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Tripartite relationship of urban planning, city growth, and health for sustainable development in Akure, Nigeria

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We live in an urban planet. As the world continues to urbanize, urban development that support the health and wellbeing of city dwellers is far more important than ever before to achieve sustainable development targets. This study explores the complex relationship among urban planning, city growth, and health as critical drivers of sustainable development in the rapidly growing nodal city of Akure, Nigeria. The study provides a four-decade spatio-temporal model of urban Land Use Land Cover (LULC) changes in Akure between the years 1984 and 2023 from acquired Landsat satellite imageries. The result shows more than 20% net change increase in developed LULC classes between the study years. A strong positive correlation exists between the years covered in the analyses and urban development (r = 0.93, p = 0.002), and a strong negative relationship with the forest land use (r = –0.94, p = 0.002) with potential debilitating impacts on residents' health, green infrastructures and the city's sustainability in the future. Furthermore, results of key informant interviews (KIIs) of officials of the Ministry of Physical Planning and Urban Development (MPPUD) in Akure, Ondo State, unveil various views on the "place of health" in urban planning practices in Akure. A lack of synergy between urban planners and public health practitioners in the city and limiting scope of functions of urban planning on the impact of health in Akure were observed. Thus, we recommend the integration of a sustainable urban planning approach as a guide to manage the city.

KEYWORDS

sustainable development, sustainable urban planning, urban health, urban growth, Nigeria

1 Introduction

There is no doubt we live on an urban planet due to the rapid and ongoing urbanization phenomenon the world is experiencing. Urbanization is a process through which the cities grow. Kuddus et al. (2020) refer to urbanization as a mass movement of populations or population shifts from rural to urban settings. The turning point in world history was in 2007 when, for the first time, more people lived in cities compared to rural areas (Aliyu and Amadu, 2017).

The United Nations estimated that 55% of the world's population resided in urban areas in 2018; while this figure was 30% in 1950, and it is expected to increase to 68% by 2050

(United Nations Department of Economic and Social Affairs, Population Division, 2015). Furthermore, this implies that the number of urban dwellers will grow by 2.5 billion between 2018 and 2050, and two-thirds of all humans will live in cities (United Nations Department of Economic and Social Affairs, Population Division, 2015). Hence, the future is urban.

The projected population growth in cities and urbanization levels vary among regions of the world. United Nations Department of Economic and Social Affairs, Population Division (2015) asserted that most of the population growth will occur in the lower-income regions of Africa and Asia while the urban population will triple and double in Africa and Asia, respectively. Although Northern America and Europe are mostly urbanized, Africa and Asia are rapidly catching up and urbanising faster compared to other regions, with the possibility to become 56 and 64% urban, respectively (Alirol et al., 2011; Aliyu and Amadu, 2017). Notably, Nigeria in West Africa, China and India in Asia are expected to experience the highest level of urbanization and urban growth by 2050 (Aliyu and Amadu, 2017).

Urbanization is majorly a result of economic development and industrialization, which often result in changes in urban settings (Keivani, 2009; Kuddus et al., 2020). Some of these changes (positive) can be physical, such as the development of infrastructures to service the urban residents; economic changes, such as increased wages, and socio-economic changes, such as increased living standards in urban places (Chen et al., 2013; Ya-Feng et al., 2020). Contrarily to the positive changes, substantial and severe problems induced by urbanization, such as the unreasonable layout of urban spaces and uncontrolled and extensive urban physical development, are notable in urban areas (Jiao, 2015; Liu and Wang, 2016).

Nigeria is not left out from rapid urbanization processes and associated uncontrolled urban expansion. According to Urbanization Research Nigeria, the urbanization rate in Nigeria was projected to be approximately 52% in 2020 based on the report compiled in 2015 (Bloch et al., 2015). Further to their findings, the urban growth (spatial) and physical development in Nigeria are increasing and concentrated around four major urban fields, among which are the south-western conurbation that stretches from Lagos in the south to Ilorin in the north and Akure in the east. Particularly in Akure, (Owoeye and Ibitoye, 2016) averred that the economic factor is the major driver of the city's urbanization because Akure is part of crude oil producing regions in Nigeria. Other factors are the educational and nodality of the city with respect to transportation (Owoeye and Ibitoye, 2016; Bayode and Siegmund, 2022).

Associated with rapid population growth and urbanization is the expansion of existing built-up/developed land area and land cover. Seto et al. (2012) asserted that urban land cover will increase by 1.2 million km^2 by the year 2030, which is approximately three times the urban land cover in 2000. This phenomenon contributes to urban sprawl, which calls for monitoring (Alabi, 2022). Therefore, it is important to study how cities' spatial extent increases and how cities are planned and sustainably managed. Geographic information systems (GIS) and remote sensing have proved to be valuable tools for monitoring urban land cover and use (Younes et al., 2023).

Rapid urbanization can hinder human and sustainable development by predisposing urban residents to negative health outcomes and increasing vulnerability to health risks. For example, unequal distribution of health infrastructures and social and economic inequities can exacerbate health inequalities (Aliyu and Amadu, 2017). Cities in low-income and middle-income countries (LMICs), such as Nigeria, are breeding grounds for poverty, inequality, environmental hazards, increased traffic accidents and injuries, spread of communicable diseases, and air pollution, among others (Moore et al., 2003; Kuddus et al., 2020). Therefore, rapid urbanization and the scale of the urban population constitute major public health challenges of the twenty-first century for urban planners and governments (Aliyu and Amadu, 2017).

Urban environmental conditions and the quality of built environments are important to the health and quality of life of a city's inhabitants. Northridge and Freeman (2011) and Carmichael et al. (2019) posited that urban (spatial) planning systems have the capacity to reduce urban health inequalities as an enabler of urban health. Through impacting the physical urban environment, urban planning and design processes can directly impact physical and mental health and social wellbeing and reduce health inequities in various ways (Smit et al., 2011). For example, the works of Jackson (2003) and UN-Habitat (2007) show the impact of built environment, urban planning policy, and city design on the mental and physical health of urban residents. However, limited consideration has been given to the impact of urban planning on urban health, thereby hindering sustainable development in LMICs (Smit et al., 2011; Tuhkanen et al., 2022).

A number of scholars alluded the complex relationship among sustainability, urban planning, and health in cities; nonetheless, these relationships have not been sufficiently explored in LMICs such as Nigeria (Northridge and Freeman 2011; Siri, 2016; Vardoulakis and Kinney, 2019; UN-Habitat and World Health Organization, 2020). Earlier studies in LMICs explored urban growth without drawing a nexus to the health impacts of urban growth (Hassan et al., 2016; Owoeye and Ibitoye, 2016; Mohammadi and Sharifi, 2021; Moradi and Sharifi, 2023; Seyam et al., 2023; Younes et al., 2023).

Akure is a medium-sized city that is rapidly growing among Nigerian cities, whose residents' health and urban growth (spatial) have been explored by several researchers (Bloch et al., 2015). With respect to urban (spatial) growth and modeling, Owoeye and Ibitoye (2016) explored land use change detection in Akure using remote sensing. Consequently, Usman et al. (2018) investigated the impact of urban sprawl in Akure with geospatial assessment, while Eke et al. (2017) analyzed the urban expansion of Akure using geographic information systems (GIS). Exploring the relationship between urban health and city growth, Alabi (2022) observed the financial and health toll of urban sprawl on residents of Akure, while Popoola et al. (2020) investigated how micro-climate is influenced by urban growth in Akure. Akinbamijo and Fasakin (2006) and Bayode and Siegmund (2022) explored determinants and disparities in the health status of Akure residents. These previous studies collectively lack comprehensive validation through statistical modeling and accuracy assessment, which limits the robustness of their findings. Moreover, theses previous studies have also failed to explore the complex relationships among city growth, urban planning, and health or investigate health concerns within the urban planning practices of Akure by incorporating the perspectives of experienced and active city planning officials. Thus, our study aims to fill the identified gaps by conducting a large-scale spatio-temporal urban growth modeling in Akure and investigating concerns for health issues by urban planners as the city experiences rapid urban growth yet not planned.

The objectives of this study are as follows: (a) explore and model the urban growth characteristics of Akure, Nigeria; (b) determine the temporal relationship between urban growth and other land use land cover classes; and (c) investigate if there are synergies between urban planners and public health officials in Akure on how to tackle potential health problems emanating from rapid urban expansion.

1.1 Urban planning and public health in cities

The health-focused origins of urban/town planning and public health can be traced to ideas and vision of planning pioneers and urban reformers—Ebenezer Howard and Patrick Geddes in Britain, Lewis Mumford in the United States, and Gräfin Dohna and James Hobrecht in Germany—more than a century ago over how urbanization was affecting the health of impoverished city residents, especially during the industrial revolution (Duhl and Sanchez, 1999; Northridge and Freeman, 2011; Baumgart, 2017). For example, the 1848 Public Health Act was put in place to combat infectious diseases in the crowded cities of Britain and building codes and emphasis on the efficient design and usage of public sewage were considered to reduce health inequalities (Peterson, 1979; Garb, 2003).

Despite the close tie, common origin and objectives between public health and urban planning, the two professional disciplines have had a roller-coaster relationship even after 1900 (Hebbert, 1999). The two professions parted ways in the early twentieth century when medical practice/public health professionals turned their attention from the environment and sanitarium to the science of bacteriology, i.e., biomedical causes of disease and disability (Hebbert, 1999; Northridge and Freeman, 2011). However, both disciplines are re-converging due to the complex health challenges of the twenty-first century.

In spite of the increasing number of urban dwellers globally, projections by the United Nations indicate that 75% of the infrastructure to service the projected population has not yet been built (UN-Habitat and World Health Organization, 2020). Communicable and infectious diseases thrive in overcrowded cities, slums, and places characterized by inadequate access to clean water, sanitation, and hygiene facilities. WHO and UN-Habitat (2020) noted that working and living in an unhealthy environment reportedly killed 12.6 million people in 2012, and approximately 4 years later, an estimated 7 million mortality cases were attributed to air pollution because only 1 in 10 cities worldwide meet standards for healthy air. Specifically, most of these challenges are more serious among cities in the Global South, where the confronted public health challenges and threats can be linked to urban and territorial planning (UN-Habitat and World Health Organization, 2020). Therefore, the increasing complexity of the urban environment and health in cities worldwide has once again steered the need for the convergence of the two disciplines (urban planning and public health) to proffer solutions to urban health challenges (Northridge and Freeman, 2011).

Rapid population growth and spatial expansion are some of the results of urbanization, which could birth poor urban physical development, weak urban planning control and poor sanitation, thereby making the urban environment incapable of providing the need for healthy shelter, potable water, waste disposal, and health service. The consequence of this led to the spread of diseases and the enactment of decrees to guide the use of land (Oyewale, 2003). This shows that the quality of the urban environment and urban health status are influenced by urban planning decisions (Didier et al., 2009).

There are direct and indirect health risks posed by the urban environments. Direct risks occur when people are inadequately protected against or exposed to disease-inducing agents, such as polluted air, soil, or water. Indirect health risks can occur through the degradation of urban and hinterland resources, depletion of green infrastructures and forest covers, low-quality urban spaces, ecosystem disruptions, inadequate waste management, and poor transportation infrastructures (Didier et al., 2009). Collectively, these risks affect both the health of urban residents and the health of the city since these urban health and environmental challenges are fallouts of how we organize, develop, manage, and live in the cities (Dodman, 2009).

Rapid urbanization and urban life are characterized by high health inequality, and the urban poor bear the brunt of the health challenges (Elsey et al., 2019). The urban poor, who are often the residents of slums and squalor or densely populated places, are vulnerable to high disease transmission, illness resulting from proximity to toxic and hazardous wastes, lack of clean water and sanitation, and water, air, and noise pollution (Satterthwaite, 1997). Urban poor are at risk of infectious diseases of poverty, such as typhoid, diarrhea, cholera, and intestinal worms from contaminated water and food, as well as waterborne diseases associated with malaria because of poor drainage and garbage collection (Meikle et al., 2001). Urban poor are restricted to geographically dangerous areas such as hillsides, riverbanks, and water basins subject to landslides, flooding, or industrial hazards (Kuddus et al., 2020). To address these health disparities in cities, urban planners are increasingly being called on by public health professionals (Corburn, 2005).

Public health issues ravaging cities identified at the 8th Global Conference on Health Promotion (2013), include obesity, diabetes, asthma, heart disease, cancer, communicable disease from overcrowding, malaria, pollution, traffic crashes, stress, industrial risk, and violence. However, several important aspects have been identified to tackle these public health issues. Some of the identified aspects include improved housing quality; equitable access to and improved coverage of basic services, recreational facilities, and regeneration of green spaces; transport options, including cycling and walking infrastructures; security from urban violence; and implementation of environmental laws to address environmental hazards and curb sprawling suburbs (UN-Habitat, 2007). To address these public health issues in cities, urban planning was therefore described as a vehicle that can aid the improvement of urban dwellers' health and achieve the New Urban Agenda targeting two of the 17 Sustainable Development Goals (SDGs), which are (i) ensure healthy lives and promote wellbeing for all at all ages, i.e., SDG 3 and (ii) make cities and human settlement inclusive, safe resilient, and sustainable, i.e., SDG 11 (WHO and UN-Habitat, 2020).

Human health and the physical environment are intricately linked. From the perspectives and tenets of public health planning, the physical environment is seen as having attributes that can be managed through social intervention that aims at enhancing the overall health and wellbeing of the entire urban system (Didier et al., 2009). This, therefore, requires cooperation and synergies between public health experts and urban planners, within and at the level of national and municipal authorities, communities, international organizations, non-governmental organizations, and researchers.

1.2 Urban planners as health experts

Lakshmanan (2012) asserted that urban and regional planning is an art of shaping and guiding the physical growth of towns and cities to meet the diverse needs of the public and to provide healthy conditions where people can live, work, and thrive physically, socially, and economically in an urban environment. Therefore, urban and regional planning can be described as a discipline that contains all elements—be it physical, social, cultural, economic, political, and ecological—of a town and other urban environment.

Urban planners, sometimes also called city and regional planners, are professionals who facilitate decision-making. Their role involves coordinating, facilitating, and creating a logical, systematic decision-making process that results in the best actions for urban or town dwellers (Litman, 2020). They also help a city to solve problems in the environment such as inadequate housing, traffic congestion, and the location of new schools and parks (Porter, 1999).

The practice of urban health promotion by controlling exposure to the agents of disease first came to fruition in the mid-nineteenth century, which provides the initial indication that urban planning is directly associated with health, in part due to the appalling effects from the fall outs of industrialization and urbanization (Duhl and Sanchez, 1999). During this period, urban planners took on the responsibilities of public health experts. Some of their objectives were the removal of unsanitary conditions and the beautification of cities; the main objectives of urban planning were functionality and public health or health promotion in cities as documented in the works and efforts of several pioneers such as Ebenezer Howard, Patrick Geddes, and Lewis Mumford who helped to shape and further the tenets of social and health planning (Egunjobi and Ogunmodede, 2019). Ever since, the goal and sole aim of urban planning has not changed.

According to Agbola and Oladoja (2003), urban planners make every person in a society realize his/her full human potential in a wholesome environment by creating a healthy, agreeable, and sustainable environment for everyday life through functional arrangement and location of facilities in space.

Urban planners, especially in the Global South, need to adopt new skills and revisit their ethical commitment. There is a need to incorporate these new demands and approaches into urban planning curricula and education (UN-Habitat, 2010). Relatively recently, new opportunities for increased collaboration between urban planning and health have emerged. Planners are increasingly involved in the preparation of joint strategic needs assessments and joint health and wellbeing strategies with health boards (Pineo, 2022).

2 Materials and methods

2.1 Study area

This study area, Akure, is located in the south-western part of Nigeria (see Supplementary Figure 1). It is a medium-sized capital city of Ondo State, and it lies in the tropics between E 5°04′42″--E 5°29′45″/N 7°26′43″--N 7°03′50″. Akure city is made up of two local Governments—Akure South and Akure North—which is relatively approximately 370 m above sea level in altitude. The city is experiencing rapid population increase and urban growth. Since Akure became the administrative capital of Ondo State, the population has increased tremendously and more than tripled. In 1963, the population of Akure was approximately 71,106, which rose to 239,124 in 1976, 239,124 in 1991, and 360,268 in 2006 (Owoeye and Ibitoye, 2016). Studies averred that the national census led to an underestimation of the population in some parts of Nigeria for political reasons, while alternative and objective population estimates from aerial imagery estimated the population of Akure to be over one million—1,283,541 (Tofowomo, 2008; Bayode and Siegmund, 2022). More about the study area have been discussed in Bayode and Siegmund (2022).

2.2 Data sources

2.2.1 Qualitative data and sampling technique

To augment the robustness of the dataset for this study, qualitative data were gathered by conducting key informant interviews (KIIs) with the officials/employees of the Ministry of Physical Planning and Urban Development (MPPUD).

Snowball sampling was adopted as the study qualitative data sampling technique to gather information about health within the scope of urban planning and growth in Akure. Snowball sampling is commonly engaged in qualitative research (Browne, 2005; Noy, 2008). It is particularly useful in registering "hidden populations," "very seldom" population, or "difficult to encounter" population (Dragan and Isaic-Maniu, 2022). The population is referred to as hidden in this context due to the low numbers of potential participants or the sensitivity of the topic (Browne, 2005). It is a recruitment method whereby one interviewee gives the researcher the name or contact of at least one or more potential persons who are eligible to be interviewed and so on (Browne, 2005; Kirchherr and Charles, 2018; Dragan and Isaic-Maniu, 2022).

According to the snowball technique, we were able to locate and interview a total of four officials between October and December 2021. They include two senior officers, one mid-level, and a junior officer. The KII was recorded and transcribed.

2.2.2 Satellite data

Satellite datasets are one of the new and effective methods of urban land use land cover or field monitoring (Zamani et al., 2022). The satellite data used for this study are Landsat satellite images from 1984 to 2023. They include Landsat 4 and Landsat 5 Thematic Mapper (TM), Landsat 7 Enhanced Thematic Mapper Plus (ETM+), Landsat 8 and Landsat 9 Operational Land Imager (OLI), and Thermal Infrared Sensor (TIRS). Landsat 4–5 consist of seven spectral bands with spatial resolution between 30 meters (Bands 1–5 and 7) and 120 meters (Band 6). Band 6 is thermal infrared but is resampled to 30-m pixels. Landsat 7 images consist of eight spectral bands with a spatial resolution of 30 m, excluding band 8, which is a panchromatic band with a spatial resolution of 15 m. Landsat 8 images consist of nine spectral bands with a spatial resolution of 30 m for Bands 1–7 and 9. Band 8 is 15-m panchromatic band, while the thermal bands 10 and 11 are collected at 100 m. The Landsat bands selected for this study all have a spatial resolution of 30 m.

Landsat images used for this study are open-source remote sensing images (data) obtained from the United States Geological

TABLE 1 Description of Landsat satellite images used for LULC analysis.

Year	Landsat satellite	Sensor	Composite bands	Spatial resolution (m)	Date of acquisition
1984	L5	Thematic mapper (TM)	Bands 4,3,2	30	11/12/1984
1991	L4	Thematic mapper (TM)	Bands 4,3,2	30	05/01/1991
1999	L7	Enhanced thematic mapper plus (ETM+)	Bands 4,3,2	30	13/12/1999
2002	L7	Enhanced thematic mapper plus (ETM+)	Bands 4,3,2	30	03/01/2002
2007	L7	Enhanced thematic mapper plus (ETM+)	Bands 4,3,2	30	12/12/2007
2014	L8	Operational land imager (OLI) and thermal infrared sensor (TIRS)	Bands 5,4,3	30	14/12/2014
2023	L9	Operational land imager (OLI) and thermal infrared sensor (TIRS)	Bands 5,4,3	30	14/02/2023

Survey (USGS) earth explore data portal.[1] The USGS data portal contains an extensive collection of publicly available geospatial datasets. We extracted the Landsat satellite imageries for Path 190 Row 055, wherein our study area is located.

Table 1 describes the Landsat sensors used for this study, their spatial resolution (i.e., pixel size), selected bands, and the date the images were captured. The Landsat images have different bands with varying wavelengths, as explicitly documented on https://www.usgs.gov/faqs/what-are-band-designations-landsat-satellites.

Before downloading the raster datasets from the portal, we developed a pragmatic search criterion to filter the datasets that have <10% cloud cover. Images between the months of December and February for each selected year were downloaded to minimize bias introduced to our results from seasonal variation and impacts of cloud cover (Taiwo et al., 2023). These months are part of the dry season months in Akure, Nigeria.

2.3 Data analysis

The data analytical techniques adopted for this study involve different tools, software, and stages. They are generally combinations of geographic information systems (GIS) and remote sensing (RS) technologies, as illustrated in Figure 1. GIS represents a combination of science and application (Laplante, 2015). It is a comprised system concerned with the organization, handling, manipulating, processing, and retrieving data whose spatial position or geographic pattern is of concern (Classen, 1977). RS is a method of collecting data at a distance from the object (earth's surface and atmosphere) under study through the use of electromagnetic sensors often by the use of satellites or aircraft (Schowengerdt, 2007). GIS and RS have been widely used in urban mapping and monitoring of urban development (Owoeye and Ibitoye, 2016; Usman et al., 2018; Popoola et al., 2020; Sharifi, 2020; Mohammadi and Sharifi, 2021; Saha et al., 2022; Moradi and Sharifi, 2023). After the pragmatic selection of the Landsat images (raster datasets) for this study, the image processing started with band combinations to develop a False Color Composite (FCC) of the images. The selected bands for composite bands/stacked bands vary from one sensor to another depending on the spectral characteristics. Bands 4, 3, and 2 were selected from Landsat 4, 5, and 7, while Bands 5, 4, and 3 were selected from Landsat 7 and 8. The analysis of the study's spatial extent was determined by clipping the FCC with the study area boundary shapefile.

The raster data processing was carried out in ArcGIS Pro. Furthermore, raster analysis such as fill gap was performed in QGIS to fill the data gaps in Landsat 7 image for the year 2007 because of Scan Line Corrector (SLC) failure in ETM+ in 2003.

2.3.1 Land use classification

Land use classification provides information on land cover and the various types of human activities for which land can be used (Karan and Samadder, 2018). The classification of land cover and use can be supervised or unsupervised. According to Richards (2013), supervised classification, the most frequently used for quantitative analysis of remote sensing data, was adopted for this study. It is a pixel-based classifier that classifies satellite image pixels based on spectral reflectance properties or multispectral composition that are similar or identical (Bayarsaikhan et al., 2009; Islami et al., 2022). The supervised classification process is mainly conducted in three steps, which are training sample selection, classification, and accuracy assessment (Seyam et al., 2023).

First, the training samples were created according to the default classification schema from the 2011 National Land Cover Database (Jin et al., 2019). Approximately 25 training samples were created for each LULC class. The five LULC classes in this study are forest, developed, water body, disturbed vegetation/cultivated, and barren/rock outcrop. The LULC is differentiated by colors to avoid confusion. This process was done using on-screen digitized features.

Second, image classification was carried out. A support Vector Machine (SVM) classifier was engaged to classify the images into five LULC classes. SVM is a supervised classification method commonly used in the LULC research community with associated advantages

1 https://earthexplorer.usgs.gov/

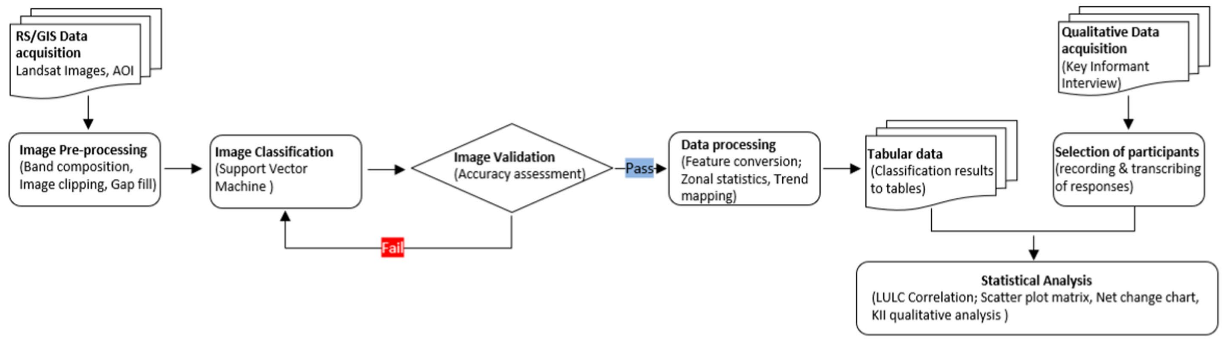

FIGURE 1
Data analysis workflow of the methodology.

such as requirements of fewer samples, less susceptibility to noise, and correlated bands (Mohammadi and Sharifi, 2021; AlDousari et al., 2022; Rahaman et al., 2022).

Based on the classification schema and classification grouping in the study by Rahaman et al. (2022), the following features can be found in the following classes. Forest area includes concentrated trees, dense plantation, gardens, and large parks. Developed areas include built-up residential, industrial, and commercial areas, impervious surfaces, and transportation networks. Water body includes ponds, lakes, wetlands, rivers, streams, and canals. Disturbed vegetation/cultivated area includes fragmented forest areas, croplands, grazing lands, etc. Barren/rock outcrop includes rocks, impervious areas, etc.

Third, data validation or evaluation for this study was conducted. This is further discussed in the next section (model validation). It is an interactive process of comparing classified LULC to the true value, i.e., ground truthing. The results for the data validation were quantified based on the Kappa assessment, and a decision was made. If the results were erroneous with a low score (i.e., fails), the data processing was carried out again till the results pass validation with high Kappa values.

2.3.2 Statistical analysis

The classified raster image was converted to polygon features upon which the Zonal Statistics as table was used to compute the area coverage (quantification) of LULC classes in square meters $\left(m^2\right)$. The tables were exported for further data statistical analysis—correlation—in R version 3.6.3. The correlation method adopted for this study is Pearson's Product Moment Correlation (Equation 1).

$$\rho_{x,y} = \frac{\sigma_{xy}}{\sigma_x \sigma_y} \quad (1)$$

Where $\rho_{x,y}$ represent the covariance between the two variables, σ_x represent the standard deviation of a land use land cover type/element, and σ_y represent the standard deviation of other land use land cover type/element. Pearson's correlation is widely used in LULC correlation analysis and some previous LULC studies (Awuh et al., 2019; Zhu et al., 2019; Maishella et al., 2020; Jamei et al., 2022; Aka et al., 2023; Yao et al., 2023) all adopted Pearson's correlation for their analysis.

Pearson's correlation is a parametric statistical test that measures the degree of linear association between two quantitative variables with association value results ranging from plus one (+1) to minus one (−1) in decreasing order of strength. A correlation value of +1 indicates a perfect positive relationship, a value of −1 indicates a perfect negative relationship, while 0 indicates no relationship/correlation (Lee Rodgers and Nicewander, 1988; Yim et al., 2010). Furthermore, Cohen et al. (2013) grouped correlation coefficients as follows: 0.10–0.29 indicate a weak/small relationship, 0.30–0.49 indicate a moderate/medium relationship, while values between 0.5 and 1.00 indicate a strong/large relationship. The key informant interview was recorded and transcribed for this study. Figure 1 shows the data analysis workflow methodology.

2.4 Model validation

It is crucial to carry out an assessment or validate the performance of the model, i.e., to test the reliability of the result or predicted land use land cover based on the training samples. The most common method of accuracy assessment to determine the accuracy result of land use classification is the contingency method (Islami et al., 2022). This is also known as a contingency matrix, confusion matrix, or error matrix.

For this study, the accuracy was assessed using an average of 267 ground truth data points (validation) or reference points. The reference points/data for this study were based on prior knowledge of the study area, field visits, and retrospective observations from Google Earth images according to studies by Aka et al. (2023) and Seyam et al. (2023). In addition to this, archives and classified maps of the study area were also considered. The distribution of the point follows a stratified random method, according to Hassan et al. (2016). In addition to quantitatively comparing classification results and reference data, other components of the confusion matrix, such as producer accuracy, user accuracy, overall accuracy, and non-parametric Kappa statistical test (coefficient), were performed to further quantify or measure the degree of the classification accuracy. Producer's accuracy and user's accuracy estimate overall accuracy (Islami et al., 2022). Particularly, overall accuracy represents the number of accurately classified pixels (LULC) of the Landsat imagery. Producer's accuracy is a false negative, i.e., errors of omission, while

User's accuracy depicts false positives, also referred to as errors of commission. The overall degree of agreement or classification precision is determined by the Kappa coefficient in Equation (2).

$$Kappa\ coefficient = \frac{(T\ x\ C) - D}{T^2 - D} \tag{2}$$

Where T is the test pixels, i.e., the total number of reference pixels, C is the total number of correctly classified pixels (Diagonal), and D is the sum of multiplied values of row and column. The accuracy assessment was carried out using Image analyst tools—segmentation and classification in ArcGIS Pro, while for explicit computation on producer's accuracy, user's accuracy, and overall accuracy (see Rwanga and Ndambuki, 2017; Talukdar et al., 2020; Islami et al., 2022).

3 Results

3.1 Spatio-temporal changes in LULC classes

The land use type for Akure since inception and from the processed Landsat image of 1984 shows that it was predominately forest land (Figure 2). According to Table 2, the spatial coverage of forest LULC in 1984 was approximately 85,513.68 hectares and 34,797.42 hectares by the year 2023, indicating a decrease of 46.16% in approximately four decades. This is contrary to the developed LULC class. Between the study years, developed land use shows an increasing trend. According to Table 2, developed land use land cover increased from 2,158.56 hectares to 22,591.53 hectares between the years 1984 and 2023, respectively, depicting a percentage increase of 18.6%. Increasing area coverage of developed land phenomenon is similar to the disturbed/cultivated land use land cover type. Based on our study analysis, the cultivated land increased from 7,652.34 hectares in 1984 to 35,505.99 hectares between 1984 and 2023. This depicts the highest increase, i.e., 27,853.65 hectares among the land use land cover classes. Developed land increased by 20,432.97 hectares, while forest land decreased by 50,716.3 hectares.

There was no distinctive increment in the values of rock outcrops and water bodies between the study periods. The values for the latter are low, likely because of the period (dry season) in which the imageries were captured.

3.2 Accuracy assessment and kappa coefficient

Supplementary Table 1 represents the result of the confusion matrix. The table also includes results of the user's accuracy (U_Accuracy), producer's accuracy (P_Accuracy), overall accuracy, and Kappa coefficient (Kappa). The Kappa index of agreement represents an overall assessment of the classification accuracy. The Kappa coefficients for the years 1984, 1991, 1999, 2002, 2007, 2014, and 2023 are 0.75, 0.77, 0.75, 0.86, 0.97, 0.74, and 0.96, respectively. According to rating criteria developed by Talukdar et al. (2020), Kappa coefficient values between 0.70 and 0.85 indicate very good or substantial agreement, while Kappa results higher than 0.85 indicate excellent or almost perfect agreement. Based on this criterion, the Kappa coefficient for this study is reliable, and classification accuracy is satisfactory. The image analysis for this study was done with freely available Landsat images of medium quality, and the season of acquisition has some ramifications in terms of accuracy, as noted by Seyam et al. (2023). This could have contributed to the discrepancies in the Kappa coefficients between the study years. We obtained some of the reference points from retrospective Google Earth images with dates that are not the same as Landsat image acquisition dates but very close. However, there are no discrepancies in the user's accuracy for

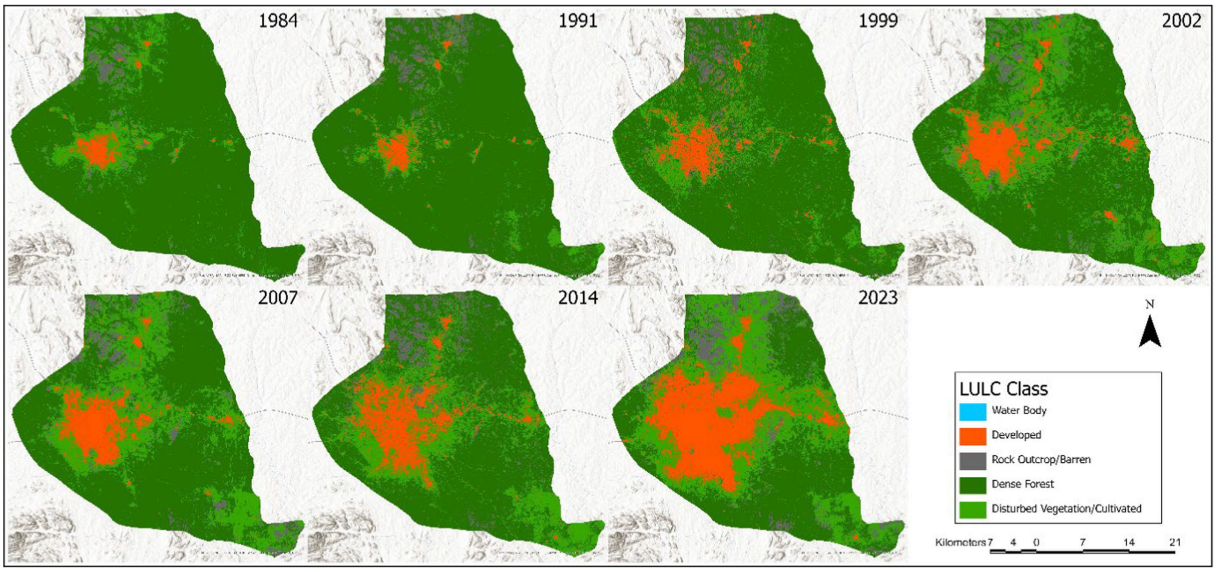

FIGURE 2
LULC classification for the years 1984, 1991, 1999, 2002, 2007, 2014, and 2023.

TABLE 2 LULC spatial coverage for the years 1984, 1991, 1999, 2002, 2007, 2014, and 2023.

LULC	Area (hectares)							
	1984 (%)	1991 (%)	1999 (%)	2002 (%)	2007 (%)	2014 (%)	2023 (%)	Increase or decrease (%)
Developed	2,158.56 (1.96%)	2,433.24 (2.21%)	5,934.78 (5.4%)	8,189.28 (7.45%)	8,387.91 (7.64%)	11,295.18 (10.28%)	22,591.53 (20.56%)	20,432.97 (18.6%)
Forest	85,513.68 (77.84%)	83,777.4 (76.26%)	70,275.06 (63.97%)	56,942.55 (51.83%)	55,251.72 (50.3%)	52,669.53 (47.94%)	34,797.42 (31.68%)	−50716.3 (−46.16%)
Cultivated	7,652.34 (6.97%)	12,317.67 (11.21%)	15,483.69 (14.09%)	28,179.9 (25.65%)	30,000.15 (27.31%)	33,687 (30.67%)	35,505.99 (32.32%)	27,853.65 (25.35%)
Water	281.89 (0.26%)	271.86 (0.25%)	281.64 (0.26%)	263.45 (0.24%)	271.88 (0.25%)	267.79 (0.24%)	297.45 (0.27%)	15.56 (0.01%)
Barren	14,249.7 (12.97%)	11,054.21 (10.06%)	17,879.21 (16.28%)	16,279.20 (14.82%)	15,942.72 (14.51%)	11,934.88 (10.86%)	166,661.99 (15.17%)	2,414.08 (2.2%)

TABLE 3 Correlation matrix between different LULC classes and time.

	Year+	Developed	Forest	Cultivated	Water	Barren
Year+	1	0.932	−0.971	0.942	0.275	0.256
Developed	0.932	1	−0.936	0.824	0.538	0.338
Forest	−0.971	−0.936	1	−0.957	−0.259	−0.39
Cultivated	0.942	0.824	−0.957	1	−0.0038	0.196
Water	0.275	0.538	−0.259	−0.0038	1	0.398
Barren	0.256	0.338	−0.39	0.196	0.398	1

+Signifies the capturing period of the Landsat satellite images used for the study's analyses.

this study. According to Rwanga and Ndambuki (2017), the user's accuracy reflects the reliability of the classification of the user.

3.3 Relationship between LULC classes

The correlation results are presented in Table 3, Supplementary Figure 2 and Supplementary Table 2. The results show a strong positive and significant correlation between the years and developed land LULC ($r = 0.93$, $p = 0.00224$). Conversely, forest land is negatively correlated with the year and developed land ($r = -0.97$, $r = -0.94$; $p = 0.000277$, $p = 0.00193$). Similarly, the cultivated land is negatively correlated with the forest land ($r = -0.96$, $p = 0.000731$). Furthermore, the cultivated land is positively correlated with the year and developed land ($r = 0.942$, $r = 0.824$; $p = 0.00151$, $p = 0.0226$). Water body and rock outcrops/barren land are not significant and, therefore, not discussed in this section.

3.4 Urban planning practices and health in Akure

The findings from the key informant interview are presented under the following questions and responses. According to the KII that was conducted, the study was able to gather succinct information about planning practices and approaches in Akure particularly if concern for health issues is well considered as the city rapidly expands. This study endeavors to seek information broadly about the master plan and synergies between the Ministry of Health (MoH) and the Ministry of Physical Planning and Urban Development (MPPUD) in Akure.

The participants expressed similar views that the overarching goal of MPPUD is to monitor physical development in Akure. However, less importance is placed on the health of residents with respect to the functions of the ministry.

> *"The ministry monitors physical development in Akure which are done by different departments. The ministry places less importance on improvement of health outcomes among the residents of Akure."*

Most participants agreed that the current master plan was last updated over 21 years, but there was no agreed date among the participants on when the master plan was developed. However, reference was made to 1984 and 1986.

> *"The current master plan was developed in the 1980's. It is the document that guides development of Akure, but it is long overdue because the built-up extent of Akure has changed tremendously. It is germane for the institute to update the master plan. The master plan was last updated in 2001."*

The participants agreed on consultation with other ministries during the development of the master plan. Nevertheless, most participants further agreed there is no synergy between the Department of Public Health in MoH and departments in MPPUD, while one of the interviewees is not sure of the relationship between the two ministries.

> *"During the development of master plan, other ministries in Ondo State were involved. We consider the MoH as a stakeholder in this regard. Despite the involvement of other ministries, particularly MoH, there is no synergy or overlapping functions focused on health issues between both ministries."*

In addition to the above findings, the participants agreed that house visitation and environmental health factors that determine health outcomes in Akure are not within the purview of MPPUD.

> *"It is not the responsibility of any department in MPPUD to check compliance with environmental health factors that influences health outcomes in Akure. This is the responsibility of public health department at health ministry."*

Furthermore, the officials interviewed in the MPPUD collectively agreed on the need to train urban planners not only in Akure but also in Nigeria on urban health issues.

> *"Urban planners are health experts. It is necessary to stress the importance and need for training on health issues in urban places by urban planners in Akure and Nigeria. Furthermore, there should be close working relationship or establishment of health department in MPPUD in Akure."*

The participants agreed on the rapid expansion of Akure and the non-usage of modern spatial technologies (e.g., GIS and RS) for monitoring the spatial growth by the MPPUD. Furthermore, the dominant views about the challenges of using GIS centers around financial cost, human resources, and political will.

> *"The use of modern spatial technologies are rarely integrated as part of the tools and necessary skillset in the ministry. Urban growth modelling are seldom carried out. Some of the barriers confronted by the ministry in respect to the use of modern spatial technologies are financial/economic hardship; lack of human resources and political will."*

4 Discussion

The study shows a continuous increase in the spatial extent of built-up/developed land use while the spatial extent of forest land use is decreasing. For example, between the years 1984 and 2023, the developed land percentage increase is approximately 946.6% while the cultivated land percentage increase is approximately 364%. Contrarily, the forest land percentage decrease is approximately 59.31% in the same period. In terms of net change, the built-up/developed land use land cover increased by 20,432.97 hectares while the net loss of forest land is 50,716.30 hectares, as shown in Figure 3.

The observed trends are similar to the studies by Owoeye and Ibitoye (2016), Popoola et al. (2020), and Alabi (2022) conducted in West African countries, study by Rwanga and Ndambuki (2017) in South Africa, and studies conducted in some Asian countries by Hassan et al. (2016), Arumugam et al. (2021), Islami et al. (2022), and Seyam et al. (2023). The study by Owoeye and Ibitoye (2016) averred the factors responsible for this trend in Akure. According to them, some of the factors are the construction of buildings, provision of public utilities, and other developmental projects embarked on by the Ondo State government at different periods due to the economic situation in that period, especially from 2002 onwards when Ondo State is classified as one of the mineral endowed regions in Nigeria. The land use change over time in Akure is periodic with a steady increase. However, the change pre-2000s is slower compared to post-2000s. Using the year 2002 as a reference, the net change in developed LULC between 2002 and 2023 is 144,022 ha. This is two times more than the net change between 1984 and 2002 (60,307 ha), as illustrated in Figure 4.

Nevertheless, the staggering figure from this analysis shows that the ongoing phenomenon is a threat to the sustainability of green infrastructures, residents' health, and environmental and ecological stability of Akure.

The monitoring of forest cover is crucial due to its impact on climate change, desertification, soil erosion, and flooding, especially when this ecosystem loses millions of hectares each year (Moradi and Sharifi, 2023). The outward growth and depletion of forest cover

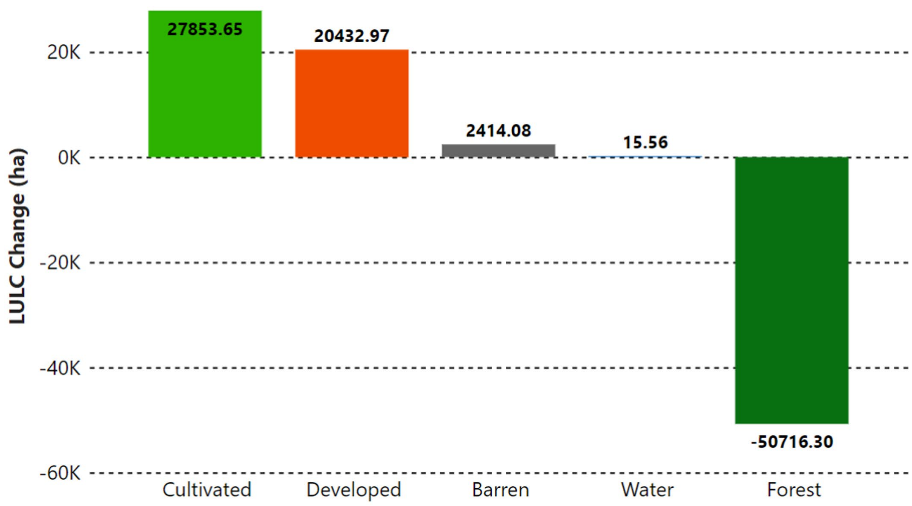

FIGURE 3
Net change of each LULC in Akure between the study years.

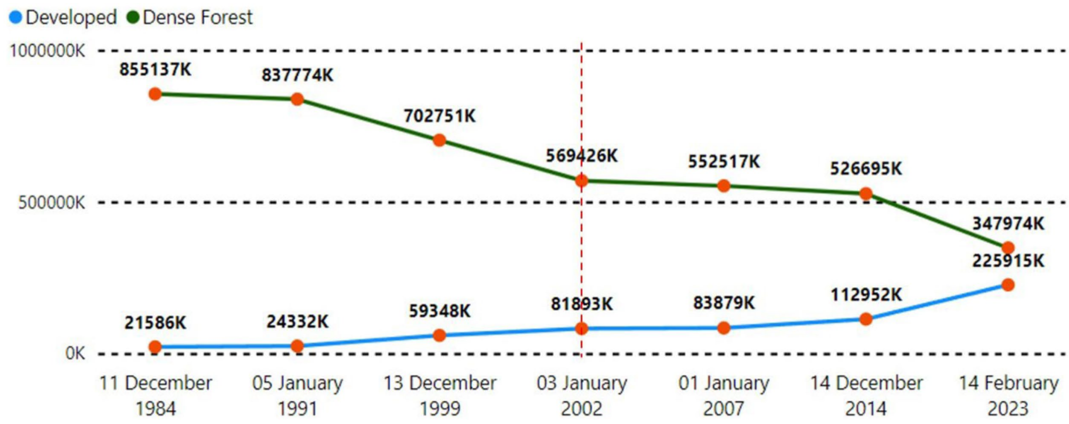

FIGURE 4
Temporal pattern of forest and developed LULC between 1984 and 2023.

contribute to ecological imbalance, changes to micro-climate, and loss of green-infrastructure investment in Akure. Vardoulakis and Kinney (2019) stressed the importance of urban green infrastructure and associated societal, environmental, and health benefits. Vegetation cover, for example, forest land use land cover, serves as a coolant to reduce the increasing global warming and as carbon sinks for carbon emission from other land use types (industrial and transportation). Therefore, continuous reduction in green spaces will predispose the population to increasing micro-climatic conditions, accelerate the thermal environment, and contribute to environmental degradation (Popoola et al., 2020; Saha et al., 2022). Consequences of environmental degradation include soil erosion and increased vulnerability to flooding.

The urban growth pattern in Akure follows the concentric ring spatial expansion along transportation routes to the east, as depicted in Figure 2. This phenomenon was observed in the LULC study of another city—Ibadan, Nigeria (Taiwo, 2022). Land use land cover changes are characterized by urban sprawl, similar to the studies by Owoeye and Ibitoye (2016) and Alabi (2022) in Akure and other African countries such as Egypt, which often leads to the depletion of parcels of land for agricultural purposes (Salem et al., 2020).

Cities and the process that drives urbanization are critical moderators of the interplay between human health and sustainability or urban space (Siri, 2016). Verburg et al. (2004) attempted to identify some of the factors/processes that drive urbanization and urban growth. According to their extensive study, urban expansion forces are probably classified into five categories, which are environmental characteristics, social factors, spatial neighbourhood factors, economic factors, and spatial policies. Their classification is in agreement and overlaps with the inferences from studies by Usman et al. (2018) on Akure. Specifically, Usman et al. (2018) noted the availability of robust social and infrastructural facilities in Akure compared to the hinterlands as drivers of the city's growth. Other factors that drive Akure's urban growth are natural population increase (increased births compared to deaths), nurturing business climate, and establishment of educational institution (Bayode, 2014; Bayode and Siegmund, 2022). The effect of these factors can be seen as the built-up LULC of the city experiences continuous expansion in time. Another reason for the outward expansion, emergence, and growth of suburbs in Akure is the social problems of the core region of Akure (Popoola et al., 2020). Furthermore, the study by Bayode and Siegmund (2022) on social determinants of infectious disease outcomes (malaria) among children below the age of five shows that poor housing characteristics, which are predominantly in the core region of Akure, is a factor, while Akinbamijo and Fasakin (2006) highlight poor waste management practices, e.g., littering of residential areas as contributing factors to the spatial disparities in health negative outcomes in Akure with high incidences in the core and suburbs. Despite scholars in Akure having echoed health issues relating to socio-environmental conditions in Akure, ways to tackle these challenges are not yet fully integrated into urban planning practices in Akure.

According to the KII with the officials of MPPUD, there is divergence in the function of public health discipline and urban planning despite the two professional disciplines sharing common origins. Among the identified Global North countries, such as the United Kingdom, one of the major reforms gave local authorities responsibility for the health of their local population. Furthermore, this development brought public health and urban planners under the same local authority, thereby creating a platform that supports closer working relationships (Carmichael et al., 2019).

MPPUD in Akure is focused on physical urban development. This undermines the relevance or "place of health" in urban planning. According to Barton and Tsourou (2013), a city is much more than physical structures such as buildings, connectors such as streets, and green infrastructures such as open spaces; a city is a dynamic, complex social space in which the health is closely linked to that of its residents. Healthy people make healthy cities. Therefore, approaches and investments that not only elevate the health of the planet but also people should be at the heart of the city's internal and external policies.

Urban planners should be perceived as de facto health professionals who should work collaboratively with other institutions to tackle health challenges in Akure, as agreed by the KII participants. This is extremely important because urban planning should no longer be seen as a unidimensional, static, technocratic activity, but rather a process of bringing together various perspectives and sectoral priorities to develop the common future of a city (UN-Habitat, 2007).

Our findings also elucidate the challenges confronted by the MPPUD on the applications of modern geospatial technologies to the modeling of urban spatial growth. In Akure, the department rarely uses these modern technologies because of financial implications, human resources with the skillset, and investments by the government. Among the arguments of Northridge and Freeman (2011), political will/power is essential to attain increased health equity in urban places. The lack of urban growth modeling indicates growth as unguided and not planned.

5 Limitations and future research

Despite the study's attempt to explore the nexus of urban planning, city growth, and health toward the sustainability of Akure, this study is characterized by or had some limitations. The first limitation is related to data availability, particularly empirical public health indicators, to further support our findings. However, we referenced previous studies on exacerbated public health challenges due to poor urban planning and built urban environments in the context of this manuscript. We therefore strongly recommend extensive future research with the inclusion of data on public health indicators to be conducted.

The second limitation is related to the qualitative sampling technique. Snowballing is a non-probability sampling technique with no sampling frame. Therefore, individuals cannot be randomly sampled, which questions the generalisability of a snowball sample (Given, 2008). This should be considered in the study interpretation, and we hope future research will employ a parametric sampling technique.

Third, rainfall is vital for vegetation. This implies that most urban green spaces are more visible and better captured by the Landsat satellite during the rainy season. The study's interpretation on forest land use should be taken with caution, and we hope that future studies will investigate the effect of seasonality LULC analysis.

Finally, more robust classifiers and algorithms can be considered in future research. Mohammadi and Sharifi (2021) elaborated on other classification algorithms such as Relevant Vector Machine (RVM), Bagging Trees (BT), Random Forest (RF), and Convolutional Neural Network (CNN). Specifically, Moradi and Sharifi (2023) observed that the CNN method outperforms existing classification methods based on the accuracy of the results. The results of SVM can be unsuitable, especially when a number of features is much more than the number of samples training referred to as the "curse of dimensionality," and ways to deal with this have been discussed by Mohammadi and Sharifi (2021). These other methods require technical know-how, and they are computationally intensive while we hope they are considered in future research. Nevertheless, Nadzri et al. (2023) observed SVM outperformed RF in their study based on the obtained Kappa results.

6 Conclusion

Our study explored the potential sustainable development impediments in Akure from the complex relationship of three tripartite sustainability wicked problems (urban growth, urban planning, and urban health). As the world continues to urbanize, urban development that supports the health and wellbeing of city dwellers is far more important than ever before to achieve sustainable development targets.

The spatial footprint of developed LULC is increasing rapidly with little regard to its impact on the city residents' health, according to our study. In addition to this, the growth of the city is poorly controlled and unplanned. The impact of this phenomenon was observed from the encroachment into the green space/forested land cover between the years of study. This can also induce environmental problems such as urban heat islands. There is a lack of close working relationships between public health professionals and urban planners in Akure, which could be from the limited urban planning functions with respect to urban health and health issues. The study calls for pragmatic and sustainable urban management approaches in Akure. For example, urban physical development control and regulations to curb urban sprawl in Akure are vital. Therefore, the use of geospatial technologies should be encouraged, and periodic training of urban planners is crucial, which can improve the effectiveness of urban growth monitoring in Akure. Furthermore, importance should be given to health in the urban planning profession in Akure. This can start with education and capacity building in various departments of ministry.

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 authors.

Ethics statement

Informed consent was obtained from the staff of MPPUD who participated in the KII. Furthermore, we adhered to the anonymity of data and presented results.

Author contributions

TB: Conceptualization, Data curation, Formal analysis, Methodology, Validation, Visualization, Writing – original draft, Writing – review & editing. AS: Supervision, Writing – review & editing.

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Conflicts 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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Supplementary material

The Supplementary material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/frsc.2023.1301397/full#supplementary-material

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