



Urban drainage and landcover change: a case study of Upper Ala River basin in Akure, southwest Nigeria¹

Matthew Olomolatan Ibitoye¹, Adebayo Oluwale Eludoyin²,
Babatunde Fafunwa³, Lateef Olaranti Opoola⁴

¹Associate Professor, Department of Remote Sensing and Geoscience Information System (GIS), Federal University of Technology, Akure, Nigeria. moibitoye@futa.edu.ng

²Associate Professor, Department of Geography, Obafemi Awolowo University, Ile-Ife, Nigeria (**Corresponding author**). oacludoyin@yahoo.com

³MSc, Department of Remote Sensing and Geoscience Information System (GIS), Federal University of Technology, Akure, Nigeria. fafunwa.babatunde@gmail.com

⁴MSc, Department of Surveying and Geoinformatics, Federal University of Technology, Akure, Nigeria. didajunior@yahoo.com

Abstract

Introduction: Developing countries, including Nigeria and many other sub-Saharan Africa are still developing programs that tend to encourage or provide growth poles factors, such as institutions, planned cities, and conversion of a settlement to administrative centers with the intention of attracting population increase through immigration. The growth pole areas often become nuclei for urban development in any of the three main models of urban development. One of the parts of the environment that become affected by urban development is the river basin, often due to competition with space for built-up areas, a situation that is often exacerbated by population increase and climate variability. A river basin is a defined unit area with topographic, hydraulic and hydrological unity; which can also be referred to as an identifiable planning region. Poorly monitored and controlled urban growth is a threat to the riparian ecosystems in many developing countries. Studies have shown that data availability is a major challenge to understand the impact of such growth on drainage basins. As at early 1990s when the study area became the administrative capital of a state (Ondo), its population surged due to migration because of

1. **Received:** 2022/02/15; **Revised:** 2022/03/29; **Accepted:** 2022/04/15; **Published Online:** 2022/06/20
©2022 The Author(s).

Published by: Veresk Ettetal.

This is an open access article under the: <http://creativecommons.org/licenses/by/4.0/>

DOI: 10.22034/wpj.2023.363889.1051





the focus of government to establish their ministries and agencies in the new capital city. The National Population Commission reported 4% population increase in the study area, and as such, pressure on previously unoccupied and protected areas becomes unexpected. Studies in Islamabad, Pakistan and in North-West Delhi, India also indicated increase in built-up areas around protected areas and within drainage basins due to population increase into administrative capital cities.

Materials and Methods: This study examined the extent of urban growth and the impact on a river basin in one of the administrative capital cities in southwestern Nigeria, using freely available Landsat datasets. Specific objectives were to assess vegetal and topographic changes in the status of riparian vegetation and other land cover, as well as the impact of urban growth on the river basin. Data included multi-date Landsat images.

Results: The Ala River in Akure, southwest Nigeria, whose vulnerability was investigated in this study, has experienced a reduction in basin area and parts that were previously classified as water bodies were later overgrown by built-up and related human activities. Physical observation of the river plain reveals that apart from bridges that were constructed to ease road transportation across the river, no important event was available to protect the basin from intrusion and attendant exploitation, at the time of the surveys. The former studies have argued for the protection of flood plains, noting that areas close to the plains are vulnerable to flood disasters. Building regulations that include the set-back rules around major rivers are rarely observed due to compromised implementation strategies that typically discouraged non-biased enforcement. In addition, parts of the downstream station of the river have been converted to dumpsites and the hitherto perennial streams in the area have either become intermittent or dried off. Also, an increase in surface temperature as well as increased built-up areas within the basin may be associated with the dryness of some of the river tributaries. In general, the wetland ecosystem in the study area has given way to poorly planned built-up and few shanty settlements. Results showed increase in built-up areas (48.1%), decline in vegetal cover (71.2%), loss of vegetal greenness (< -0.33) and increased land surface temperature (0.23-0.25°C).

Conclusions: The study concluded that the Landsat images with ground surveys can provide reliable results for ecosystem monitoring in the area. Conscious sustainable urban planning and strategies for the sustenance of the urban wetlands as well as policy towards urban greening are recommended. Future studies will be focused on hydro-morphometric analysis of the river basin.

Keywords: Akure, Southwest Nigeria, Drainage basin, Landcover change, Land surface temperature, Urban growth, Impervious surface, Water Productivity.



1. Introduction

Urbanization, the process of town development, is known to be a global phenomenon, with both positive and negative consequences, depending on the level of efficiency of government policies for infrastructure and environmental management (Onanuga & et al. 2022). According to Du & et al. (2019), over 60% of the global population live in urban area, and the proportion of the urban areas will increase to about 65% by 2025 (United Nations 2011). Studies have linked development of urban areas to different issues, including unfair/imbalance distribution of resources described by the core-periphery model (Baldwin & et al. 2001), spread effects (of both development and social vices), and population distribution across spatial spaces (Cohen, 2004; Chirisa, 2008). In general, a number of studies have revealed that areas where urbanization is at the climax in developing countries have increased their campaigns for counter-urbanization and urban greening, among others, to improve the environmental conditions in the urban areas.

Conversely, developing countries, including Nigeria and many other sub-Saharan Africa are still developing programs that tend to encourage or provide growth poles factors, such as institutions, planned cities, and conversion of a settlement to administrative centers with the (conscious or unconscious) intention of attracting population increase through immigration (Akinbode & et al., 2008). The growth pole areas often become nuclei for urban development in any of the three main models (Burgess' concentric, multiple nuclei, or sectoral) of urban development (Wen & Tisdell, 1999; Briassoulis, 2019). One of the parts of the environment that become affected by urban development is the river basin, often due to competition with space for built-up areas, a situation that is often exacerbated by population increase and climate variability (Pathirana & et al., 2014; Hugo, 2017; Wang & et al., 2018). A river basin is a defined unit area with topographic, hydraulic and hydrological unity; which can also be referred to as an (or series nested) identifiable planning region. (Faniran, 1974; Eludoyin & Adewole, 2020).

Recently, due to urban growth, physical structures are developing in river basins (Mohapatra & Sharma, 2014), despite that they are considered viable for protection using set-backs-to-major-streams rule. Owing to increased rates of rural-urban and urban-urban in-migration patterns, settlements that have been declared as administrative capitals tend to witness population increase than they attracted before they achieved the status of the administrative capital (Akinbode & et al., 2008). These settlements often possess better educational,



health and commercial facilities than the other areas within the state or county, and perception soared on their capacity to provide better life for real and potential immigrants (Shukla & et al., 2013). Consequently, pressure on protected zones and previously unoccupied region appear to increase, even as the bid-rents of the areas soar more than the previously settled environment (Chirisa, 2008; Shukla & et al., 2013). The bid-rent theory, a geographical economic theory, suggests that different land users will compete with one another for land close to the City Centre, especially for profits (McMillen & McDonald, 1998). Conversely, however, wealthier and more affluent people tend to leave heavily populated and commercial regions to settle in less dense, periphery and (in countries where laws or implementation are lax) protected areas as explained in the counter-urbanization concept (Dean & et al., 1984). Marx & et al. (2013) argued that slums could also be created around such areas, especially in regions with significant economic gap, a situation that is common in Africa and Asia.

In the present study area, as occurs in nations, where blue-print for development is based on state creation and where significant economic gap and lax in set-back rules persist, studies have revealed significant threats to the riparian ecosystem, flood plains and other constituents of a river basin (Symeonakis & et al., 2004; Krishan & et al., 2009). Studies (including Fox & et al., 2012; Shukla & et al., 2013; Fenta & et al., 2017) have analysed landuse change in a Mediterranean basin at Giscle, Southeast France, Agula basin in Northern Ethiopia and selected river basins in New Delhi, India. The studies reported that increase in built-up areas is capable of demeaning the functionality of a river basin, and possess consequent negative influence on the downstream environment. Other studies (such as: Abbas & Fasona, 2012; Huang & et al., 2018) warned that poorly planned urban growth endangers the basin and make people vulnerable to flooding and its consequences. In the study area, as recorded for most part of the country, information is at best scattered and descriptive about the condition of river basins in response to urban growth effects of urban. Existing studies (such as Olatunji, 2007; Rahaman & et al., 2012; Adediji & et al., 2013; Matano & et al., 2015) are generic and cover large areas despite the importance of case-specific studies. Explanations to the generic nature of many of the existing studies include the methodological limitations of overtly field-based approach. In the present study, efforts are to demonstrate the applicability of free/open-source satellite imageries that are available for researchers in the area in a combined field and desktop-based approach. Specific objectives are to assess vegetal and



topographic changes in the status of riparian vegetation and other landcover of the Ala River basin, and as well evaluate the impact of urban growth on the river basin. Access to fine resolution datasets which have been of significant boost to hydrological researches are lacking for many parts of the sub-Saharan Africa, and quite obviously for many rivers in Nigeria (see: Eludoyin & Iyanda, 2019). Nonetheless, the medium to small resolution, open access digital images can be of great benefit, if adequately understood. Consequently, a demonstration of the capability of the available datasets is demonstrated in this study.

2. Materials and Methods

2-1. Study area

The study area, upper Ala River basin in Akure, Ondo State, Nigeria, is about 55km². It is a major tributary of River Ogbese, which discharges into Owena River. The entire river drains about 40% of the entire southwestern region in Nigeria, and is being managed by the Owena River Basin Authority in Nigeria. Figure 1 shows the areas drained by the river in the study area, most part of which is now covered by built-up areas. The river flow benefits from the seasonal rainfall pattern in the region, being within the Humid tropic climate (Am) region of Koppen's classification. The wet season (April – October) with averaged rainfall of 2378 mm is characterized by period flooding, which has been linked to poor adherence to planning and cadastral regulations in the area. Dry season is typically occurring between late November and March, and during the short dry spell of the 'little dry season' of the August-break (Odekunle & Adejuwon, 2006). Annual average temperature is about 26.7°C, with annual range of 22-32°C (Udo, 1981). The vegetation of the study area, as typical of most part of the southwestern Nigeria has changed from the natural tropical rainforest to derived savanna, which largely comprises secondary vegetation and fallow land (Iloeje, 1981; Barbour & et al., 1982). The soils are largely of the Ijare series of Ferralsol that is derived from the Precambrian Basement Complex rocks (Olatunji, 2007; Anifowose, 1989). Major rocks are granites, migmatites, quartzite complexes and coarse biotite granites that constitute the undulating relief of the area. The settlement slopes southeastwards in the direction of the river basin.

Population and landuse evaluations suggest that Akure as one of the fast-growing settlements in Nigeria (Akinbode & et al., 2008); its human

populations have increased from 71, 106 in 1963 to 239, 124 and 340, 021 in 1999 and 2006, respectively (NPC Official Gazette, 2006), and was estimated as 420, 594 in 2018 (World Population Review, 2018), suggesting about 23.9% increase in 12 years. Studies also reveal concurrent land use pattern change, including conversion of parts of river basins and other areas to built-up areas due to population pressure (Ibitoye & et al., 2020; Biney & Boakye, 2021). The (Ala) basin is characterized by range of steep ($6.4-17.9^\circ$) with pockets of gentle slope ($0-3.5^\circ$) close to the stream channel (Figure 2a), suggesting more runoff generation from highland to lowlands, as expected.



Fig. 1. The study area, upper Ala River Basin in Akure, Ondo State, Nigeria

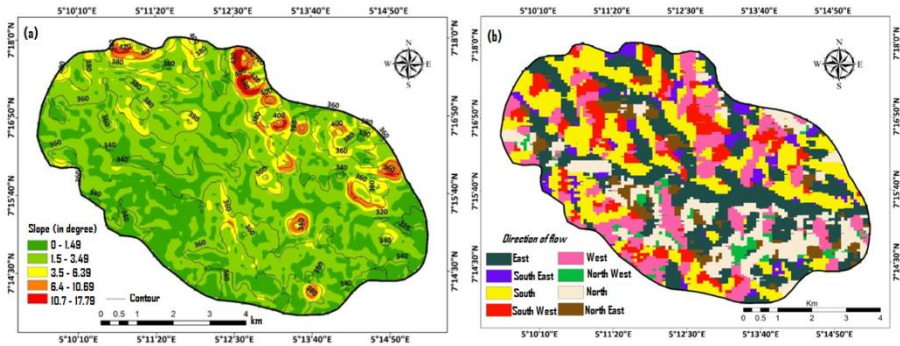


Fig. 2. Some hydrological (height and slope (a) and flow direction (b)) characteristics of Ala River basin

The flow direction map indicate dominant runoff flows from the East, South and South-eastern directions (Figure 2b). Eroded materials are transported from steep slope to moderately low terrain with gentle slope, and therefore tend to accumulate more and to initiate rill and gully erosion in the area. The growth of urban land use with its associated surface features, such as buildings and artificial drainages, tend to alter the flow of runoff direction, though in agreement with the general slope pattern of the basin, but against the pattern of flow in an undisturbed ecosystem.

2-2. Data

Data analyzed included 30m resolution images of Landsat Thematic Mapper (TM) 5 of 1986, Landsat Enhanced Thematic Mapper Plus (ETM+) 7 of 2002 and Landsat 8 OLI / TIRS of 2017 covering the study area, Akure, Ondo State. The data were downloaded (Path/Row = 190/055) from the archive of United States' Geological Survey (USGS). The data also included 2.5m Google Earth imagery of 2007 and 2018. The images were preferred because they are free and accessible to potential users worldwide (see also: Wolter & et al., 2012; Eludoyin & Iyanda, 2019) while the dates were selected based on availability and quality. Whereas the Landsat data were processed for determination of land surface temperature (LST) for the assigned years (1986, 2002 & 2017) while impervious surface cover was delineated from the 2007 and 2018 Google Earth images, due to availability. The available 1966 1: 100,000 (spatial resolution) topographical map covering the area was used as basemap for delineation of the Ala River basin before urban growth and population increase became prominent. The coordinates of conspicuous benchmarks, including road junctions, existing bridges, among others taken using a



handheld Global Positioning System (Garmin 78CS model, $\pm 3\text{m}$ spatial resolution) were used to perform a local georeferencing of the images for data quality assurance as described by Adewole & et al. (2020). Data were analyzed in ArcGIS (version 10.5) which was preferred because of its availability at subsidized rate in Nigerian Universities at the time of this study.

2-3. Data analysis

Land use change was analyzed following Anderson (1976) model of land use classification into three major land use classes namely, built-up, vegetation, and bare land/outcrop. The land use classification was achieved using supervised image classification technique via maximum decision likelihood rule as described in Abrams & et al. (1996), Jain & et al. (2014), among others in the preferred software (ArcGIS). Accuracy of the classification was assessed in terms of their Kappa coefficients as described by Bogoliubova & Tymków (2014). In addition, the Normalized differential vegetation index (NDVI) - a common approach for determining change in vegetation greenness using change in their spectral characteristics, and a pathway to describing hydrological impact of impervious surface (Gandhi & et al., 2015) was estimated as a ratio difference between measured canopy reflectance in the red (600-700 nm) and near-infra red (750-1300 nm) bands respectively. Digital Elevation Model (DEM) of the drainage basin was generated from the digitized contour derived from the topographical map. The DEM was thereafter used to produce gradient information (especially slope and flow pattern) using the *Surface analysis* tool in ArcGIS 10.5 software. Both flow and gradient analyses were intended to provide information about runoff generation, flow pathways and water retention capacity of the basin (Jenson & Domingue, 1988). Flow direction in the GIS software was estimated using the 'eight-direction' flow model, which expresses the directional pattern as consisting of East (1), Southeast (2), North (4), Southwest (8), West (16), Northwest (32), North (64) and Northeast (128) (Jenson & Domingue, 1988). Furthermore, land surface temperature was derived from each Landsat image using their radian reflection values as described in Eludoyin & et al. (2019). Lastly, delineation of the basin into areas converted into impervious surfaces (with propensity to prohibit water infiltration through soil profile; Chithra & et al., 2015) was archived for 2007 and 2018 from the Google Earth images, to compare the effects of built-up activities.

2-4. Accuracy assessment

Table (1), which contains the results of the accuracy assessment of the image classification procedure used in the study shows overall accuracy of 93.3%, 90.0% and 86.7%, for classification of the 1986, 2002 and 2017 Landsat image, respectively. The Kappa values exhibited strong correlation between the images and ground truthing as the values (0.8-0.90) tend towards one unit, following Bogoliubova & Tymków (2014).

Table 1: Accuracy assessment of images used for land use/land cover classification in the study area

| Land use/cover | Producer | User | Kappa coefficient |
|---------------------|----------|------|-------------------|
| 1986 | | | 0.90 |
| Vegetation | 100 | 83.3 | |
| Built-up | 100 | 100 | |
| Bare ground/outcrop | 80 | 100 | |
| Overall accuracy | 93.3 | | |
| 2002 | | | 0.85 |
| Vegetation | 90 | 81.8 | |
| Built-up | 100 | 90.9 | |
| Bare ground/outcrop | 80 | 100 | |
| Overall accuracy | 90 | | |
| 2017 | | | 0.80 |
| Vegetation | 80 | 88.9 | |
| Built-up | 100 | 90.9 | |
| Bare ground/outcrop | 80 | 80.0 | |
| Overall accuracy | 86.7 | | |

3. Results and Discussion

3-1. Change in landcover within the drainage basin within the study period

Table (2) shows the extent of changes in land cover between 1986 and 2017 in the study area. Built-up areas increased by 3.35 km² between 1986 and 2002, and by 4.48km² between 2002 and 2017 in the river basin. Such increase also shows the loss of vegetal area, especially riparian vegetation to built-up purpose. The vegetation cover, which was about 26.9 km² and occupied 49.2% of the entire basin in 1986 reduced by 5.9 km² and 19.2 km² in 2002 and 2017, respectively. Bare-land/outcrops as well as open surfaces also change from 11.7km² in 1986 to 14.3km² and 23.04 km², respectively in 2002 and 2017. The increase in open surface reveals depletion of previously vegetated area



due to human activities, including farming and construction activities. Figure 3 (a-b) shows that the built-up which was predominantly evident in the southwestern part of the basin area spread through the entire area by 2017.

As at early 1990s when the study area became the administrative capital of a state (Ondo), its population surged due to migration because of the focus of government to establish their ministries and agencies in the new capital city. The National Population Commission (NPC, 2006) reported 4% population increase in the study area, and as such, pressure on previously unoccupied and protected areas becomes unexpected. Studies in Islamabad, Pakistan (Hassan & et al., 2016) and in North-West Delhi, India (Rahaman & et al., 2012) also indicated increase in built-up areas around protected areas and within drainage basins due to population increase into administrative capital cities.

Table 2: Land use/cover area and change between 1986 and 2017
(Negative percentage change indicates a decrease)

| Classes | Land use/cover area (ha) | | | Percentage change | | |
|------------------|--------------------------|------|------|-------------------|-------------|-------------|
| | 1986 | 2002 | 2017 | 1986 - 2002 | 2002 - 2017 | 1986 - 2017 |
| Built Up | 16.0 | 19.4 | 23.8 | 1.3 | 1.6 | 1.5 |
| Vegetation | 26.9 | 21.0 | 7.7 | -1.4 | -4.2 | -2.3 |
| Bareland/Outcrop | 11.7 | 14.3 | 23.1 | 1.4 | 4.1 | 3.1 |
| Total land cover | 54.6 | 54.6 | 54.6 | | | |

3-2. Change in vegetal greenness

Figure (3ci-iii), which shows the results of NDVI analysis over the study period reveals lower value ranges (-0.03-0.36 in 1986, -0.33-0.33 in 2002, and 0.04-0.32 in 2017), suggesting gradual replacement of previously vegetal area by surface as described by (Gandhi et al. 2015). Surface features include bare land/concrete surfaces, degraded or poorly vegetated areas. Previous studies of impervious surfaces in the southwestern region (e.g., Ibitoye & et al., 2019) suggest that whereas vegetated surfaces allow excess surface water to infiltrate into the soil open or poorly vegetated surfaces promote surface runoff, and consequently threats of flooding events in an area. In general, the results of the NDVI suggest that built-up areas in the drainage basin can be linked with the removal of vegetation over the study period.

3-3. Changes in land surface temperature (LST)

Analysis of the LST (Table 3) showed that mean LST values varied respectively as 27.15°C - 34.65°C in the built-up area, 23.95°C - 31.9°C in the

open surface/bareland/outcrop, and 21.6°C - 28.8°C in the vegetated region, between 1986 and 2017 (also Figure 4). Mean LST generally was higher in the built-up area than other landuses and extended over the study area as tendency for population increase and urban growth reveals. The general increase in air temperature in the built-up area at the expense of the surrounding (vegetated) periphery has been well explained by the concept of urban heat island phenomenon, which studies (e.g., Akinbode & et al., 2008; Balogun & Daramola, 2019) have recorded in the larger Akure (the study area) environment. An increase in ambient air temperature in the study area, as revealed by the results suggests an impact of the increased built-up area over time. Ibitoye & et al. (2017) associated an increase in temperature to the potential impact of mostly non-transpiring and non-evaporating materials and structures that are used for building construction in the area. According to Hua & et al., (2012), such materials often hinder solar radiation from penetrating through them, resulting in urban land surface heat.

Table 3: Mean Land Surface Temperature in different land uses in the study area

| Land use/cover type | Land surface temperature (°C) | | | | |
|-----------------------|-------------------------------|------|------|--------------------------------------|----------------------|
| | 1986 | 2002 | 2017 | Changes in LST between 1986 and 2017 | Annual change in LST |
| Built up | 27.2 | 34.4 | 34.7 | 7.5 | 0.24 |
| Vegetation | 21.6 | 23.0 | 28.8 | 7.2 | 0.23 |
| Bare surface/outcrops | 24.0 | 27.0 | 31.9 | 7.9 | 0.25 |

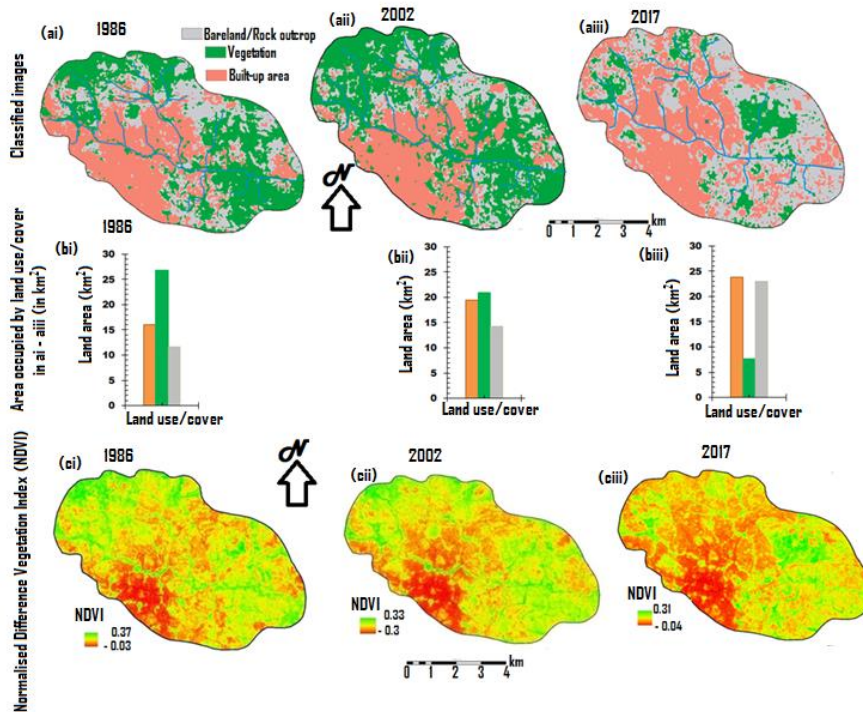


Fig. 3a-c. Changes in dominant land use/cover area (ai-biii) and greenness (in terms of Normalized Difference Vegetation Index, NDVI) in the basin area within the study period

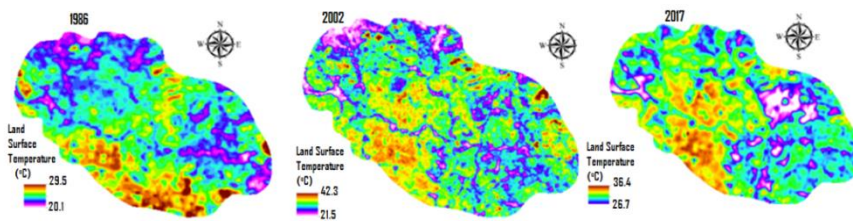


Fig. 4. Changes in land surface temperature of the study basin between 1986 and 2017

3-4. Change in impervious surfaces

Analysis of the 2007 and 2018 Google Earth images shows that 49.9 ha (69.2% of the entire basin area) contained 467 buildings and were impervious (refer to Table 4). The impervious surfaces have increased to 51.2 ha (71.1% of the entire basin) and contained 537 buildings as of the period (Figure 5 a-b).

As of 2018, a Government Residential Area (Okuta-Elerinla) has also been planned for the area, and a wide range of the drainage basin is undergoing significant uplift. Plate 1 shows samples of buildings in the basin area that have become susceptible to the effect of the gully, especially as the environmental implications of many of the constructions are rarely considered, enforced, or implemented.

Table 4: Quantification of pervious and impervious surfaces between 2007 and 2018 along the selected stream catchment in the study area

| Surface type | Area covered in Ha and % (in parenthesis) | | Change (in Ha) between 2007 and 2017 |
|---------------------|--|--------------|---|
| | 2007 | 2017 | |
| Impervious | 49.88 (69.2) | 51.22 (71.1) | + 1.34 |
| Pervious | 22.20 (30.8) | 20.86 (28.9) | - 1.34 |
| Number of Buildings | 467 | 537 | + 70 |

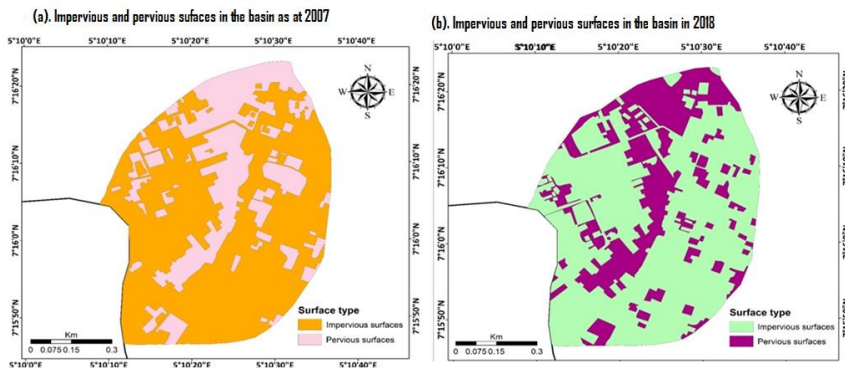


Fig. 5. Comparison of impervious and pervious surfaces in two selected years (2007 and 2018) in the basin



Plate 1. Sample built-up induced erosion surfaces in the basin area



4. Discussion

Urbanization and other factors of land use/ land cover change are important drivers of wetland loss in many ecosystems (e.g., Araujo & et al., 2021; Seifollahi-Aghmiuni & et al., 2022; Xu & et al., 2022), but with different level of consequences due to varied responses and commitments towards environmental sustainability. The study area is typical of settlements in the region with rapid environmental change due to urbanization. Urbanization has been earlier described as the process of town development, which might be a source of problems, requiring solutions or influence to bring about development in an area (Onanuga & et al., 2022). In many areas where urban growth is rarely or poorly monitored and managed, as reported in many parts of the sub-Saharan African region, urbanization can be a problem (Ward & et al., 2000; Hassan & et al., 2016; Ofoezie & et al., 2022). Studies revealed that although a number of rules and regulations exists in countries in the region, they are often not followed or implemented, probably due to weak and compromised structure in many of the societies (see: Okorodudu-Fubara, 1998; Ofoezie & et al., 2022).

The Ala River in Akure, southwest Nigeria, whose vulnerability was investigated in this study, has experienced a reduction in basin area and parts that were previously classified as water bodies were later overgrown by built-up and related human activities. Physical observation of the river plain reveals that apart from bridges that were constructed to ease road transportation across the river, no important event was available to protect the basin from intrusion and attendant exploitation, at the time of the surveys. Studies (e.g., Ologunorisa & et al., 2022) have argued for the protection of flood plains, noting that areas close to the plains are vulnerable to flood disasters. Building regulations that include the set-back rules around major rivers are rarely observed due to compromised implementation strategies that typically discouraged non-biased enforcement (see: Okorodudu-Fubara, 1998). In addition, parts of the downstream station of the river have been converted to dumpsites and the hitherto perennial streams in the area have either become intermittent or dried off. Also, an increase in surface temperature as well as increased built-up areas within the basin may be associated with the dryness of some of the river tributaries. In general, the wetland ecosystem in the study area has given way to poorly planned built-up and few shanty settlements.

The condition of the Ala River basin exemplifies the degradation of wetlands across the countries; similar occupation of the river basin by built-



ups and related land use activities have reportedly caused degradation of water quality elsewhere (see also: Onanuga & et al., 2022). The situation is a clear action against the target of Sustainable Development Goal 11, which is focused on the target to ‘make cities and human settlements inclusive, safe, resilient and sustainable. Pieces of evidence shown in this study characterized the study area to experience damaged riparian vegetation and stream channels. Given the tendency for increased rainfall (see: Eludoyin & et al., 2009; Adeyefa, 2022), and poor river basin information system (Eludoyin & et al., 2009; Ologunorisa & et al., 2022) over the area, it is clear that the sustainable concepts of urban greening and smart city, (Bowler & et al., 2010; Zubizarreta & et al., 2016; Eremia & et al., 2017) are of relevance to the study area for effective planning. Smart-city, Digital City, Intelligent City, or Sustainable City is an evolving or work – in – progressive approach to alleviating current and potential urban problems as well as making future urban growth and development sustainable through the application of innovation and technology to make urban environments more inclusive, liveable, and sustainable (Haque & et al., 2022).

5. Conclusion and Recommendation

Landscape and urban development have resulted in the greater vulnerability of the wetland ecosystem around the upper Ala River basin in the study to environmental consequences, such as flooding and wetland losses. The desire to urbanize as well as high-level interaction between man and the physical environment are expected to increase over time as population increases, and with the capacity for exacerbated stress on the urban wetlands. Conscious sustainable urban planning and strategies for the sustenance of the urban wetlands as well as policy towards urban greening are recommended. Future studies will be focused on t hydro-morphometrical analysis of the river basin.



References

- Abbas II. & Fasona, M.J. (2012). Remote sensing and geographic information techniques: veritable tools for land degradation assessment. *American Journal of Geographic Information System*, 1(1): 1-6.
- Abrams, M., Bianchi, R. & Pieri, D. (1996). Revised mapping of lava flows on Mount Etna, Sicily. *Photogrammetric Engineering and Remote Sensing*, 62: 1353–1359.
- Adediji, A., Jeje, L.K. & Ibitoye, M.O. (2013). Urban development and informal drainage patterns: Gully dynamics in Southwestern Nigeria. *Applied Geography*, 40: 90-102.
- Adejuwon, J.O. & Odekunle, T.O. (2006). Variability and the Severity of the “little Dry Season” in southwestern Nigeria. *Journal of climate*, 19(3): 483-493.
- Adewole, A.O., Ike, F. & Eludoyin, A.O. (2020). A multi-sensor-based evaluation of the morphometric characteristics of Opa river basin in Southwest Nigeria. *International Journal of Image and Data Fusion*, 11(2): 185-200.
- Adeyefa, A.O. (2022). Assessment of rainfall characteristics of the early and late growing seasons during significant years of extreme little dry season in southwestern Nigeria. *African Geographical Review*.
DOI: <https://doi.org/10.1080/19376812.2022.2054437>
- Akinbode, O.M., Eludoyin, A.O. & Fashae, O.A. (2008). Temperature and relative humidity distributions in a medium-sized administrative town in southwest Nigeria. *Journal of Environmental Management*, 87(1): 95-105.
- Anderson, J.R. (1976). *A land use and land cover classification system for use with remote sensor data*. US Government Printing Office 164, Washington.
- Anifowose, A.Y.B. (1989). The performance of some soils under stabilization in Ondo State, Nigeria. *Bulletin of the International Association of Engineering Geology-Bulletin de l'Association Internationale de Géologie de l'Ingénieur*, 40(1): 79-83.
- Araujo, R., Ponte, M., X. & Eslamian, S. (2021). Effects of land cover change on hydrological responses of a Large-Scale Basin in Brazilian Amazon. *International Journal of Hydrology Science and Technology*, 12(1): 39-58.
- Baldwin, R., Forslid, R., Martin, P., Ottaviano, G. & Robert-Nicoud, F. (2001). 10 The core-periphery model: key features and effects. *The Monopolistic Competition Revolution in Retrospect*. **DOI:** 10.1017/CBO9780511492273.011
- Balogun, I.A. & Daramola, M.T. (2019). The outdoor thermal comfort assessment of different urban configurations within Akure City, Nigeria. *Urban Climate*, 29: 100489.
- Barbour, K.M., Nwafor, J.C., Oguntinyinbo, J.S. & Onyemelukwe, J.O. (1982). *Nigeria in Maps [cartographic Material]*. New York: Africana Publishing Company.



- Biney, E. & Boakye, E. (2021). Urban sprawl and its impact on land use land cover dynamics of Sekondi-Takoradi metropolitan assembly, Ghana. *Environmental Challenges*, Vol.4. **DOI:** <https://doi.org/10.1016/j.envc.2021.100168>
- Bogoliubova, A. & Tymków, P. (2014). Accuracy assessment of automatic image processing for land cover classification of St. Petersburg protected area. *Acta Scientiarum Polonorum. Geodesia et Descriptio Terrarum*, 13(1-2).
- Bowler, D.E., Buyung-Ali, L., Knight, T.M. & Pullin, A.S. (2010). Urban greening to cool towns and cities: A systematic review of the empirical evidence. *Landscape and urban planning*, 97(3): 147-155.
- Briassoulis, H. (2019). Combating land degradation and desertification: The land-use planning quandary. *Land*, 8(2): 27.
- Chirisa, I. (2008). Population growth and rapid urbanization in Africa: Implications for sustainability. *Journal of Sustainable Development in Africa*, 10(2): 361–394.
- Chithra, S.V., Nair, M.H., Amarnath, A. & Anjana, N.S. (2015). Impacts of impervious surfaces on the environment. *International Journal of Engineering Science Invention*, 4(5): 27-31.
- Cohen, S. (2004). Social relationships and health. *American Psychologist*, 59(8): 676.
- Dean, K.G., Brown, B.J.H., Perry, R.W. & Shaw, D.P. (1984). The conceptualization of counter-urbanization. *Area*, 9-14.
- Du, J., Cheng, L., Zhang, Q., Yang, Y. & Wei Xu, W. (2019). Different flooding behaviors due to varied urbanization levels within river basin: a case study from the Xiang River Basin, China. *Int J Disaster Risk Sci.* 10: 89–102.
- Eludoyin, A.O. & Adewole, A.O. (2020). A remote sensing-based evaluation of an ungauged drainage basin in Southwestern Nigeria. *International Journal of River Basin Management*, 18(3): 307-319.
- Eludoyin, A.O. & Iyanda, O.O. (2019). Land cover change and forest management strategies in Ife nature reserve, Nigeria. *Geojournal*, 84(6): 1531-1548.
- Eludoyin, A.O., Eludoyin, O.M. & Oyinloye, M.A. (2009). Monthly variations in the 1985–1994 and 1995–2004 rainfall distributions over five synoptic stations in western Nigeria. *J Meteorol Clim Sci.*, 7: 11-22.
- Eludoyin, A.O., Omotoso, I., Eludoyin, O.M. & Popoola, K.S. (2019). Remote sensing technology for evaluation of variations in land surface temperature, and case study analysis from Southwest Nigeria. In: *Geospatial Challenges in the 21st Century* (pp. 151-170). Springer, Cham., Switzerland
- Eremia, M., Toma, L. & Sanduleac, M. (2017). The smart city concept in the 21st century. *Procedia Engineering*, 181: 12-19.
- Faniran, A. (1974). Drainage basin development and political boundaries in Africa. *The Nigerian Journal of Economic and Social Studies*, 16(3): 445-459.
- Fenta, A.A., Yasuda, H., Haregeweyn, N., Belay, A.S., Hadush, Z., Gebremedhin,



- M.A. & Mekonnen, G. (2017). The dynamics of urban expansion and land use/land cover changes using remote sensing and spatial metrics: the case of Mekelle City of northern Ethiopia. *International Journal of Remote Sensing*, 38(14): 4107-4129.
- Fox, D.M., Witz, E., Blanc, V., Soulié, C., Penalver-Navarro, M. & Dervieux, A. (2012). A case study of land cover change (1950–2003) and runoff in a Mediterranean catchment. *Applied Geography*, 32(2): 810-821.
- Gandhi, G.M., Parthiban, S., Thummalu, N. & Christy, A. (2015). NDVI: Vegetation change detection using remote sensing and GIS—A case study of Vellore District. *Procedia computer science*, 57: 1199-1210.
- Haque, A.B., Bhushan, B. & Dhiman, G. (2022). Conceptualizing smart city applications: Requirements, architecture, security issues, and emerging trends. *Expert Systems*, 39(5): e12753.
- Hassan, Z., Shabbir, R., Ahmad, S.S., Malik, A.H., Aziz, N., Butt, A. & Erum, S. (2016). Dynamics of land use and land cover change (LULCC) using geospatial techniques: a case study of Islamabad Pakistan. *SpringerPlus*, 5(1): 1-11.
- Hua, L., Wang, M. & Zhao, X. (2012). Temporal and Spatial Characteristics of Urban Heat Island of an Estuary City, China. *J. Comput.*, 7(12): 3082-3087.
- Huang, X., Hall, A.D. & Berg, N. (2018). Anthropogenic warming impacts on today's Sierra Nevada snowpack and flood risk. *Geophysical Research Letters*, 45(12): 6215-6222.
- Hugo, G. (2017). *New form of urbanization: beyond the Urban-Rural Dichotomy*. Routledge: Abingdon-on-Thames, UK
- Ibitoye, M.O., Aderibigbe, O.G., Adegboyega, S.A. & Adebola, A.O. (2017). Spatio-temporal analysis of land surface temperature variations in the rapidly developing Akure and its environs, southwestern Nigeria using Landsat data. *Ethiopian Journal of Environmental Studies and Management*, 10(3): 389-403.
- Ibitoye, M.O., Komolafe, A.A., Adegboyega, A.S., Adebola, A.O. & Oladeji, O.D. (2020). Analysis of vulnerable urban properties within river Ala floodplain in Akure, Southwestern Nigeria. *Spatial Information Research*, 28(4): 431-445.
- Iloje, M. (1981). *Regional Geography for West Africa*. Macmillan Publishers, Nigeria
- Jain, A.K., Katiyar, S.K. & Chauhan, M.S. (2014). Assessing landscape changes of the catchment area of Upper Lake Bhopal using patch analysis. *International Journal for Innovation Education and Research*, 2(07): 96–101.
- Jenson, S.K. & Domingue, J.O. (1988). Extracting topographic structure from digital elevation data for geographic information system analysis. *Photogrammetric engineering and remote sensing*, 54(11): 1593-1600.
- Krishan, G., Kushwaha, S.P.S. & Velmurugan, A. (2009). Land Degradation Mapping in the Upper Catchment of River Tons. *Journal of Indian Society of Remote Sensing*, 37: 119-128.



- Marx, B., Stoker, T. & Suri, T. (2013). The economics of slums in the developing world. *Journal of Economic Perspectives*, 27(4): 187-210.
- Matano, A.S., Kanangire, C.K., Anyona, D.N., Abuom, P.O., Gelder, F.B., Dida, G.O. & Owuor, P.O. & Ofulla, A.V.O. (2015). Effects of Land Use Change on Land Degradation Reflected by Soil Properties along Mara River, Kenya and Tanzania. *Open Journal of Soil Science*, 5: 20-38.
- McMillen, D.P. & McDonald, J.F. (1998). Population density in suburban Chicago: a bid-rent approach. *Urban Studies*, 35(7): 1119-1130.
- Mohapatra, S.N.P. & Sharma, M. (2014). Rapid urban expansion and its implications on geomorphology: a remote sensing and GIS Based study. *Geography Journal*. DOI: <http://dx.doi.org/10.1155/2014/361459>
- NPC Official Gazette (2006). *National population figures*. Bureau of Statistics, Abuja Nigeria.
- Ofoezie, E.I., Eludoyin, A.O., Udeh, E.B., Onanuga, M.Y., Salami, O.O. & Adebayo, A.A. (2022). Climate, Urbanization and Environmental Pollution in West Africa. *Sustainability*, MDPI, 14, (in press).
- Okorodudu-Fubara, M.T. (1998). *Law of environmental protection: Materials and text (938 p)*. Nigeria: Caltop Publication.
- Olatunji, A.J. (2007). Soil erosion problems in upper Ala watershed, Southwestern Nigeria. *Agricultural Journal*, 2(4): 471-477.
- Ologunorisa, T.E., Eludoyin, A.O. & Lateef, B. (2022). An evaluation of flood fatalities in Nigeria. *Weather, climate, and society*, 14(3): 709-720.
- Onanuga, M.Y., Eludoyin, A.O. & Ofoezie, I.E. (2022). Urbanization and its effects on land and water resources in Ijebuland, Southwestern Nigeria. *Environment Development and Sustainability*, 24(5). DOI: 10.1007/s10668-021-01458-1
- Pathirana, A., Deneke, H.B., Veerbeek, W., Zevenbergen, C. & Banda, A.T. (2014). Impact of urban growth-driven landuse change on microclimate and extreme precipitation—a sensitivity study. *Atmospheric Research* 138: 59–72.
- Rahaman, A., Kumar, S., Falsa, S. & Siddiqui, M. (2012). Assessment of Land use/land cover Change in the North-West District of Delhi Using Remote Sensing and GIS Techniques. *Journal of Indian Society of the Remote Sensing*. DOI: 10.1007/s12524-011-0165-4.
- Seifollahi-Aghmiuni, S., Kalantari, Z., Egidi, G., Gaburova, L. & Salvati, L. (2022). Urbanization-driven land degradation and socioeconomic challenges in peri-urban areas: Insights from Southern Europe. *Ambio*, 51(6): 1446-1458.
- Shukla, S., Khire, M.V. & Gedam, S.S. (2013). Effects of Increasing Urbanization on River Basins- State of Art. *International Journal of Engineering Research & Technology*, 2(12): 2742-2747.
- Symeonakis, E., Koukoulas, S., Calvo-case, A., Amau-Rosalen, E. & Makris, I.



- (2004). *A landuse change and land degradation study in Spain and Greece using remote sensing and GIS*. XXth International Society for Photogrammetry and Remote Sensing Congress, commission VII, WG VII/4 Istanbul, Turkey: 1-6.
- Udo, R.K. (1981). *Geographical Region of Nigeria*. Heinemann Educational Books (Nig.) Ltd. Ibadan
- United Nations (UN) (2011). *World urbanization prospects: the revision*. United Nations Department of Economic and Social Affairs (Population Division) New York, USA.
- USGS (2018). *What are the band designations for the Landsat satellites?* Retrieved from: <https://landsat.usgs.gov/what-are-band-designations-Landsat-satellite>.
- Wang, L.Y., Xiao, Y., Rao, E.M., Jiang, L., Xiao, Y. & Ouyang, Z.Y. (2018). An Assessment of the Impact of Urbanization on soil Erosion in Inner Mongolia. *International Journal of Environmental Research and Public Health*, 15(550): 1-13.
- Ward, D., Phinn, S.R. & Murray, A.T. (2000). Monitoring growth in rapidly urbanizing areas using remotely sensed data. *The Professional Geographer*, 52(3): 371-386.
- Wen, J. & Tisdell, C.A. (1999). Growth poles, unbalanced growth, and new growth theories. In: Dahiya S.B (Ed), *The Current State of Economic Science*, Vol.5, Spellbound Publications, Rohtak, India.
- World Population Review* (2018). Available at: <http://worldpopulationreview.com/countries/nigeria/population/cities>.
- Wulder, M.A., Masek, J.G., Cohen, W.B., Loveland, T.R. & Woodcock, C.E. (2012). Opening the archive: How free data has enabled the science and monitoring promise of Landsat. *Remote Sensing of Environment*, 122: 2-10.
- Xu, Q., Zhou, L., Xia, S. & Zhou, J. (2022). Impact of Urbanisation Intensity on Bird Diversity in River Wetlands around Chaohu Lake, China. *Animals*, 12(4): 473.
- Zubizarreta, I., Seravalli, A. & Arrizabalaga, S. (2016). Smart city concept: What it is and what it should be. *Journal of Urban Planning and Development*, 142(1): 04015005.