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Urban theories and urbanization perspectives in cities across Nigeria

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Abstract

One of the emerging research trends from urbanization is the study of urban growth patterns. These growth patterns are primarily based on the growth of the local economy that directly affects agricultural lands. In Africa, the local economy has spurred the extinction of many agrarian sectors. Yet, few studies at the regional level have paid attention to these changes. Using diverse scientific literature on global urbanization, urban remote sensing, and economic geography, this study aimed to understand the theory behind urban developments in Nigeria. The primary data were collected in two study regions in the country's eastern and southern parts, making it a large dataset to assess urban formation in these areas. We examined the evolution of urban development from the perspectives of infrastructural development, expansion, change in land use, and urban job migration opportunities that affect agrarian activities. White-collar job opportunities are limited in urban areas, substantially increasing the startup of small-scale businesses. We introduce the notion of natural resource urbanism, which implies urbanization that is triggered by the influx of natural resource revenue to strengthen the dwindling local economy. The infusion of a shared natural resource revenue creates a reform in the local economy and the advent of a consumption-based economy. A shared natural resource revenue drives massive infrastructural developments, but the dependence on the availability of those natural resources in the states raises concerns about its long-term sustainability for strengthening the local economy.

1. Introduction

Many recent studies have focused on urban concepts in big cities, propelled by the growth in scientific literature on urban theory in the global south and showing more interest in the urbanization processes in less agglomerated areas (Taubenböck *et al* 2012, Brenner and Schmid 2015, Simone 2020), but less attention has been given to the relatively fast-growing cities in Africa. This focus on the global south has expanded the urban literature database with comparative urbanism, provincial and universal theoretical debate, and the scrutiny of the northern theory on other cities (Kalnay and Cai 2003, McFarlane and Robinson 2012, Vanum 2012, Peck 2015, Nijman 2007, 2015a).

We go into these discussions with a study of urban growth perspectives in Nigeria, known as the fastest-growing nation and the agricultural giant of Africa (Bloch *et al* 2015, Sean *et al* 2018, Ojo and Ojewale 2019). Our study areas are decentered away from the global south that draws so much attention for urban studies. We argue that this focus on undeveloped regions less represented in the literature on urbanization is relevant to some of the debates in urban theory. Furthermore, the urbanization processes in southeast Nigeria are far from being overlooked. They are a major ethnic group with the third fastest urbanization of cities in Nigeria (Achionye *et al* 2018, Essien 2021). In this study, we focus primarily on the economic changes that drive these urban developments. According to the literature, rural–urban migration has been one of the major causes of urban transition due to the availability of employment opportunities in urban areas across Nigeria (Bloch *et al* 2015,

UNCTADstat. 2014, World Bank 2016)—a transformation that has resulted in the high cost of local products, reflecting the low production of agricultural products (Essien 2021).

The empirical part of our study focuses on four midsize cities across two regions in Nigeria. Warri and Uyo are in the south while Aba and Umuahia are in eastern Nigeria. We collected our primary data from the National Bureau of Statistics of Nigeria (NBS) 2020, which is a rich data set for our study regions. We utilized three different literature databases: urban formation at a regional level, economic geography, and urban remote sensing. While previous studies were significant, they offer limited applicability to Nigerian urbanization. We engaged a broader multiplicity approach (van Duijne *et al* 2022) and combined frame switching with the transduction method (van Meeteren *et al* 2016). Frame switching consists of utilizing theoretical perspectives to interpret limited empirical facts (van Duijne *et al* 2022). The transduction method examines the relationship between empirical observation and theoretical formulation (Schmid *et al* 2018, van Duijne and Nijman 2019).

One of the primary debates we are concerned with is the impact of the shared natural resource revenue on urban areas. This allocation is mainly used to redesign the urban areas due to the lack of substantial growth in the local economy. Our findings show that restructuring and modernizing the urban areas has caused a decline in agricultural production with no alternative substantial job opportunities in the urban areas, leading to the opening of small-scale businesses littered around the urban areas. The shared natural resource revenue plays a significant role in the urban development and local economic reform. This revenue drives urban reformation, but its dependence on the natural resource availability in the state raises questions about its long-term sustainability.

1.1. Urban theories and formations in Nigeria

Based on the transformation in its midsize and mega cities, the Nigerian urbanization level is notably high. Globally, it is one of the fastest-growing urbanized nations, with half its 1.8 million inhabitants currently residing in urban areas (NPC 2021, Ojo and Ojewale 2019). Urban opportunities employ the largest number of people by far, in contrast to agriculture, which has previously been the primary source of livelihood for many years (NBS 2021, UNCTADstat 2014, World bank 2016). Urban expansion rates have certainly increased in recent years, despite the low economic growth and limited employment opportunities in the urban areas (NPC 2021, UNCTADstat 2014). As such, Nigerian urbanization negates conventional urban theory, which shows a positive correlation between urban growth and economic growth (Mahendra and Seto 2019, Mendonça *et al* 2020, Sapena *et al* 2020). The research literature provides different explanations for Nigeria's exploding urban growth. Some viewpoints suggested that this resulted from an increased demand for human labor due to the ongoing construction work despite the dwindling economic growth (Sean *et al* 2018, Essien 2021). Others point to the low accommodation costs in suburban areas that allow migrants to easily commute to the urban areas on a daily basis (Essien 2021). Rural–urban migration has been attributed as the primary driver of urban growth (UNCTADstat 2014, Bloch *et al* 2015, Kyle 2018) due to the lack of basic utilities such as water, electricity, and telecommunication in the rural areas. Furthermore, the major threat to these environments is the significant loss of agricultural land. Urban studies in Nigeria have shown that over the last twenty years, sixty million people have changed their source of income from agrarian work to a non-agricultural income (NPC 2021, UNCTADstat 2014). Nevertheless, some still cannot find another better source of income. The demise of agriculture occurs despite the lack of alternative urban job opportunities, leaving many households with an uncertain future. This is primarily ascribed to the lack of farm mechanization, low crop yields, and low agriculture wages (World bank 2016, NBS 2021). These studies offer an important framework for investigating the perspectives of economic growth and urban growth in the emerging cities in Nigeria. This stands as a guide for our empirical study, and in designing an appropriate conceptual framework, we will provide an in-depth assessment of the four cities in our case studies.

1.2. Global and regional theories on urban economic geography

A linear debate in urban literature shows that economic growth and urban growth are normally linked (Seto and Kaufmann 2003, Henderson 2010, Ivan and Gordon 2013, Mahendra and Seto 2019, Mendonça *et al* 2020, Sapena *et al* 2020). According to the United Nations, the urbanization process is generally associated with economic growth and social transformation that has brought about urban migration, life expectancy changes, and poverty reduction (United Nation 2019). Life in urban areas is associated with the availability of social amenities, access to better health care, education, good road networks, and better job opportunities (United Nation 2019). Furthermore, studies also show there is a positive correlation between urban growth rate and GDP per capita (Ivan and Gordon 2013, Mahendra and Seto 2019). Studies in economic geography argue this assertion of a positive correlation between economic growth and urban growth. However, these studies focus primarily on cities in the global south, where rapid urbanization has not transformed or triggered an increase in the standard of living (Collier and Venables 2017, Henderson and Turner 2020). Glaeser (2014) attributed this to

the adverse effects of diseconomies of scale in metropolitan cities in the global south, while other studies have mainly emphasized the negative effects of low economic growth in urban areas, which is urbanization devoid of industrialization (Jedwab and Vollrath 2015). This is noticeable in national economies that seem to be dependent on natural resource exports, which results in many of the big cities having economies that are based on consumption instead of production (Gollin *et al* 2016). According to the World Bank (2015), cities need to offer generative urbanization, which involves cities providing an enabling environment for resilient, productive, and inclusive economies. This type of urbanization is lacking in our study area and other African cities. However, as highlighted above, the contention about urbanization being devoid of industrialization does not appear to be applicable in Nigeria. Nigerian urbanization indicates the opposite. In recent years, a relative economic growth has influenced and accelerated urban migration in many cities across the country. Nigeria's urban growth and the share of urban population growth are far above many other African countries. It is potentially unsurprising, therefore, that Nigeria does not feature in most studies on urbanization devoid of industrialization. Another limitation of these studies is that they focus on the mechanisms of the big cities, not the urban development processes.

1.3. Urban remote sensing theories

Globally, remote sensing has been used to monitor urban growth at various spatial resolutions (Schulz *et al* 2021, Song *et al* 2018, Taubenböck *et al* 2012), and time series data have been used to monitor urban sprawl in European cities (Barnes *et al* 2001, Soule 2006, Fuladlu *et al* 2021). However, it remains challenging to map urban land use cover in Africa (Xiong *et al* 2017, Yin *et al* 2020a), due to the heterogeneous landscapes of the region (Schulz *et al* 2021) and the multiple small-scale farming leading to the misrepresentation of urban land use classes (Nabil *et al* 2020). Furthermore, sub-Saharan Africa has experienced enormous unplanned environmental challenges such as climate change, population growth, and low agricultural production, which encourage the continuous change in urban land use (FAO 2016, Essien 2021). Various satellite products from low to high spatial scales that have been used to map land use on the continent, such as Globland (30 m) (Chen *et al* 2015), Copernicus Global Land Cover (100 m) (Buchhorn *et al* 2019), FROM-GLC (10–30 m) (Gong *et al* 2019), ESA GlobCover (300 m) (Arino *et al* 2008), and the 20 m ESA CCI Landcover Prototype (CCI Land Cover 2017). However, Nabil *et al* (2020) argue that the significant discrepancies between the land use classes and the accuracy of the products were relatively low for cropland. This is especially notable in Africa, where small pieces of land are characterized for different purposes, and there is a high level of subsistence farming with diverse landscapes. Further studies in this region with high-resolution data have focused more on the agrarian land and did not map the various built-up urban areas (Nutini *et al* 2013, Sedano *et al* 2019). This points to the availability of only coarse-resolution land cover maps in this region or land cover maps that are linked with global coverage (Schulz *et al* 2021), as well as drawing attention to the lack of consistent land cover maps of Nigerian cities in urban literature, given that Nigeria is the fastest-growing nation in Africa (World bank 2016). This inconsistency has created a need to develop a consistent urban land use map that shows different urban development stages in midsize cities across the country.

1.4. Aims and objectives of this study

The literature on urbanization has provided some essential conventional paths for this study on urbanization perspectives in cities in Nigeria. We build on previous studies and contribute to various theories, and we examine this literature to show the limitations and relevance to our case studies. This research on the study areas is conducted using Earth observation data and engaged frame-switching pluralism (Barnes and Sheppard 2010, van Meeteren *et al* 2016). The main aim of this research is not to add more contradictory theories among the various strands of literature, but to offer a better understanding of the urban growth perspective in cities across Nigeria.

2. Conceptual framework

Most of the literature on urbanization is insightful but has limitations when it comes to urban growth in Nigeria. As mentioned earlier, our exploratory study and the approach is built on remote sensing data, frame switching, transduction, and strategy pluralism, allowing us to use numerous theoretical viewpoints in a continuous interplay with empirical observations (van Meeteren *et al* 2016, Schmid *et al* 2018, van Duijne *et al* 2022). The conceptual framework (figure 1) is centered across four distinct arguments from previous literature. We will elaborate on these arguments in the section below.

According to the research literature on urban geography, the first argument is that employment opportunities in urban areas are the key drivers of urban population growth in the global south. This employment-based growth is accompanied by local economic reform in terms of the demand and increase in

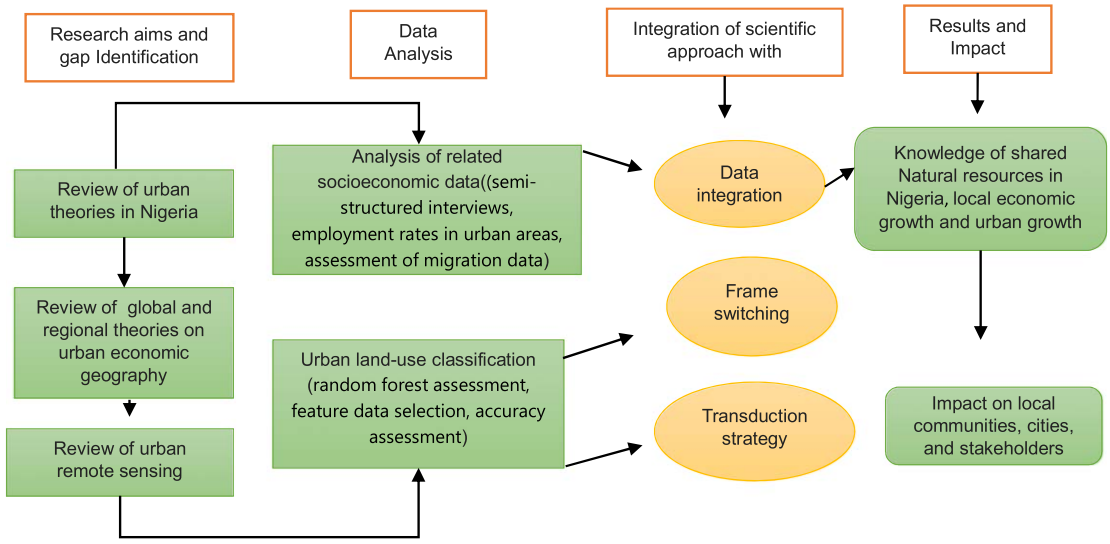

Figure 1. The methodological framework for the assessment of urban theories using remote sensing data, frame switching, transduction, and strategy pluralism to provide a new insight on urban growth patterns in Nigeria.

production. However, in Nigeria, employment opportunities in urban areas are relatively limited. In contrast, the local economy that was previously based on agricultural products is being continuously diminished, and is not being replaced by the urban economy reform.

Secondly, the migration patterns in these emergent cities are entirely different from those in developed countries. With the increase in thatched houses in the urban areas, immigration is significantly high due to the people gathering around the urban areas to queue for white-collar job opportunities that are relatively difficult to find. In some cases, people move to another city to keep hunting for urban job opportunities. Can this be attributed to the urban population growth based on people moving from city to city? Similarly, data on emigration is relatively high depending on the state's natural resource availability. However, this lack of economic prospects in urban areas has given rise to families selling their landed properties to raise funds to start a small-scale business or giving these funds to the male children to use and looking for greener pastures in the nearby cities (while the family stays and hopes the male children can change the fortune of the family). This is not the rural–urban migration that is common in most of the urban geography literature. We argue that predominantly male children migrate to work as laborers, while the sale of agricultural land is used to finance this migration.

Thirdly, based on the urban remote sensing literature, land use maps are essential for urban and environmental planning. However, mapping large areas with heterogeneous patterns remains challenging in sub-Saharan Africa due to the availability of only coarse satellite images in the region (Schulz *et al* 2021). Innovation in remote sensing applications has increased the availability of high-resolution satellite images and provides access to data for various scientific purposes; however, the research focus and methodological approach vary according to the different situations and environmental needs. We argue that the random forest (RF) approach is suitable for mapping agglomerated settlements across Nigeria's cities.

Fourthly, the disproportionate share of revenue from natural resources into the local economy, and the massive infrastructural development, modernizes and recreates Nigeria's cities with funds generated from the sale of the country's natural resources (crude oil). Revenue from natural resources distributed by the federal government is the primary source of capital for many cities in Nigeria. This has aided the expansion of the local economy, provided no-interest loans to small-scale start-up businesses, and improved the infrastructure (electricity, water, and new road networks) to link nearby urban communities. We argue that the disproportionate shares of the revenue from the natural resources can shape and alter cities' master plans. We discuss our findings in the next section.

2.1. Study layout and case studies

This empirical research was performed in three phases: (i) the creation of urban land use land-cover maps using data from the Landsat historical archive, (ii) the collection of reference data from visits to the case study areas, and (iii) the collection of data from a recent socioeconomic survey of the states and urban areas in Nigeria from the National Bureau of Statistics (National Bureau of Statistics 2020). Our land use and land cover analysis was in the states of Delta, Abia, and Akwa Ibom, with total populations of five million six hundred and thirty-six

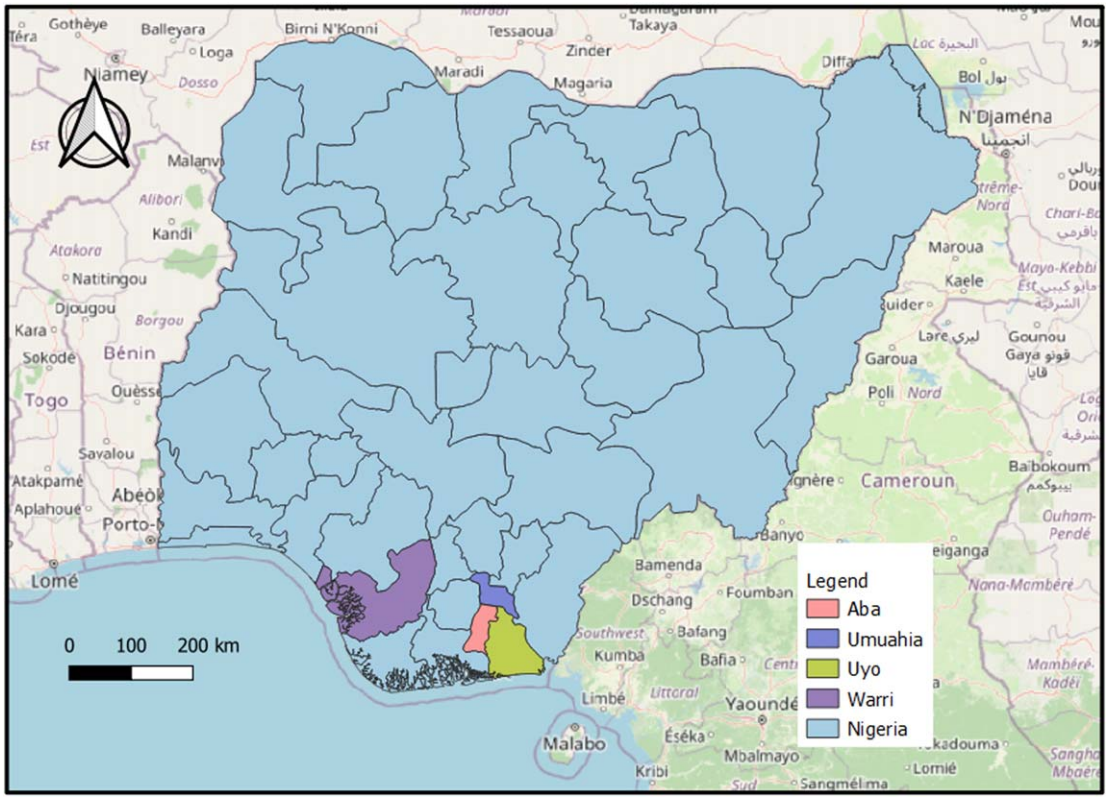

Figure 2. A map of Nigeria showing the location of the four midsize cities.

thousand one hundred, three million seven hundred and twenty thousand, and five million four hundred and fifty-one thousand, respectively. The study areas were selected due to their distinct urban characteristics. We analyzed data on population size, employment and unemployment in the study areas from 2000 to 2020, and we aligned this data to the spatial boundary of each of the states (figure 2).

According to population data for the year 2000, the total share of the Nigerian population living in the urban areas of the state capital was 31 percent. For Delta, with a population count of one million three hundred thousand, it was 24 percent; for Abia, with a population count of seven hundred and forty thousand, it was 12 percent; for Akwa Ibom state, with a population count of nine hundred and eighty thousand, it was recorded at 17 percent. In 2018, Delta had 26 new suburban areas, which were former rural and fishing areas, and more than 74 percent of people in these areas depended on nonagricultural and fishing incomes. Abia had 17 new suburban areas, which were former rural areas, and 40 percent depended on agricultural incomes, and Akwa Ibom had 23 new suburban areas, and 68 percent depended on non-agricultural incomes. Our land use and land cover analysis shows that the areas with road networks created substantial clusters, and the additional population of people living in these areas meant that the overall population count was exceeded because the official population count is usually within the urban spatial boundaries.

The second stage of the study design involved nine field visits to the research areas (two in Delta, four in Abia, and three in Akwa Ibom). These served to visit sites that were not visible with our satellite data, gather reference data, select case study areas for our primary data analysis, and group the different urban land use classes. In many sites, infrastructural development, such as road networks, had improved, and major highways linking states had been expanded due to the regional economic increases between states (Essien and Cyrus 2019).

We selected two study areas in the south (Warri and Uyo) located in Delta and Akwa Ibom, respectively, and two in the east (Aba and Umuahia) located in Abia (figure 2). The satellite images from the year 2000 show that Warri and Uyo had already experienced an early form of structural development; in contrast, Aba and Umuahia had little clusters in the urban areas and a high proportion of nonurban areas surrounding different settlement types. The settlement patterns in these areas (Aba and Umuahia) were not well defined. However, they were known as the core areas that pioneer rural–urban migration in the region (Ogu *et al* 2017). The settlement patterns in Warri and Uyo were distinct from each other in terms of population size and rural–urban migration, with the settlements in Warri and Uyo appearing to be more complex than in Aba and Umuahia. The Warri and Uyo settlements consist of eighteen urban communities with a combined population of 3.4 million people. The total share of people with skilled and unskilled employment is currently 61 percent, increasing from 34 percent

Table 1. Land cover types and descriptions.

Land cover types	Class descriptions
Residential	Building and impervious surfaces within the urban areas
Commercial	Small and large-scale business areas
Mixed usage	New buildings, small-scale businesses, and neighborhood farming activities
Cropland	Land for agricultural purposes and small-scale farming activities
Forest	Natural vegetation and tree plantation areas
water	Stagnant streams and flowing water bodies

in 2000. The Aba and Umuahia settlements consist of nine unplanned urban settlements with a combined population of 1.1 million. The share of people employed has increased from 20 percent in 2000 to 48 percent in 2020. The population growth in Warri and Uyo has been attributed to immigration as these are the headquarters of most of the major oil firms in Nigeria. In contrast, growth in Aba and Umuahia is seen as natural growth.

Thirdly, we used our primary data collected from the national households and business survey by the National Bureau of Statistics in Nigeria. The data consist of 72 semi-structured interviews with key informants by region, 317 household surveys, and industry access to electricity and the age of their workers. Our study focused on the findings based on household surveys that are related to occupation, source of income, commuting, migration, and results from industry surveys related to the size, location, and type of business, and the supply network. The interview data aid in interpreting the household and industries survey data. At the same time, our analysis aims to throw more light on urban geographies in our case study and the urbanization patterns of the areas.

3. Methods and remote sensing approach

Our approach consisted of data pre-processing, calculation of texture and spectral properties for each image, and classification using the random forest algorithm (RF). We downloaded atmospherically corrected Landsat five thematic mapper I, Landsat seven enhanced thematic mapper plus (ETM+) and Landsat 8 operational land imager (OLI) data from the USGS Earth Explorer portal (Earth Explorer, 2020). The data were subsets to our study areas of interest, and the spectral properties of the data were imported for green, red, blue, and near-infrared. For each year and scene, we stacked different bands with similar spectral properties to obtain the true and the false colour of the image to use for urban land cover classification. Each of the images was cloud-shadow-free and consisted of around 8-to-80-pixel-level observations (i.e, the month and year). We checked the data at different temporal scales for monitoring seasonal variation. We grouped our feature sets into six urban land use classes based on field visits and reference data. We used our feature sets to build the RF, which included feature selection, model training, and parameter iteration. Model training, quality assessment, and validation were carried out with independent testing and training datasets.

3.1. The urban land cover classification plan

For a detailed urban land cover change map from 2000 to 2020, we defined our urban land use classes based on the built-up areas and vegetation types in the study area using a rectangular extent to measure the city's administrative units. We used the same extent for the other cities to the quantify urban land cover changes that occurred within the same extent in the cities. Despite our extent's spatial resolution, we used reference data for consistency and terrain base accuracy. However, we based our final urban land cover classification on what we surveyed in the field and what we mapped using satellite data, i.e, we identified several other vegetation types in the field. However, since our focus was not on different vegetation mappings, we merged them with classes of similar types. We classified our data based on the built-up areas, location to the main road, nature of the built-up areas, and new buildings in the areas. We mapped urban land cover change from 2000 to 2020 with a 30-m grid cell size. Our satellite-based urban land cover classification for southeastern Nigeria relied on training data from our fieldwork. We used GPS coordinate points as our reference data during our reconnaissance survey of the study area and randomly selected each point of the urban land class type, subsequently using the reference data to identify different urban land cover classes in the areas and creating six land cover class types in the study area (table 1).

Table 2. Household incomes in urban areas.

	Warri (N = 246)	Uyo (N = 312)	Aba (N = 231)	Umuahia (N = 201)
Household incomes from agriculture	5.4%	7.3%	5.1%	8.2%
Household incomes previously from agricultural products	15.9%	17.1%	21.9%	25.1%
Household incomes from private enterprise	33%	27%	46%	41%

Source: Author, based on NBS households survey 2020.

3.2. Random forest classification scheme

We used a random forest classifier (Breiman 2001) to group different land cover pixels. Random forest is a robust tree-based classifier that can detect noise (Pelletier *et al* 2017) and builds several trees from random prototypes of the training data (Denisko and Hoffman 2018). We set the two main parameters in our RF algorithm—the number of trees to be nurtured (ntree) and the number of generated features (mtry). We set the ntree parameter so multiple iterations can generate a better result (Fox *et al* 2017). This is applied when the number of the predictor variables is large (Strobl *et al* 2009). The mtry parameter equally affects each distinct tree's correlation and intensity, influencing the generalization error and classification accuracy (Breiman 2001). We set both parameters to get the best performance of our model. For ntree, we set the number of iterations of trees to 500 and increased the values based on our results, and for mtry, we ran different iterations for every subset of our training data. We selected the model with the best results, i.e, the model with the least prediction error and the best accuracy compared to the validation data (Calderón-Loor *et al* 2021). Six urban land cover types were classified using the random forest model (figure 4). To validate our training data, we divided the training data randomly into two parts. Subsequently, we used 70% of these training data for the urban land cover classification and 30% for the validation data (Calderón-Loor *et al* 2021).

3.3. Feature data selection

A large input of datasets usually affects the classifier's performance by generating multi-collinearity and redundant data (Paul and Kumar 2019, Schulz *et al* 2021). Feature selection tends to lower the noise level in the data by removing redundant features through aggregating smaller features into useful parts (Cao *et al* 2017). With random forest classifiers, features were generated and tested to check the performance of the model. The first set of data containing all the bands was selected without using the feature selection. However, the second set of data was selected based on reduction of multi-collinearity (Katrutsa and Strijov 2017). This was accomplished through the calculation of the correlation matrix of all features and a stepwise process of removing pairs of features with correlations higher than 0.7; the filter feature was a set based on mutual information and multi-collinearity using an approach (Jin *et al* 2019, Kiala *et al* 2019) for feature sets that had correlation values higher than the marginal threshold.

3.4. Accuracy assessment and post-classification

We used the validation data to compute eight confusion matrices, one per year, to determine the producer, user, and overall accuracy of the urban land cover classification. To check the urban land cover classification error, we computed the omission and commission errors (Olofsson *et al* 2014). Additionally, we used the urban land cover classes to calculate per-class pixel confidence metrics to measure these contract levels (Shadman Roodposhti *et al* 2019). To assess the accuracy of our urban land cover change map, we randomly spread our GPS coordinate points across each urban land use class. We visually examined all the pixels and the temporal changes in urban land cover classes for each year. Subsequently, we computed statistical metrics to assess urban land transition in the different classes (table 1). Post-land cover classification between changes in other land cover classes often leads to estimation errors (Olofsson *et al* 2014). However, we used our reference data to measure the adjusted error in each urban land cover class (Olofsson *et al* 2014).

4. Results

4.1. The local economy in the urban periphery of Nigeria

The transformation in the employment sector is the primary force instigating rural–urban migration in Nigeria. Our findings in table 2 show that the majority of the people do not engage in agricultural income-earning. Presently, in Warri and Uyo, less than 12.7 percent of the household depends on an agrarian income, in contrast to 13.3 percent in both Aba and Umuahia. Furthermore, 33 percent of households in both Warri and Uyo, and 47 percent in both Aba and Umuhia, indicated that they previously made a living from agricultural incomes. This shift in employment activities can also be seen among the youth of the areas, allowing agricultural activities

Table 3. Urban occupations by sector.

Occupation of households in urban areas	Warri (%)	Uyo (%)	Aba (%)	Umuahia (%)
Private enterprise owner	49.1	43.6	55.4	48.1
Construction employees	3.6	5.2	1.3	2.4
Public workers (Government)	14.2	16.4	9.6	12.4
Petty traders (Hawkers)	6.7	5.3	9.5	7.3
Private, professional practice	2.3	1.6	1.4	1.8
Labor worker(manual)	13.7	16.4	9.3	12.8
Farmers	8.3	9.5	9.2	10.2
Apprenticeship workers		1.3	3.1	2.6
Skillful workers (Technicians)	2.1	3.4	1.1	3.3

Source: Author, based on NBS households survey 2020.

Table 4. Migration in urban areas.

	Warri % (N = 212)	Uyo % (N = 201)	Aba % (N = 198)	Umuahia % (N = 205)
Immigration	16.4	14.8	6.3	5.1
Emigration	5.1	7.3	10.2	12.3

Source: Author, based on NBS households survey 2020.

to sink into extinction, indicate a higher increase of unemployed people in the urban areas. This increase shows that the Aba and Umuahia switch is more recent than that in Warri and Uyo.

Figure 4 show that most households working in the urban centers live in the unplanned suburban areas, characterized by informal settlement patterns, particularly in Warri and Uyo. Many have abandoned their subsistent farming and commute long distances in search of a white-collar job. Warri and Uyo provide more job opportunities than Aba and Umuahia due to their larger sizes and being the location of major crude oil industries in the region. Table 3 indicates the type of work in households living in the urban periphery, and findings show 14.2 percent in Warri, and 16.4 percent in Uyo are public workers, and 49.1 percent and 43.6 percent are private enterprise owners in Warri and Uyo, respectively. In comparison, 9.6 percent and 12.4 percent are public workers in Aba and Umuahia, respectively, and 55.4 percent and 48.1 percent of urban residents in Aba and Umuahia, respectively, are in private enterprises. This primarily consists of retail shops, hair salons, photocopying centers, and other forms of businesses. The interview data show most households go into private enterprise due to limited employment opportunities in the urban areas, while some sell their family-landed property to fund the enterprise. In some cases, they must serve a master (business owner) without salary for seven years (with only a stipend) to accumulate unpaid salary to start their own business in the eighth year. This practice is quite common in Aba and Umuahia.

The second most common employment opportunities in the urban areas are as manual workers (13.7%, 16.4% in Warri Uyo, respectively, and 9.3% 12.8% in Aba and Umuahia, respectively), such as brick layers, tailors, phone repairers, street hawkers, small roadside businesses, and drivers.

Companies are rarely big or large-scale in Nigeria. In Warri and Uyo, more than 40 percent of the companies are small, in contrast to 70 percent in Aba and Umuahia. Over 80% of these companies do not have more than twenty employees, including the owner and his household. Table 4 indicates that the local population often seek employment opportunities elsewhere due to limited job opportunities in their communities. Few of the companies in Warri and Uyo are larger than those in Aba and Umuahia, implying that urban migration is imminent and is more rampant than in Aba and Umuahia (table 4). As shown in table 5, most of these companies sell spare parts, electronics, secondhand clothing, phone accessories, and other small-scale products. Production is carried out on a small scale and goods are rarely exported. These companies produce goods such as crude oil, aluminum doors, fashion designs, baked goods, shoes, and others. In some cases, due to low sales, products can only be made based on customers' requests, indicating a low turnover for these companies. However, Aba and Umuahia engage more in small-scale economies, where most workers commute long distances to hawk different items along motorways in the urban centers, though this has a minimal effect on urban land in Umuahia (figure 4).

In the different suburban areas, there is clear proof of a cluster around the various built-up areas (figure 4), and retail businesses are likely to emerge more in the different regions. Furthermore, labor migration is low in Aba and Umuahia. Nevertheless, it plays a significant role in urban densification in Warri and Uyo through people relocating to these areas in pursuit of jobs with oil firms, which are rare and, thereby, result in people

Table 5. Firm employment rate in urban areas.

	Warri %	Uyo %	Aba %	Umuahia %
Education (private and public service)	33.1	29.2	20.3	25.1
Construction (private)	3.3	5.6	1.2	3.5
Technology (technicians)	2.6	1.9	3.7	2.9
Health (private and public)	9.3	7.8	6.3	9.7
Merchandising (sales, wholesale, and retail)	46.3	48.8	61.4	54.6
Production	1.3	2.1	0.7	
Transportation	2.4	3.2	5.3	2.4
Professional practice firm (real estate values, etc)	1.7	1.4	1.1	1.8

Source: Author, based on NBS households survey 2020.

opening small-scale businesses to survive in the urban areas. Many companies import goods from within their region. In Warri and Uyo, 31% of the companies' goods are produced in the region, while in Aba and Umuahia the level is over 64%. Finally, urban transition in Warri and Uyo has existed for a long time. The urban areas are densely packed with various unapproved buildings marked for demolition due to the lack of governmental approval. The urban population cannot be sustained by the small manufacturing sector. This has forced more people to work outside the urban areas. However, the local economic patterns in the four cities are similar, such as the prevalence of small-scale and retail businesses. Additionally, while the local economic growth in Warri and Uyo appears higher, it has not evolved significantly in contrast to Aba and Umuahia.

4.2. The federal allocation remittance

The increases in the shared natural resource revenue to most states in Nigeria have influenced urban growth in cities across the country. This revenue is being shared based on the natural resources found in the states. The Delta and Akwa Ibom states are among the pioneers that have driven Nigeria's economy with their natural resources (crude oil). The inflow of this revenue from the federal government plays a key role in urban development and the growth of the local economy in cities across Nigeria. In addition, studies show that the influx of capital from activities elsewhere usually accelerates, but does not maintain, the local economic process (van Duijne *et al* 2022). These revenue influxes were related in the four cities, but were particularly very effective in Warri and Uyo, which received more share of the oil revenue from the federal government than Aba and Umuahia due to the presence of oil wells in their states. This capital inflow triggers growth in these localities. Examples include: (i) increasing salaries for public workers, which encourages expansion in retail sectors—in Warri and Uyo, public servants are known to open small-scale businesses to boost their household incomes; (ii) supporting individual businesses and companies to boost their production and reduce unemployment in the cities—across the four cities, 46% of private enterprises and 33% of individuals have benefited from this revenue; (iii) supporting infrastructural development, such as road construction, mounting electricity poles, expansion of drinking water distribution networks, and other infrastructural projects. According to the 64% of household responses in the survey data, cities have evolved in the past twelfth years, pushing development, extinction of agricultural land, and demolition/reconstruction of cluster settlements to modernize their cities.

However, a shared natural resource revenue is essential to urban geographers in evolving urban developments. A shared natural resource revenue as shown in figure 3, can be perceived as a major driver of urban growth in these regions, resulting in injected urbanism, which means investing income generated elsewhere (van Duijne *et al* 2022). An estimated 78 percent and 82 percent of revenue sources in Warri and Uyo depend on the shared natural resource revenue, in contrast to Aba and Umuahia, which uses its local economic revenue to sustain urban development (figure 3). This can be attributed to poor infrastructural development and the slow urban development pace in Umuahia (figure 4). In Warri and Uyo, the shared natural resource revenue aids in financing infrastructural expansion, creating more white-collar employment, providing no-interest loans to private enterprises, and creating a consumption-based economy and unplanned building expansion patterns. However, there is uncertainty for long-term urban sustainability in these areas receiving the natural resource revenue. If the external revenue source is not properly managed, the urban formations and their resilience may be challenging to maintain in the long term.

4.3. Urban land cover classification

We produced multi-temporal high-resolution land cover maps using a consistent random forest (RF) classifier methodology for southeastern Nigeria from 2000 to 2020 (figure 4). The classification's overall accuracy was from 82% to 91%, and the producer and user accuracy ranged from 67% to 99%, for the study areas. The accuracies were not consistent at the class level, i.e, the user accuracy for Warri in 2020 ranged from 60% to 90%

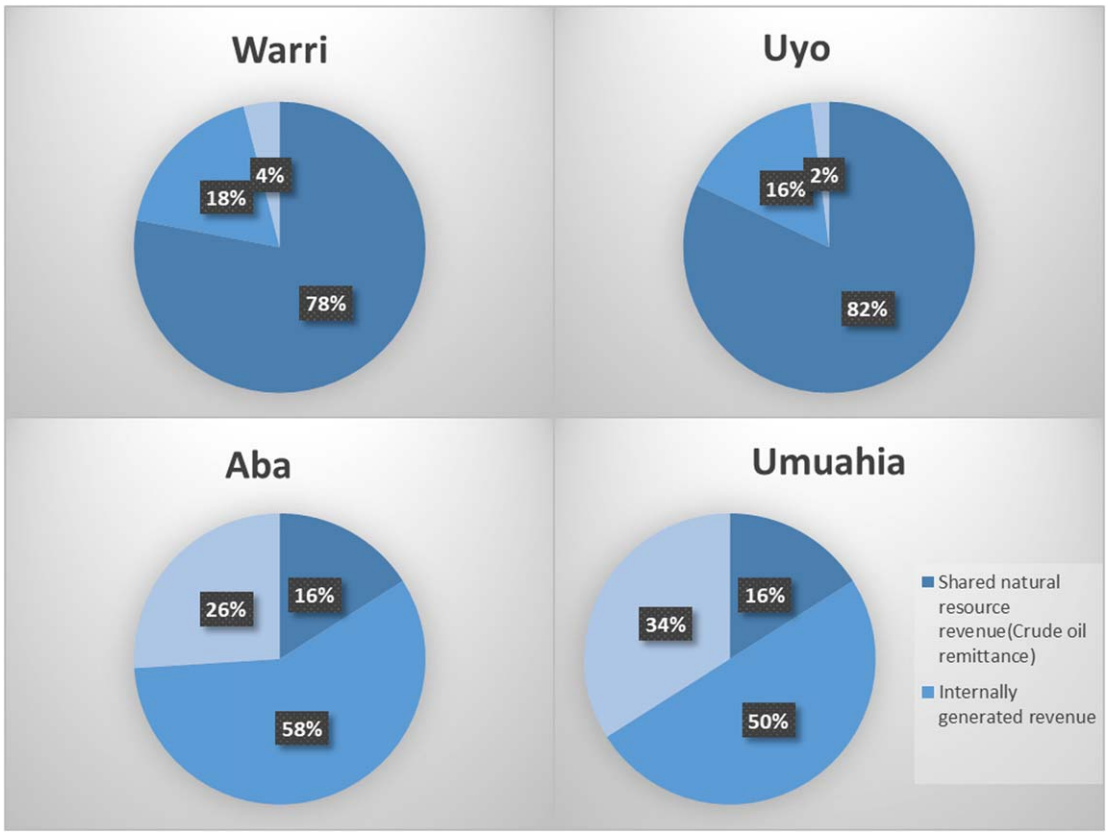

Figure 3. Source of the states' revenue (Source: Author, based on NBS households survey 2020).

for residential and commercial areas; however, for mixed usage and cropland the producer accuracy ranged from 80% to 90% (tables 6 and 7). This followed a similar pattern for other years, with residential and mixed usage having the lowest producer and user accuracy (tables 6 and 7). We also found a few misclassifications in residential and commercial areas. Similarly, the land cover map of Warri shows a high level of ambiguity, with confusion between commercial, residential areas and mixed usage (tables 6 and 7).

The land cover map illustrates that around 12.6% of the total land has experienced a significant land cover change in the study areas. Residential areas in Warri and Uyo experienced the highest expansion of 5% (35 km^2) and 21% (42 km^2), respectively, in 2020 compared to the area covered in 2000, increasing mainly from previous croplands (tables 6 and 7). Contrarily, forest areas have undergone the biggest decrease in size from 2000 to 2020 by 11.5% (−92.5 km^2) in Warri, and 34% in Uyo (−65 km^2). Cropland also experienced an area loss of 27.1% (−67.1 km^2) in Warri and 62% (−65 km^2) in Uyo, with most of these areas being transformed into commercial and mixed usage areas. The residential land cover class in Warri was relatively stable from 2000 to 2020, with a 5% increase in area (table 6).

In Aba and Umuahia, the residential areas experienced a relative expansion of 19% (40 km^2), 5% (18 km^2) by 2020, spreading across different land cover classes than its size in 2000. Again, forest areas suffered the highest losses, decreasing by between 2000 to 2020 by 44% (−58 km^2) in Aba and 13% (−93 km^2) in Umuahia (table 7). Cropland areas also suffered relative losses of 39% (−92 km^2) in Aba and 27% (−59 km^2) in Umuahia, with most of these areas being transformed into residential and mixed-usage areas (table 7). Furthermore, Warri and Uyo experienced a more significant increase in residential, 26%, and mixed usage, 46%, from 2000 to 2020 (figure 4) based on the negative impact of urban migration (table 4). In contrast, Aba and Umuahia experienced changes of 24% in the residential area that are not relatively continuous towards the city's center, and mixed usage has increased by 37% (figure 4) due to the relative increase in small-scale businesses in this area. Aba has been the commercial city for the entire southeastern region with a market-oriented base economy. As shown in (table 6), mixed usage and commercial area are the urban land cover classes that experience the highest increase in all four cities. These classes are solely located in the urban communities where many migrants create informal settlements, and most local economic activities occur. These activities put further pressure on residential areas and other classes within the urban communities by forming clusters along many built-up areas. This can also lead to urban agglomeration that can foster the emergence of new suburban areas if not adequately monitored.

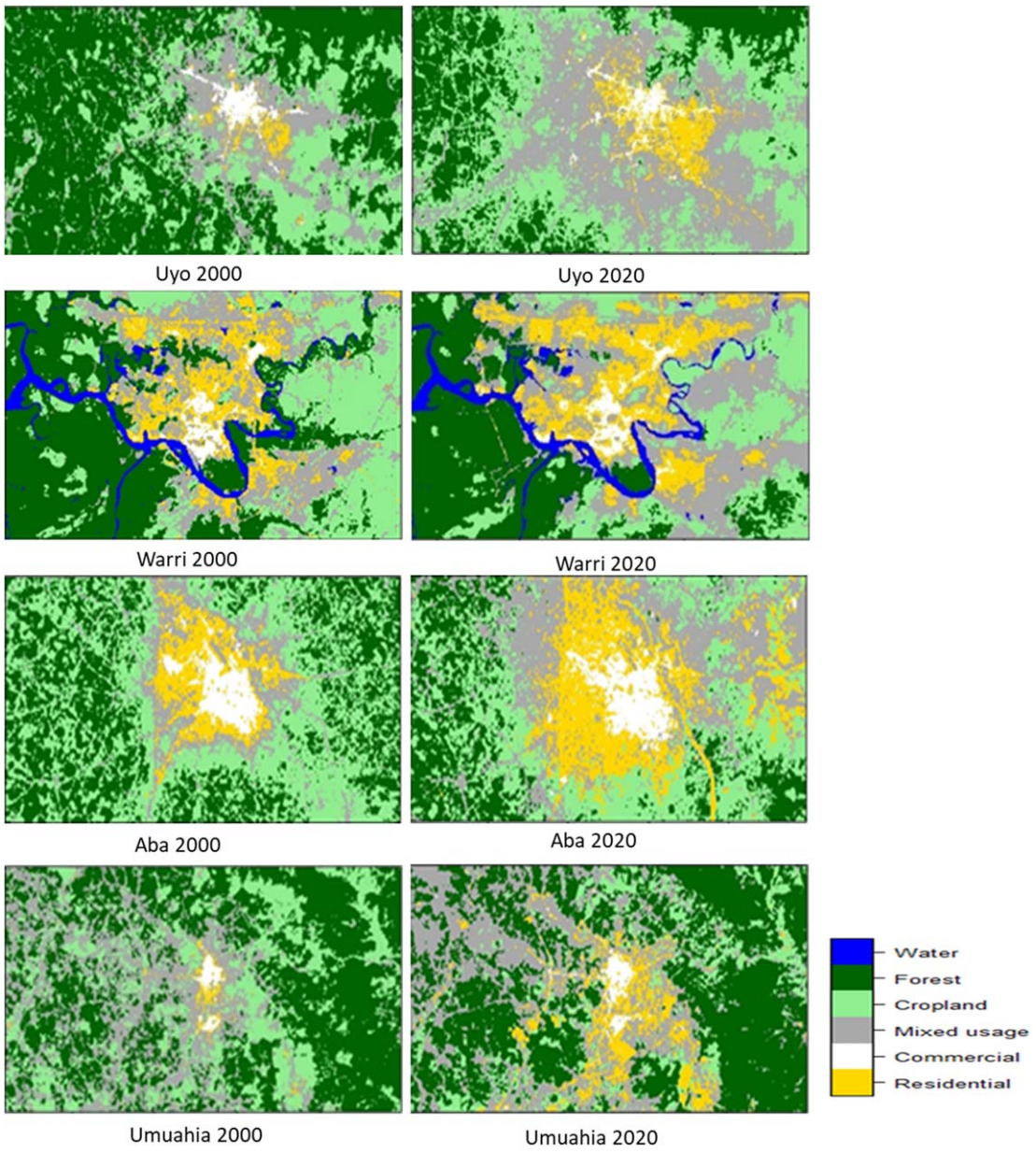

Figure 4. A map of the urban land cover change in the four Nigerian cities studied.

5. Discussion

Our study aimed to explicate the urban formation process in Nigerian cities and to build on the present traits of urban literature. The literature on urban growth has provided significant insights into urban growth in metropolitan cities (Taubenböck *et al* 2012, Güneralp and Seto 2013, Brenner and Schmid 2015, Mahendra and Seto 2019, Sapena *et al* 2020, Simone 2020). However, there are few studies on urban growth in African cities (Güneralp *et al* 2017, Pieterse 2019), and a scientifically reflexive empirical study is vital to address this limitation (Nijman 2015a, Robbin *et al* 2022). We explored the remote sensing data, structure switching, and transduction approaches, allowing us to consider different theoretical viewpoints in a continuous interplay with empirical observations (van Meeteren *et al* 2016, Schmid *et al* 2018, van Duijne *et al* 2022).

Our study shows that the urban growth processes in Warri and Uyo are primarily triggered by labor migration, agreeing with the results of the existing literature on urban studies (Gao *et al* 2014, Li *et al* 2015, van Duijne *et al* 2022). In Aba and Umuahia, our findings show that a low income and the lack of modern facilities to process agricultural products are the key drivers of the local economic reform. However, the production of agricultural goods is low across the different cities in Nigeria, which has created more informal settlements in the urban areas (figure 4), and Warri and Uyo have formed relatively small urban clusters in these settlements. The local goods are not exported outside the country and are rarely distributed outside the region due to poor road

Table 6. Changes in urban land classes from 2000 to 2020.

	Aba (area/km^2)			Umuahia (area/km^2)			Uyo (area/km^2)			Warri (area/km^2)		
Land cover types	2000	2020	Changes %	2000	2020	Changes %	2000	2020	Changes %	2000	2020	Changes %
Residential	21	40	19	13	18	5	21	42	21	30	35	5
Commercial	13	25	12	10	18.5	8.5	13	23	10	14	15.2	1.2
Mixed usage	34	54	20	55	72	17	41	63	22	53	77	24
Cropland	131	92	−39	86	59	−27	127	65	−62	94	67.1	−27.1
Forest	102	58	−44	106	93	−13	99	65	−34	104	92.5	−11.5
Water										13	6.1	−7.1

Table 7. Confusion matrix and validation points for Warri 2020 urban land classification.

	Residential	Commercial	Mixed usage	Cropland	Forest	Water	PA	UA
Residential	258	65	177	0	0	0	0.7	0.6
Commercial	17	479	4	0	0	0	0.8	0.9
Mixed usage	55	2	423	17	0	3	0.7	0.8
Cropland	0	0	0	460	40	0	0.9	0.9
Forest	0	0	0	4	496	0	0.9	0.9
Water	0	0	0	0	0	500	0.9	1.0

*****PA: Producer Accuracy; UA: User Accuracy******

networks in some areas. This has meant that the goods are produced for retail and consumption only in the local regions.

With regard to migration, the urbanization processes in our study areas differ from the urban growth in the developed world. Emigration is relatively low due to limited employment opportunities and the high cost of living in the big cities such as Lagos and Abuja. Immigration is moderate since people don't understand the local economic settings in cities, resulting in migrants going back and forth when they can't find urban employment opportunities. This means that the local populations are relatively stable across the regions. However, in the study areas it is common to sell the family-landed property to fund and encourage the male children to go into private business, after having gained more experience learning the business elsewhere in the community. This approach has given rise to various retail enterprises and created new urban formations. The adverse effects of the loss of family-landed property and agricultural land has been neglected in the past (Essien and Samimi 2021).

The sharing of revenue from natural resources (crude oil) by the federal government, and other local income sources, has boosted the reform of the local economy and shaped many informal settlements in the urban areas. This has resulted in an urbanization process that depends on remittance income from other places (van Duijne *et al* 2022). Our study shows that the spatial characteristics of urban growth in the four cities and their urban formations are relatively different. The agrarian land cover is small, and areas with a high level of economic restructuring are urbanizing. The patterns of built-up areas in Aba and Umuahia reflect local economic reforms in terms of expansion in residential and commercial areas (figure 4). In contrast, Warri and Uyo show more of an infusion of the shared natural resource revenue from the federal government in terms of urban infrastructural development and the implementation of different housing schemes by the state government.

Furthermore, our results show that the mixed usage and commercial areas have user accuracies of 81.2 percent and 90 percent, respectively, and producer accuracies of 70 percent and 80.6 percent, respectively, which we consider to be high given that previous studies did not identify these classes (Akpan-Ebe1 *et al* 2016, Nse *et al* 2020). In particular, bare land and vegetation covers were better differentiated from cropland than in previous studies in the same study area. Bloch *et al* (2015) used a pixel-based approach to map urban areas across Nigeria, but mixed usage was not differentiated from built-up areas. This may be a result of the urban agglomeration in sub–Saharan Africa. This is why recent studies have mostly used image segmentation and high-resolution satellite data to map land use cover in Africa (McCarty *et al* 2017, Neigh *et al* 2018, Schulz *et al* 2021). However, our results show that the Landsat 30-m resolution was able to map mixed usage and commercial areas when using a three-by-three matrix filter with a 30 m grid cell size, which agreed with previous studies (Jin *et al* 2019, Sedano *et al* 2019, Samasse *et al* 2020).

In addition to the qualitative improvement by differentiating previous land use classes (mixed usage and commercial areas) in our urban land use map, we discovered that the existing urban land cover map was not able to depict commercial areas. A significant part of the commercial area was classified as a built-up area by similar studies (Akpan-Ebe1 *et al* 2016, Nse *et al* 2020). Relying on satellite data alone, as previous studies have (Akpan-Ebe1 *et al* 2016, Nse *et al* 2020, Mashi *et al* 2021), could have its limitations in identifying commercial areas in sub–Saharan Africa, particularly the informal and cluster settlements, which are the core developmental areas that usually trigger the local economic growth in Africa. Especially in our study areas, informal settlements have intensified urban expansion in the residential areas by absorbing adjacent new suburban areas into the urban periphery due to accelerated small-scale local economic growth (figure 4). These spatial expansions keep focusing on the periphery of existing urban communities and put pressure on the urban edge to be continuously shifted for development purposes. These results concur with other studies (UNCTADstat 2014, World Bank 2016) showing that peripheral growth and increases in urban land cover change significantly affect a city's development. In addition, the suburban land expansion in 2020, as shown in our spatial maps, is marked by residential areas emerging as unplanned informal settlements, while commercial areas and mixed usage areas coexist with planned and unplanned residential growth (figure 4). Similarly, commercial and mixed usage space is pervaded by open spaces, recreation centers, informal markets, and small-scale retail shops. In Aba, for

instance, the local economy has triggered the increase of commercial and mixed usage areas along road networks and newly developed suburban areas, i.e., many shopping malls have been opened within the road networks close to the urban edge. These structures comprise supermarkets, Shoprite, and other diverse small-scale business activities influencing urban land cover changes (figure 4).

6. Conclusions

In this study, we show that our case studies provide a reference base for the many urbanizing cities in Nigeria, especially the developing cities in Africa that are underrepresented in the research literature on urbanization, but are experiencing the loss of agricultural land and reforms in the local economy. Sharing the revenue from the natural resources triggers urbanization and could be practiced in other parts of Africa and the undeveloped world, where this revenue is used as the nation's primary income source. In Nigeria, this economic restructuring is creating new challenges for the millions of people living in the urban areas, and this study empirically identifies the source of these social problems. In addition, we provide a comprehensive urban land cover map of four cities in Nigeria and show the capability of remote sensing to map core agglomerated settlements in Nigeria. Our urban land cover map can be used for various purposes such as the perception and exploring of urban expansion, analyzing the local economic situation, and monitoring and planning growth in built-up areas. Our results demonstrate the mapping of mixed usage and commercial areas that are the direct effect of local economic growth, but have not been included in previous studies.

Data availability statement

All data that support the findings of this study are included within the article (and any supplementary files).

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