) latent variables (independent variables) on the dependent variable (*ResDev_AgricZone*-Residential Development in Agricultural Zone) are discussed below:

Policy awareness ($\beta = -0.260$, $p < 0.002$): The result shows that policy awareness (Aware_1) has a significant negative effect on residential developments in agricultural zones, with a regression factor of -0.26, meaning it predicts 26% of the total variation explained by the eight (8) factors. This suggests that increased awareness of planning regulations (e.g., Urban and Regional Planning Law of 1992) will reduce residential development conversion of agricultural land. When 'Aware_1' (policy awareness) increases by one standard deviation, 'ResDev_AgricZone' (residential development in agricultural zones) decreases by 0.26.

Work travel ($\beta = 0.01$, $p = 0.32$): Work travel, measured by distance, cost, and time to work, does not significantly influence residential development in agricultural lands. With a regression factor of 0.01, it only predicts 1% of the variance explained by residential development in agricultural land. This result is not statistically significant since the p-value is 0.32.

Migration ($\beta = 0.128$, $p = 0.05$): Migration contributes 12.8% of the total variance in residential development in agricultural lands with a regression factor score of 0.128; it has a positive statistical significance ($p = 0.05$), meaning when migration increases by one standard deviation, residential development in the agricultural zone increases by 0.128. Table 13 also shows that only 25.5% of Ikorodu homeowners originate in Ikorodu, while 16.5% come from other parts of Lagos; 58% migrated from different parts of Nigeria or are Foreigners. Migration has a positive relationship with peri-urban growth, consistent with recent research on peri-urbanization in SSA (Ingwani et al., 2024; Korah et al., 2024; Salem and Tsurusaki, 2024).

Health and living cost ($\beta = 0.392$, $p < 0.001$): Health and Living Costs significantly drive residential development in peri-urban agricultural lands by contributing 39.20% of the total variance explained with a regression score of 0.392, which is statistically

TABLE 10 Agricultural land required for providing daily dietary requirements.

Year	Population	Urban density (Pers/Ha.)	Urban area (Ha)	Urban fractal dim. (D)	Daily dietary req. per capita (kcal/person/day)	Food density (kcal/Ha/Day)	Agricultural land deficit	Agric. land per capita in Ikorodu (Ha)	Physiological density
1984	170,535	94	1819.26	0.943	2057	192820.4	1504.05	0.08	13
2000	390,620	60	6489.9	0.96	2,195	132114.7	−14412.29	0.03	30
2016	1,699,138	117	14580.7	1.562	2,360	275018.4	−108892.1	0.01	169

FIGURE 7
Decline trends in agricultural land per capita.
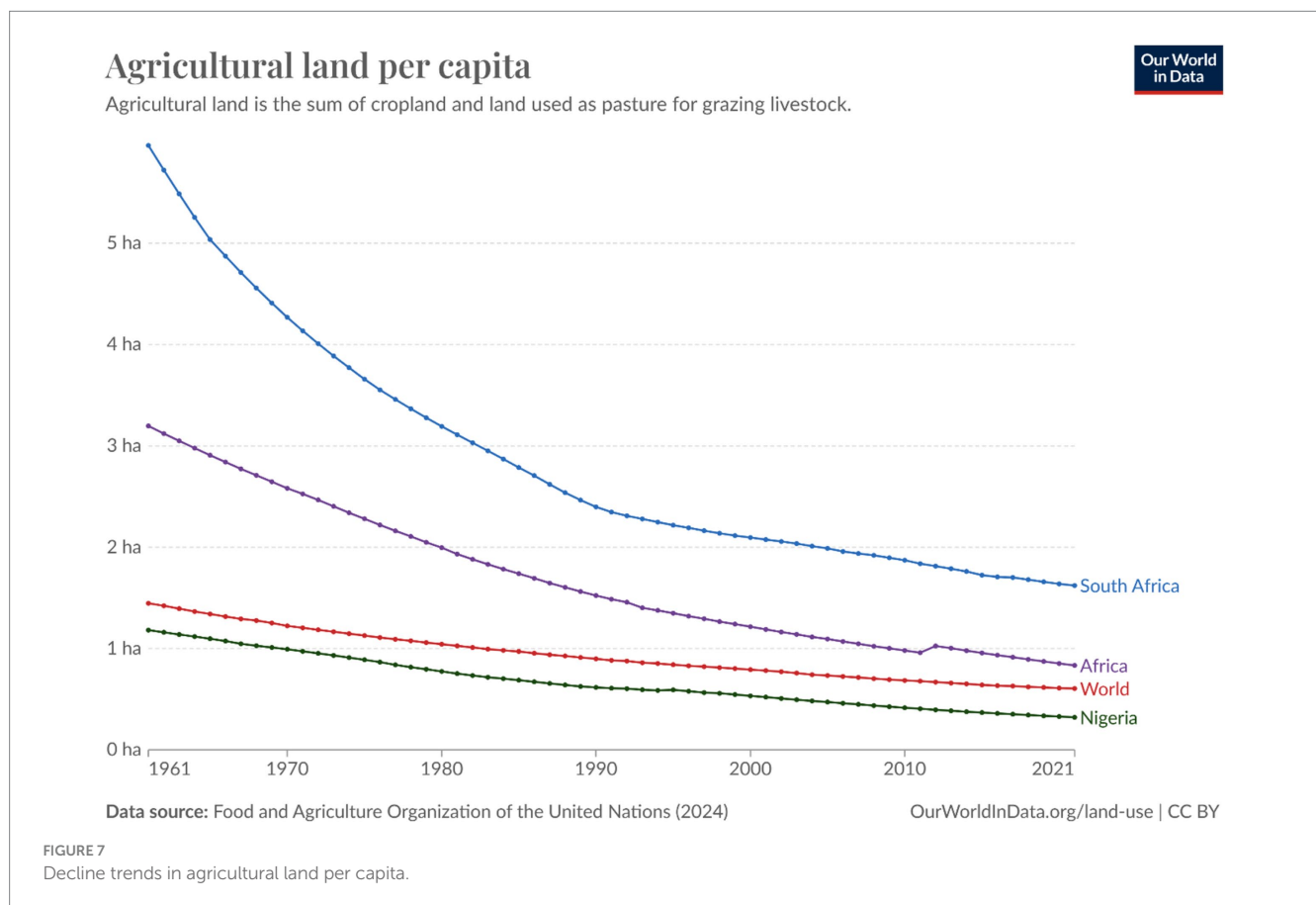
significant ($p = 0.00$). This implies that when 'Living_4' goes up by one standard deviation, 'ResDev_AgricZone' goes up by 0.392. Higher living costs in the city, land costs, health stress, and leisure-related factors positively drive peri-urban growth and agricultural land conversion. The findings of previous studies reveal similar trends in SSA and developed countries. In a similar study of peri-urban land, system changes in Greater Copenhagen between 1984 and 2004, where 92% of homeowners' decisions to build in peri-urban areas were motivated by recreational and ecological opportunities (Busck et al., 2006). A study of the Swiss Alps shows that proximity to suburban green spaces is a primary motivation (Conedera et al., 2015). Also, a recent study of the growth of Ikorodu attributed the cost of living and cheaper land compared with other parts of Lagos to be a major driver of residential development in Ikorodu (Adedire, 2018).

Amenity ($\beta = −0.171$, $p = 0.23$): Access to transportation infrastructure and proximity to other amenities has a negative but non-significant effect on residential development on agricultural land, with a regression score of −0.188 and p-value of 0.19.

Residential mobility ($\beta = 0.111$, $p = 0.09$): Residential mobility positively affects the conversion of agricultural land but is not significant. The total effect of residential mobility on residential development in agricultural land is 0.111 (p-value = 0.09). Due to the total effects of residential mobility, when 'ResMobile_6' goes up by one standard deviation, 'ResDev_AgricZone' goes up by 0.111. The implication is that there is more pressure on agricultural land due to the increased demand for housing due to population shifts, primarily from migrant tenants.

Development control ($\beta = −0.04$, $p = 0.39$): Development control has a weak and a negative statistically non-significant effect on

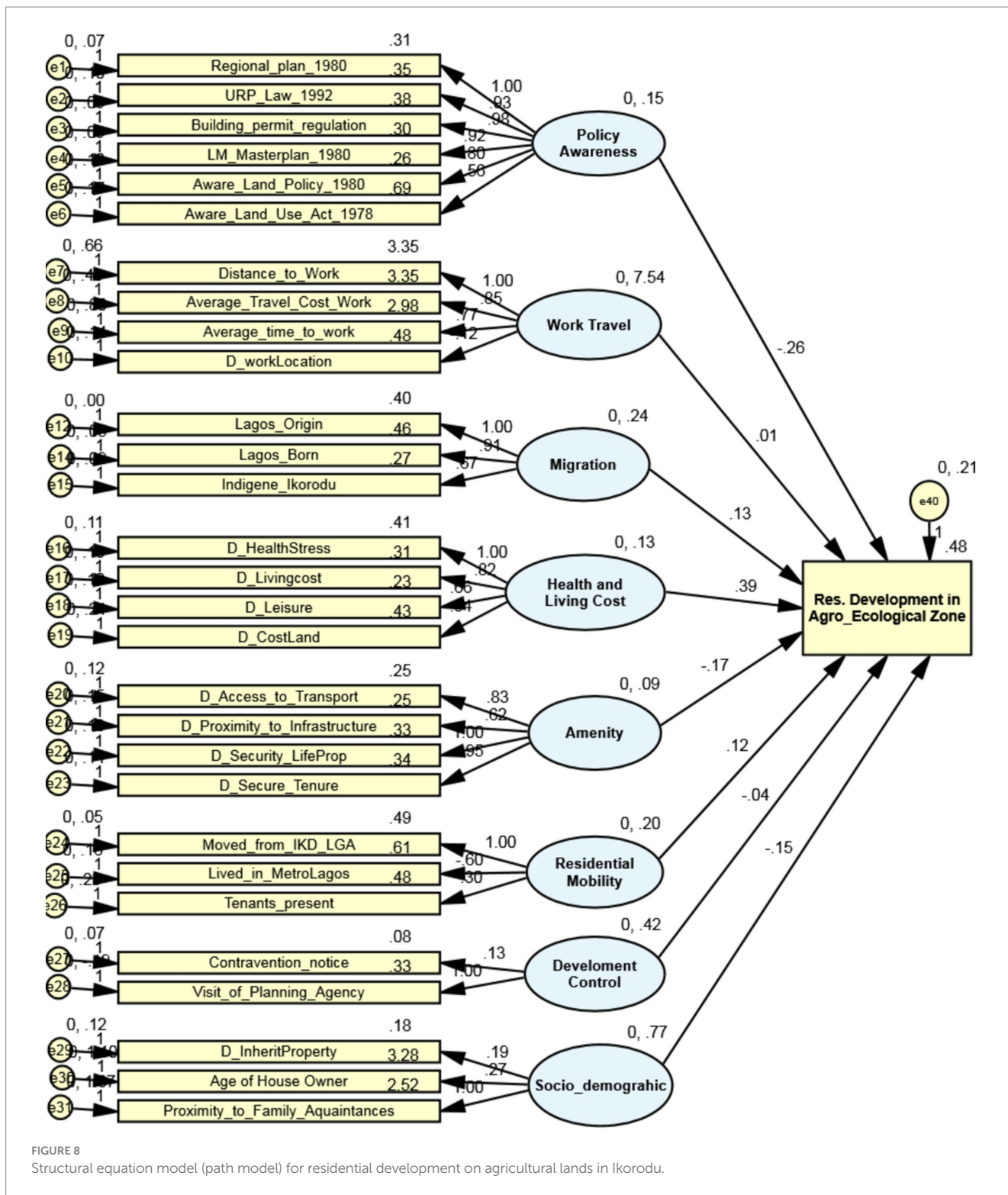TABLE 11 Unstandardized and standardized regression score of manifest variables.

Measurement model parameters			R^2	Standardized R^2 estimate	S.E.	C.R.	P	Label
Regional_plan_1980	<---	Aware_1	1	0.83				
URP_Law_1992	<---	Aware_1	0.93	0.75	0.07	14.03	***	W1
Building_permit_regulation	<---	Aware_1	0.98	0.78	0.07	15.06	***	W2
LM_Masterplan_1980	<---	Aware_1	0.92	0.76	0.06	15.06	***	W3
Aware_Land_Policy_1980	<---	Aware_1	0.80	0.70	0.06	13.13	***	W4
Aware_Land_Use_Act_1978	<---	Aware_1	0.56	0.47	0.07	8.13	***	W5
Distance_to_Work	<---	Travel_2	1.00	0.96				
Average_Travel_Cost_Work	<---	Travel_2	0.85	0.96	0.02	40.94	***	W6
Average_time_to_work	<---	Travel_2	0.77	0.92	0.02	33.46	***	W7
D_workLocation	<---	Travel_2	−0.12	−0.67	0.01	−15.32	***	W8
Lagos_Origin	<---	Migrate_3	1.00	0.99				
Lagos_Born	<---	Migrate_3	0.91	0.89	0.04	25.17	***	W9
Indigene_Ikorodu	<---	Migrate_3	0.67	0.73	0.04	16.71	***	W10
D_HealthStress	<---	Living_4	1.00	0.74				
D_Livingcost	<---	Living_4	0.82	0.64	0.10	8.57	***	W11
D_Leisure	<---	Living_4	0.66	0.57	0.09	7.36	***	W12
D_CostLand	<---	Living_4	0.54	0.39	0.10	5.67	***	W13
D_Access_to_Transport	<---	Infra_5	0.83	0.59	0.12	6.95	***	W14
D_Proximity_to_Infrastructure	<---	Infra_5	0.62	0.43	0.11	5.55	***	W15
D_Security_LifeProp	<---	Infra_5	1.00	0.65				
D_Secure_Tenure	<---	Infra_5	0.95	0.61	0.13	7.16	***	W16
Moved_from_IKD_LGA	<---	ResMobile_6	1.00	0.90				
Lived_in_MetroLagos	<---	ResMobile_6	−0.60	−0.56	0.16	−3.71	***	W17
Tenants_present	<---	ResMobile_6	0.30	0.27	0.10	2.92	0.003	W18
Contravention_notice	<---	LUControl_7	0.13	0.30	0.14	0.95	0.345	par_97
Visit_of_Planning_Agency	<---	LUControl_7	1.00	1.37				
D_InheritProperty	<---	Social_8	0.19	0.44	0.05	3.54	***	W20
Age	<---	Social_8	0.27	0.22	0.12	2.29	0.022	W21
Proximity_to_Family_Aquaintances	<---	Social_8	1	0.56				

***Statistically significant results (p-value =0.000).

TABLE 12 Total effect of drivers on agricultural land use change (structural model).

Structural model parameter			Estimates	SE.	CR.	P	Label
ResDev_AgricZone	<--	Aware_1	−0.260	0.083	−3.117	**0.002*****	W22
ResDev_AgricZone	<--	Travel_2	0.011	0.011	0.998	0.319	W23
ResDev_AgricZone	<--	Migrate_3	0.128	0.065	1.959	**0.050*****	W24
ResDev_AgricZone	<--	Living_4	0.392	0.116	3.364	***	W25
ResDev_AgricZone	<--	Infra_5	−0.171	0.142	−1.206	0.228	W26
ResDev_AgricZone	<--	ResMobile_6	0.123	0.071	1.717	0.086	W27
ResDev_AgricZone	<--	LUControl_7	−0.040	0.047	−0.868	0.385	W28
ResDev_AgricZone	<--	Social_8	−0.148	0.071	−2.075	**0.038*****	W29

***Statistically significant results.

FIGURE 8
Structural equation model (path model) for residential development on agricultural lands in Ikorodu.

agricultural land conversion. The total effect of development control on residential development in agricultural land is −0.040 (*p* value = 0.39). That is when development control goes up by one standard deviation, residential development in the agricultural zone decreases by 0.04. However, the non-significance suggests ineffective enforcement of planning and land use regulations. Ineffective development control in PUAs in other African states is closely linked

with agricultural land loss (Anane and Cobbinah, 2022; Dekolo et al., 2015; Sumbo et al., 2023).

Socio-demographic factors (β = −0.148, *p* = 0.04): The total effect of social and demographic factors on residential development on agricultural land is −0.148 (*p*-value, 0.04). That is when Social and demographic factors increase by one standard deviation, residential development in the agricultural zone decreases by 0.148.

TABLE 13 Place of origin of homeowners in Ikorodu.

	Frequency	%	Cumulative percent
Ikorodu	82	25.5	25.5
Lagos metropolis	35	10.9	36.3
Other Lagos Peri-urban areas	18	5.6	41.9
Neighbouring ogun state	48	14.9	56.8
Other south-west states of Nigeria	102	31.7	88.5
Other states of Nigeria	36	11.2	99.7
Foreign country	1	0.3	100.0
Total	322	100.0	

Socio-demographic factors like family inheritance patterns and proximity to family in established communities may resist pressures to sell farmland for residential developments (Sumbo et al., 2023).

The SEM analysis proves that policy awareness, migration dynamics, health and living costs, and socio-demographic factors are critical drivers of agricultural land use conversion in Lagos' peri-urban areas.

4 Discussion

4.1 In-depth analysis and awareness of urban sprawl and ecosystem service depletion

The findings from Ikorodu reflect a broader global challenge where urban expansion often occurs at the cost of essential ecosystem services. The change analysis revealed a significant transformation in Ikorodu's landscape, resonating with worldwide trends in rapidly urbanizing regions (Seto et al., 2011; Güneralp and Seto, 2013; Salem and Tsurusaki, 2024). While fractal dimensions have been applied in various SSA cities, synthesizing 45 urban areas shows heterogeneity in growth patterns and diverse degrees of regional fragmentations (Forget et al., 2020). A comparison of the Fractal Dimension Index (FDI) of Ikorodu and Greater Cairo reveals some commonalities and differences in urban growth patterns in African cities. In Ikorodu, FDI rose from 0.94 in 1984 to 1.56 in 2016, transitioning from a fragmented to a more consolidated urban development on agricultural, while Greater Cairo's FDI increased from 1.44 in 1973 to 1.75 in 2021, indicating a fragmented landscape due to both planned and unplanned urban expansions (Salem et al., 2024). Both cities show fragmented and unplanned growth in agricultural lands. Cairo's higher FDI is attributed to leapfrogging satellite expansions on farmland and desert areas, while Ikorodu is limited to expanding low-density developments on peri-urban agricultural lands. Even though both cities' sprawl challenges are at different scales and driven by different factors, they reflect weak development control and planning regulations, which call for cohesive policy interventions targeted to their peculiarities.

4.2 Global urbanisation challenge and comparative insights

Urban sprawl evidence in Ikorodu, characterized by the extension of built-up areas into agricultural lands, reflects the pattern of peri-urban development seen in cities across sub-Sahara Africa (Cobbinah and Amoako, 2012; Yiran et al., 2020). It also underscores the global challenge of urban sprawl on provisioning ES, as seen in previous studies, and the need for sustainable urban land management practices (Madallah and Tarawneh, 2014; Rubiera Morollón et al., 2016).

4.3 Sustainable urban planning strategies and land governance

The findings on the lack of policy awareness and development control in Ikorodu resonate with the need for effective urban land governance to preserve ES, aligning with literature emphasizing the importance of integrated policy approaches that balance urban growth with environmental sustainability (Eppler et al., 2015; Perveen et al., 2017). Insights from the study underscore the need for an integrated urban planning approach, emphasizing the need to incorporate ES assessments into urban development strategies. Planning that goes beyond land use and emphasizes land functions and the value of ES would birth more resilient and sustainable urban environments. Also, a participatory approach involving all local stakeholders will make policies more acceptable and effective (Kenter et al., 2011; Wu et al., 2017).

5 Conclusion

This study's in-depth analysis of Ikorodu, Lagos, provides critical insights into the dynamics of urban sprawl and its implications for ES. Significant land cover changes were characterized by a 127.46% increase in built-up areas and a cumulative decrease of 83.49% in agricultural lands (−51.29%) and forested lands (−32.65%). This trend reflects a broader global trend of urban expansion at the cost of agricultural and forested lands. The fractal analysis results underline a persistent sprawling pattern, indicating that despite becoming more compact in some areas, Ikorodu's growth largely remains uncoordinated and dispersed.

The study underscores the urgent need for spatial planning frameworks to integrate ES considerations. Urban expansion undermines the ES function of land—from food provisioning to climate regulation. The decreased ALPC in Ikorodu is a plain reminder of the potential threats to food security and local livelihoods in the face of unrestrained urban growth. Such insights

are invaluable for policymakers and urban planners balancing urban development with environmental sustainability. This study recommends a multidimensional approach to urban planning encompassing land use regulation, public awareness campaigns, and the integration of ES valuation into development decisions. Policymakers should consider strengthening public awareness and education on land use policies, improving capacities for development control, investing in and incentivizing affordable housing projects, and promoting sustainable and inclusive land governance.

Future studies suggested include longitudinal studies that could further explore the dynamic interplay between urban sprawl and ES. Comparative research across different urban contexts could provide deeper insights into the relationships between migration and peri-urban sprawl and practical strategies for managing urban expansion while preserving ES. In addition, studies are needed to focus on the socioeconomic dimensions of urban sprawl in African cities.

The transition of Ikorodu from an agricultural PUA to an urbanized landscape sums up the challenges and opportunities inherent in managing rapid urban growth in African cities. Aligning urban planning with ES will allow cities like Ikorodu to evolve into models of sustainable development, offering a high quality of life for their residents while preserving the ecological intricacies upon which they depend. The findings from this study contribute to the growing discourse on sustainable urbanization in Africa, providing a compelling case for integrating agroecological considerations in urban development planning.

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.

Author contributions

SD: Conceptualization, Formal analysis, Writing – original draft, Writing – review & editing. ME: Writing – original draft, Writing – review & editing. OJ: Visualization, Writing – review & editing. CA: Resources, Writing – review & editing. TG: Resources, Writing – review & editing.

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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.

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The author(s) declare that no Generative AI was used in the creation of this manuscript.

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