Changing Patterns of Urban Green Spaces in Akure, Nigeria

CHIAMAKA LOVELYN OLISA[1], MICHAEL AJIDE OYINLOYE[2], AYO EMMANUEL OLAJUYIGBE[3], SAMUEL OLUMIDE AKANDE[4], BABATOPE SUNDAY OLISA[5]

[1,2,3] Department of Urban and Regional Planning, Federal University of Technology, Akure,NIGERIA.
[4]Centre for Space Research and Applications, Federal University of Technology, Akure, NIGERIA
[5]Department of Logistics and Transport Technology, Federal University of Technology, Akure, NIGERIA

Abstract:- Greenery and natural landscapes are vital to human well-being, especially in cities. Notably, the majority of people aspire to live in cities in search of opportunities and a better quality of life, which harms urban green spaces, also known as the "lungs of the city." Current debates on urban planning and sustainable development in Nigeria and around the world are fundamentally influenced by the rapid growth of urbanization and the ensuing domination of concrete spaces over natural spaces. This study examined patterns in Akure's urban green areas while taking into account the spatiotemporal pattern of vegetation cover between 1984 and 2022. The collected satellite imagery was analyzed using the ArcGIS application program, and the Normalized Difference Vegetation Index (NDVI) was used to calculate the rate and patterns of urban green space. Over time, changes in the spatial distribution of urban green spaces and the growth of non-green spaces were monitored and estimated. The depletion's implications for planning were addressed. To educate and inform urban residents about the protection, conservation, and preservation of natural landscapes within urban landscapes, it is thought that examining and analyzing the physical planning and environmental consequences of unchecked depletion of urban green spaces will be useful for making sustainable environmental policy decisions in harnessing the resources potentials.

Key-words: Patterns, Non-green, Green, Spaces, Urbanization, Depletion, Vegetation, Environment

Received: December 8, 2022. Revised: August 26, 2023. Accepted: September 19, 2023. Published: November 7, 2023.

1 Introduction

The global urban debate is greatly influenced by urbanization and its accompanying negative consequences. With the majority of the world's population striving and willing to live in cities, the trend of urbanisation is growing at an alarming rate. As a result, by 2050, it is projected that 68% of people will live in urban areas as more people move into cities in search of jobs and other livelihood-sustaining activities [1]. The rapid encroachment of urban land use on urban green spaces and the rate at which green spaces are being lost remain key issues for the physical development of urban regions. Buildings, roads, bridges, land reclamation, and concrete platforms are replacing vegetation (greens), according to [2], who also claim that increased landuse development, particularly in urban areas, has resulted in a decrease in green spaces and vegetated waters.

This puts complex population shifts, dynamics of urbanization, climatic change, and environmental degradation in the path of planners. Urban environmental pressures are exacerbated in a warming environment by population growth and the construction of buildings like grey infrastructure, which typically leaves little room for blue-green components and processes [3]. The accelerated rate of urban land use encroachment on the urban environment and the rate of blue-green space depletion, there is a need to maintain a balance in land use allocation and planning as the city grows and alters its urban ecosystems. The urban ecosystem could be classified among open space elements that form an integral part of sustainable urban land use development [4]. Open space, as defined by the Ministry of Housing, Communities, and Local Government in its National Planning Policy Framework (NPPF), includes not just land but also areas of water (such as rivers, canals, lakes, and reservoirs) that offer important opportunities for sport and recreation and can act as a visual amenity' [5]. As stated by José & Justyna (2020), one of the contemporary tools to combat challenges associated with urban planning and environmental management is the adoption of the concept of urban blue-green infrastructure [6].

Urban green infrastructure (UGS) refers to an interconnected network of natural and designed landscape components, including water bodies and green and open spaces at the city scale [7]. In this study, green space will comprise green spaces such as publicly accessible and private green spaces, natural or incidental green spaces (remnants of native vegetation), and blue spaces (waterbodies).

The need for urban green infrastructure cannot be overemphasized in curbing thermal discomfort in urban heat islands. With the prevailing global warming incidents resulting from climate change and environmental degradation, many cities in advanced nations are turning to Green Infrastructure (BGI) system solutions to enhance climate resilience. Moreover, restoring the health of urban ecosystems becomes imperative as urban residents often complain of intense heat and atmospheric conditions in most urban habitats across the world [8]. This study's goal is to assess the changing patterns of urban green spaces in Akure and raise awareness of the need to ensure viable conservation and preservation of green vegetation cover. The specific objectives for achieving this goal include: assessing the spatiotemporal pattern of blue-green space in the study area between 1984 and 2022; examining the rate of depletion of blue-green space in the study area; and formulating the physical planning implications of green space depletion in Akure.

Akure was chosen for this study because it is a city undergoing significant land use changes without paying attention to the maintenance of green and blue areas. Akure is blessed with riparian zones along river tributaries, green belts, vegetated regions, and wetlands with various floral compositions. These ecological resources can be used in Akure to foster urban resilience and sustainable land use development, as well as to lessen the issues caused by climate change, urban heat islands, and urban sprawl. Biophilic practices are being included into urban resilience and sustainability planning in the modern age as mitigation strategies for the effects of climate change, which intensifies floods and raises sea levels, as well as the consequences of severe heat, drought, and unexpected storms.

2 Related Studies

There have been many studies on green infrastructure. [7] used a web-based questionnaire to examine the human dimensions of urban blue and green infrastructure in Perth (Australia) and Moscow (Russia). However, the study did not use geospatial data sources and techniques to measure the rate of shrinkage and expansion of blue and green spaces in the study areas. To determine the rate of depletion of Akure's urban blue and green infrastructure and to propose management strategies that involve documentation, inventorying, and conservation of blue-green spaces in the study area, this study will monitor the spatial decadal changes in Akure's urban blue and green infrastructure between the years 1984 and 2022.

Kathryn and Yvonne (2017) opined that cities are growing rapidly, resulting in changing land cover and reduced levels of green infrastructure globally [9]. The rate at which natural resources disappear due to urbanisation and other anthropogenic activities is of utmost global concern. This scenario is more noticeable in urban areas or developed societies than in rural areas, where Akure is not exceptional. Oyinloye (2013) stated that landcovers (forest reserves, gallery forest, and light forest) are continually disappearing in Akure and its environs due to an increase in built-up area [10]. Also, it has been observed that there was a significant decrease in the area covered by waterbodies between 1984 and 2014 in Akure. [11]. The gradual disappearance of this land cover and waterbodies is thus posing a threat to biodiversity and would have impacts on a wide range of environmental and landscape attributes if not monitored, controlled, and managed.

According to [12], as urban population density has expanded globally, regulators and planners have paid much greater attention to evaluation and procedures meant to promote sustainable and ecologically friendly growth and improve the quality of life in urban environments. According to him, "the world population in urban areas is projected to grow from 3.3 billion people in 2007 to 6.4 billion by 2050" [12]. Nevertheless, it is predicted that by 2050, 70% of the world's population will reside in urban areas, up from the current estimate of over 50% [13]. As a result, this development has presented planners and developers with the problem of developing functional open spaces that offer chances and advantages for cities.

[14] revealed that rural and urban planning will not be complete without well-planned, organized, sustainable, and environmentally friendly green spaces and waterbodies Open space is regarded as one of the land use components of the city environment that is dynamic in daily life and improves the quality of life for people who live in cities. They contribute significantly to the development of healthier and more livable communities by offering beneficial environmental, social, and economic advantages. [15]. He continued that environmental quality of life (QoL) has been linked with poverty alleviation decision-making strategies where green space is a quality of life (QoL) indicator; hence, the need to investigate the depletion of green spaces and ensure their preservation becomes imperative.

This study will be beneficial as it cuts across four of the seventeen identified problems that the Sustainable Development Goals (SDGs) of the United Nations seek to address. The first goal is to make cities and human settlements inclusive, safe, resilient, and sustainable with the indicators of access to green space and public space; climate action; life below water and life on land, with an outcome target to conserve and restore terrestrial and freshwater ecosystems [16]. The global urban discourse is of utmost concern as regards urbanisation and its associated negative repercussions.

.

3 Method

3.1 The Study Area

Akure is the study area of this research work. Akure is a city situated in south-western Nigeria and is the largest city and capital of Ondo State [17]. It is a city in Nigeria located on longitude 5.081 to 5.487 decimal degrees and latitude 7.078 to 7.436 decimal degrees, with a population of 360,268 persons in 2006 [18]. The spatio-temporal pattern of urban green spaces in Akure metropolis covered 38 years (between 1984 and 2022). The vegetation type of Akure is forest vegetation, which is categorized as forests, Gallery forests, and forest reserves. In these forests, typical rainforest trees such as Mahogany, Obeche, Iroko, Afara, etc. are present and used for timber. Other economic trees include African pear, Bamboo, Raffia palm, Oil palm, Orange, Mango and Coconut. The persistent clearance of vegetation in and around Akure has led to the development of derived forests around the town [19].

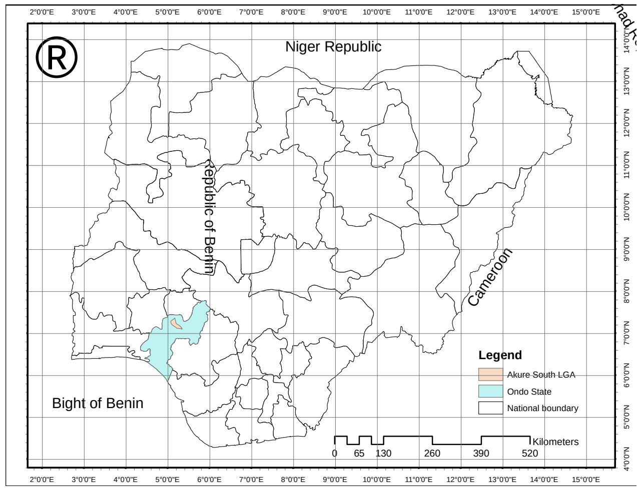

Fig. 1: Map of Akure in its National Setting
Source: (PEAS Associates, 2019)[20]

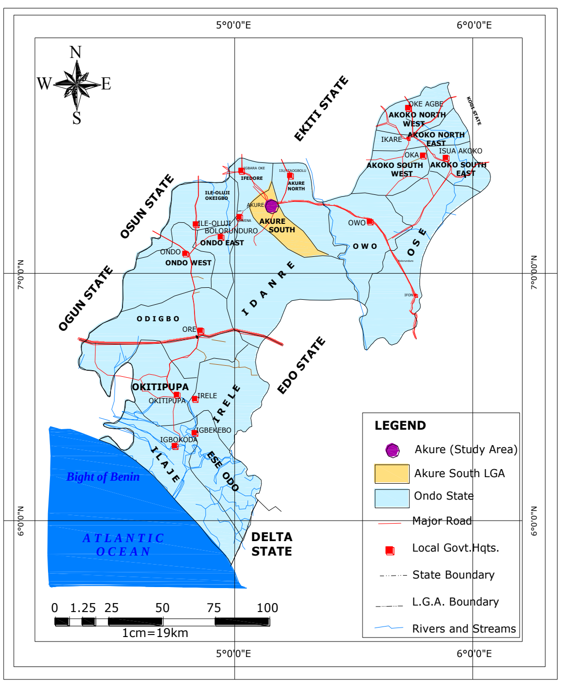

Fig. 2: Map of Akure in its regional setting [20]

Fig. 3: Map of Akure Township showing network of waterbodies and major roads; Source: Adapted from [21] (Digitized by the Author, 2022)

4 Data Acquisition and Method

The study assesses the changing patterns of urban green space depletion in Akure. The use of spatial analysis method was deployed, which involved geo-data collection and analysis of spatiotemporal patterns of green spaces. The sources of data used for the study were secondary. Published and unpublished materials were consulted for the study. Geospatial data analysis was conducted on green spaces and non-green space change for a period of 38 years (1984-2022). The rate of depletion of vegetation cover was analyzed using the Normalized Difference Vegetation Index (NDVI). Data was computed and analyzed using the percentages of the areal extent covered indicated by spectral indices. NDVI is a spectral index that measures healthy green vegetation. The combination of its normalized difference formulation and use of the highest absorption and reflectance regions of chlorophyll make it robust over a wide range of conditions. [22] asserted that NDVI is widely used as an efficient indicator of vegetation cover and spatiotemporal vegetation dynamics. Fig. 4 shows the flowchart of NDVI for the study. The value of this index (NDVI) ranges from -1 to 1. The common range for green vegetation is 0.2 to 0.8. Fig. 4 shows the flowchart of how this study was carried out.

$$NDVI = \frac{NIR - RED}{NIR + RED} \qquad \text{........ (1)}$$

The study made use of the Landsat imagery as the main data source for analysis. Landsat TM 1984, Landsat TM 1991, Landsat TM^+, Landsat TM^+ 2002, Landsat ETM^+ 2015, Landsat OLT 2022 georeferenced. Band Maths/Raster Algebra were calculated using raster calculator in ArcMap 10.7

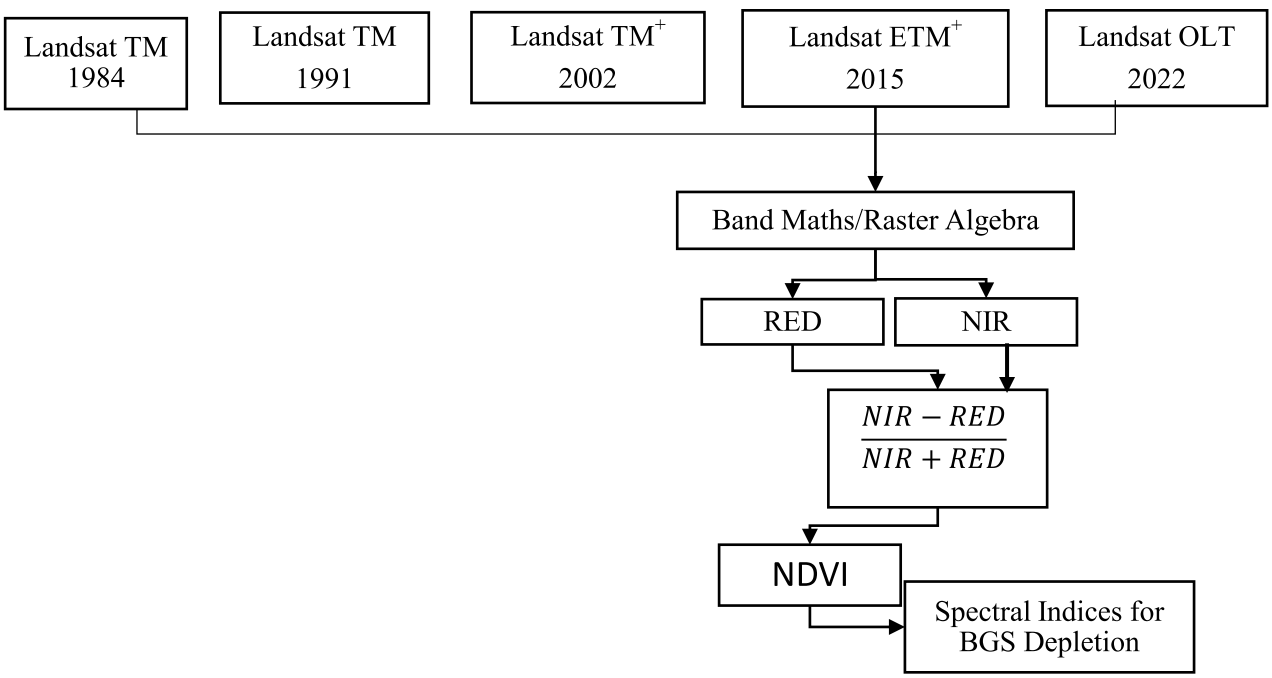

Fig. 4: Flowchart of NDVI for the study
Source: authors 2023

4.1.Population Density of Akure at ward scale

The population density of wards in Akure was determined using attribute variables like the total number of residential buildings in each political ward, the average number of households per building, and the average number of persons per household. This parameter was adopted by Fasakin and Owolabi to determine the household population density of Akure in 2010 and some ward areas in Ilorin, Nigeria [24]. As observed and pointed out by [23], and [24], an average of seven (7) persons make up a household, while an average of four (4) households make up a building for cities in developing countries[23]; hence, the average residents' population in a residential building in these cities is 28 persons per residential building. Table 1 shows the population distribution of residents at the ward scale in the Akure metropolis.

Table 1: Population distribution household by wards in Akure

S/N	Ward	Number of residential buildings	Population density
1	Gbogi/Isinkan I	3267	91476
2	Gbogi/Isinkan II	1395	39060
3	Ijomu/Obanla	1187	33236
4	Odopetu	1323	37044
5	Lisa	2218	62104
6	Oke-Aro/Uro I	3817	106876
7	Oke-Aro/Uro II	2584	72352
8	Oshodi/ Isolo	2878	80584
9	Owode/ Imuagu	3826	107128
	Total	22495	629860

Source: Author's computation, 2022

Note: As observed and pointed out by [18] *Fasakin (2000) that average of seven (7) persons make up a household and an average of four (4) households make up a building* [23]*;* [24]

Table 2: Urban Green Space Standards in Developed Cities

Sn.	Cities	Size (hectares)	Population	M2/ person
1.	London	4	1000	40
2.	Edinburgh	2.9	1000	29
3.	Cambridge	4.6	1000	46
4.	Washington	3.8	1000	38
5.	Minneapolis	2.0	1000	20
6.	Los Angeles	4.85	1000	48.5
7.	Kansas City	3.64	1000	36.4

Source: [27]; [25]

The study attempts to calculate the permissible amount of green space for Akure's resident population using a standard approach. It is important to note that the execution of urban green space regulations varies across cities, especially in developed and well-established cities in the United Kingdom and the United States of America. According to the World Health Organization (WHO), each city should provide at least 9 square meters of urban green space for each person [26]; [27] provided that this space is accessible, safe, and functional. [28]. However, the study estimated Akure's amount of urban green space at the ward level by taking into account urban green space standards in developed cities.

5 Results

5.1. Spatial distribution of Akure urban green spaces

The study revealed spatial changes in green space coverage of Akure metropolis from the period under study. NDVI estimations covered 38 years (between 1984 and 2022). The total area of each class was computed in hectares, square kilometres, and percentages as shown in Table 3. The NDVI results showed a significant variety of shapes, structures, and patterns of urban green spaces within the Akure urban fabric, covering the nine political wards of the Akure metropolis, as shown in Fig.5. In 1984, findings showed that urban green space coverage was 166.38sqkm (92.74%) of the total area covered of 179.4015sqkm; while non-green space coverage was 13.0239sqkm (7.26%). This statistic shows a substantial amount of natural vegetation cover in Akure as of 1984. The city's urban population was characterised by peasant farmers and civil servants who also engaged in subsistence farming. The green features were dominated by evergreen forest canopy, crop plantations, shrubs and grasses; hence, this is attributable to the dominance of vegetative covers in Akure, an agrarian region where a huge population depends on farming and agricultural practices. This region was known in history for its engagement in cocoa plantations, yam farming and cash crops due to the traditions and culture of the region's population. In 1991, a significant decrease in green space area coverage and an increase in non-green areas were observed. As shown in Table 3, urban green space coverage was 154.0251sqkm (85.86%), while non-green space area was 25.3764sqkm (14.14%) of the total area coverage of 179.4015sqkm. The result showed a substantial change in patterns and area coverage of green space in 2002. Green area coverage had a reduction in area coverage by 11.55%; the green space area was 136.2438sqkm (75.94%) while the non-green space coverage increased to 43.1577sqkm (24.06%) of the total landmass of Akure metropolis. This record shows a 70.07% increase compared to the previous year's record.

Table 3 shows a continuous decrease in green spaces as of 2015. The green space coverage was 113.5953sqkm (63.33%) revealing a percentage decrease of 16.62%. Compared with the year 2002 record, the non-green spaces had a significant increase of 52.48%; the area covered by non-green spaces was 65.8062 sqkm (36.68%). A significant spread of non-green areas into green-dominated spaces is shown in Fig. 5, creating varieties of white patches and Isles within the green spaces.

In the year 2022, the result showed that green space had lost a substantial amount of natural landscape components to non-green spaces (built-up areas). Green space coverage was 31.5468sqkm (17.59%); thus, the rate of depletion of green spaces was 72.23%. Meanwhile, the non-green spaces increased in land area to 147.8547sqkm (82.42%). This record indicates a statistical estimate of an 82.05 percent increase in non-green spaces.

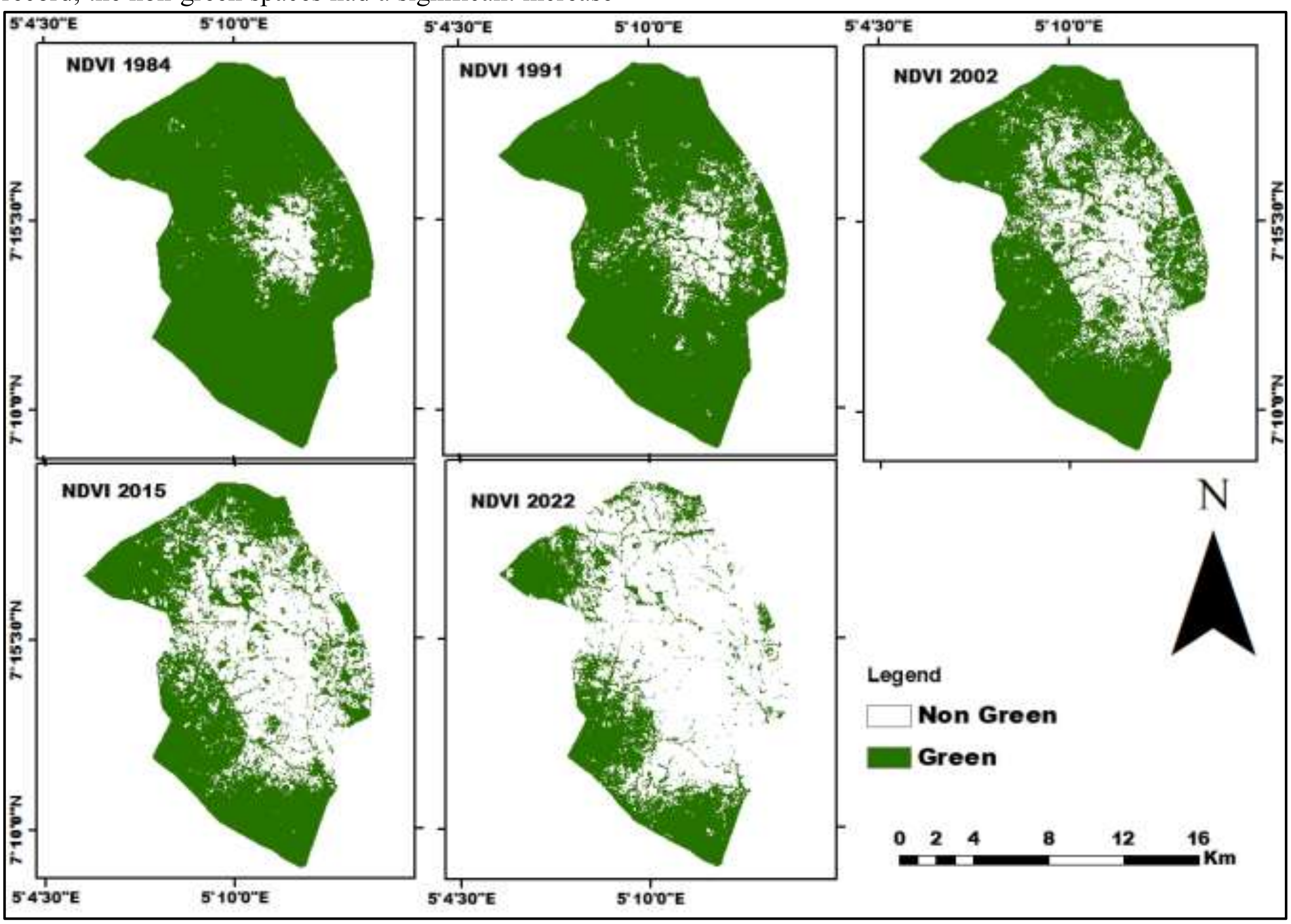

Fig.5: Spatio-temporal change pattern of Urban green spaces in Akure between 1984-2022
Source: Authors, 2023

Table 3: Estimation of area coverage of Green space and Non-green spaces in Akure between 1984 and 2022.

Year	Area (sqm)	Hectares	Area (km2)	Area coverage Occupied in (%)	Absolute change	Percentage Decrease in Green space	Rate of Change
Green Area							
1984	166,377,600	16637.76	166.3776	92.74	-	-	-
1991	154,025,100	15402.51	154.0251	85.86	-12.3525	7.42	1.06
2002	136,243,800	13624.38	136.2438	75.94	-17.7813	11.55	1.05
2015	113,595,300	11359.53	113.5953	63.33	-22.6485	16.62	1.28
2022	31,546,800	3154.68	31.5468	17.59	-82.0485	72.23	10.32
Total	179,401,500	17940.15	179.4015	-	-	-	-
Non-Green Area							
Year	Area (sqm)	Hectares	Area (km2)	Area coverage Occupied in (%)	Absolute change	Percentage Increase in Green space	Rate of Change
1984	13,023,900	1302.39	13.0239	7.26	-	-	-
1991	25,376,400	2537.64	25.3764	14.14	12.3525	94.85	13.55
2002	43,157,700	4315.77	43.1577	24.06	17.7813	70.07	6.37
2015	65,806,200	65,80.62	65.8062	36.68	22.6485	52.48	4.04
2022	147,854,700	14785.47	147.8547	82.42	82.0485	124.68	17.81
Total	179,401,500	17940.15	179.4015	-	-	-	-

Source: Field work, 2023

Table 3 indicates the severity of the depletion of green spaces using the percentage change approach. Percentage change is calculated by dividing absolute change by the initial time values multiplied by 100; while the rate of change was also calculated by dividing the percentage change by the number of years (n); the absolute changes were determined taking cognizance of the initial time values, percentage change, and change in rate. Absolute change and percentage change are mathematically expressed below: Where;

$$Absolute\ change = initial\ time\ value - present\ time\ value \ldots. \quad (2)$$

$$percentage\ change = \frac{Absolute\ change}{Initial\ time\ values} \ \ldots \quad (3)$$

Fig. 6 indicates the spatiotemporal changes of green and non-green spaces in Akure. Findings revealed that urban green space provisions decreased at an average rate of 3.44. The linear equation disclosed the level of reliability between two variables green space and non-green space. The Linear trendline shows a steady increase in non-green spaces over 31 years months with the R^2 value of 0.8408 indicating a pretty good fit of the estimated trendline values to the actual data. Meanwhile, green spaces had a significant and steady decrease at 0.8408 R^2 from the initial year of 1984 to 2022. This shows an 84.08% propensity the data will follow the pattern in the chart into the future if relevant agencies show less concern for urban green spaces.

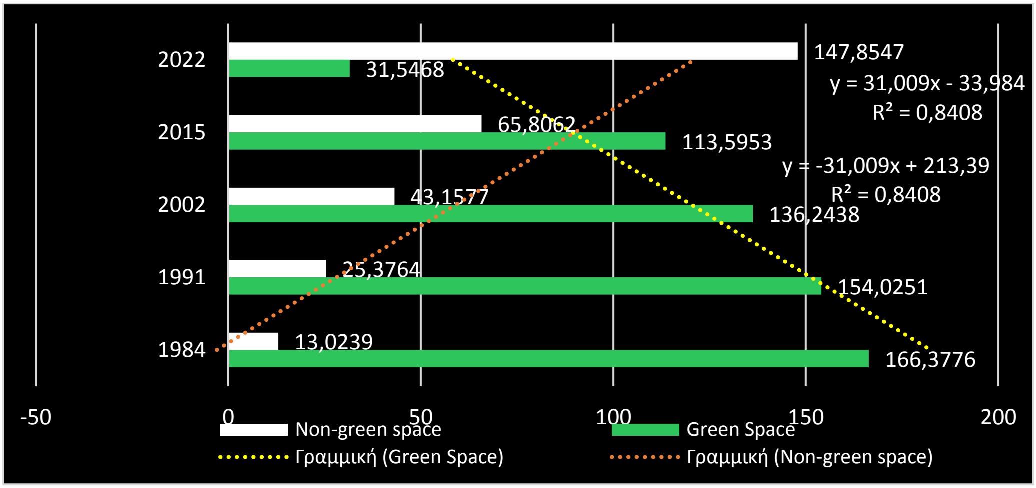

Fig.6: Chart showing the spatio-temporal changes in Green and Non-green spaces in Akure Metropolis between 1984-2022; **Source**: Author, 2023

6 Discussion

6.1. Urban Green space dynamics in Akure metropolis

Spatial changes observed in the amount of green spaces in Akure's metropolis between 1984 and 1991 were estimated to be 12.3525 sq km; that is a 7.42 percentage decrease throughout the investigation. The developed area increased significantly in size. It is noteworthy that all built-up areas are referred to as non-green spaces for this study and are represented in white. Urban green spaces are depicted in a green colour to represent the undeveloped regions of a city, such as incidental, unorganised, and organised open spaces set aside for leisure, relaxation, and the improvement of health and welfare within and/or surrounding built-up areas. As shown in Fig.5, between 1984 and 2022, NDVI computations were conducted throughout 38 years in hectares, square kilometres, and percentage fields. The urban landscape of Akure is comprised of nine political wards; NDVI results revealed that they all exhibit significant changes in shapes, structures, and patterns of urban green spaces. The area covered by green space was 166.38 square kilometres (92.74%) in 1984, compared to 13.0239 square kilometres (7.26%) of non-green space.

According to this study, Akure had a sizable amount of natural vegetation cover as of 1984. This is attributable to the fact that the urban population of the city was made up primarily of peasant farmers and government workers who also engaged in subsistence farming. Akure was an agrarian region with a large population that depended on farming and agricultural practices, the green components were dominated by evergreen forest canopy, crop plantations, bushes, and grasses. Due to their traditions and culture, the people of Akure have been recognized historically for their involvement in yam farming, cash crops, and cocoa plantations.

In 1991, there was a significant decrease in green space area coverage and an increase in non-green areas. As shown in Fig.6, Isles and patches of green spaces within the core zones of green spaces. This indicates the appearance of physical developments such as residential buildings, roads, public institutions, commercial buildings and places of worship. The emergence of small, isolated, or weakly interconnected green patches equivalent to ecological islands became noticeable as the built-up area began to encroach into the adjoining natural green landscape of Akure. Green space coverage was 154.0251sqkm (85.86%); while non-green space area was 25.3764sqkm (14.14%) of the total area coverage of 179.4015sqkm.

The estimated spatial change for 2002 revealed an 11.55% decrease in the area covered by green spaces. Contrary to the spatial pattern of 1991, which was entirely dominated by core zones, the pattern of spatial change is made of various patches/Isle shapes, bridges, loops, and bridge networks of green landscapes. The landmass of Akure metropolis was covered by green space with 136.2438 square kilometers area coverage at (75.94%) and 43.1577 square kilometers (24.06%) of non-green space. Comparing this record to the previous year's record, there is an enormous increase of 70.07%. This increase in the area coverage of built-up (white colour) was attributable to the urbanisation process occurring in the Akure metropolis. The phenomenon or process of population concentration in Akure metropolis and the increase in the density of settlements and areas like Ipinsa, Oke-Odu, Olu-foam, Aule, Apatapiti, Igisogba, Gaga, Ilere, and Ijoka all within Akure territory can be referred to as urbanisation. This is in agreement with [29], who stressed that the process of population migration has a high propensity to cause an increase in the proportion of the population living in all urban areas and suburban settlements; hence, the proportion of this population is increasingly concentrated in larger urban settlements.

In 2015, Fig. 5 demonstrated a noticeable spread of non-green spaces (built-up regions) into core green spaces. The percentage drop in green space coverage was 16.62%, while the percentage rise in non-green space coverage was 52.48%. Fig. 5 shows that non-green areas extend significantly into green-dominated spaces, resulting in a variety of white patches and Isles inside the green spaces. Non-green spaces are evident and substantial in their spread into green spaces, especially light and secondary vegetation. Buildings and construction are replacing cultivated land. This is due to anthropogenic activities that have resulted in the removal of much of the plant cover in the studied region. The non-green spaces (colour white) became obvious in the image; though, the figure shows a dominance of green spaces being grasses and shrubs and light vegetation. The chart in fig. 6 indicated an intensification of land exposure to the bare surface with 4.68% (8.393 sq km) and a substantial increase in the non-green spaces (Built-up area) with 37% (57.413 sq km) out of 179.4045 sq km.

Furthermore, the deterioration of natural vegetation cover in Akure is due to population increase and urban sprawl caused by anthropogenic activities, particularly on forest plant and tree species. It is vital to note that the current rate of vegetative extinction induced by humans is thought to be faster than the background rate of extinction caused by historical farming and cultivation methods. According to [28] urbanization generated by economic development and faster population expansion places pressure on inhabited land regions, green renewable energy environment/sites, determining the design, direction, and rate of change influencing green space landscapes. Concrete projects, mining in the forest, and deforestation all contribute to the massive destruction of natural vegetative components. In 2022, investigations revealed that green space has lost a significant quantity of natural landscape components to non-green spaces (built-up regions). Green space coverage was 31.5468 sq km (17.59%); the rate of green space depletion was 72.23%. Meanwhile, non-green spaces rose in land area to 147.8547 square kilometers (82.42%). This data shows a statistically significant rise in non-green spaces of 82.05 percent. Akure has a substantial domination of non-green spaces (built-up areas), with a vast and continuous distribution of landuse developments and a few smaller green spaces sprinkled throughout the built-up regions. The remaining green zones are isolated core green spaces linked together by loops and bridges. Loops are interconnecting passageways inside the same core green area for the interchange of resources and energy; typically, in the form of road green belts within patches. In contrast to the 1984 NDVI image pattern, which was dominated by large core green spaces, the 2022 imaging pattern is characterized by isolated green spaces that are distributed.

Urban Green spaces are unevenly dispersed, with big green spaces concentrated in the southern portion of the Akure metropolis; many small, scattered green spaces are distributed throughout the city, demonstrating the most visible pattern of green space fragmentation since 1984. Urban green space (UGSs) is typically discontinuous, with little connectivity; in contrast, Urban green space (UGSs) is relatively discontinuous, with minimal connectedness; whereas green space patches in the center and east demonstrate a more complicated kind of total extinction.

6.2. Urban Green space ratio in Akure at ward scale

The study demonstrates the application of NDVI in the analysis of spatial patterns of UGSs and enhanced an in-depth understanding of the spatial patterns of UGSs in the study area. However, the study took cognizance of the urban green space depletion at the ward level and delineated Akure metropolis into nine wards. It made a clear distinction between the intensity of urban green space depletion in different regions.

Understanding the ratio of green space depletion at the ward scale will help in determining regions vulnerable to the negative impact of loss and degradation of green space. Urban green space ratio refers to the ratio of green spaces (parks, gardens, botanical gardens, urban agricultural areas, open areas, recreational areas, children's playgrounds, riparian areas, grasses, shrubs, and forest areas) to built-up areas in a city. Interestingly, the calculation and application of the green space ratio can vary depending on the local planning guidelines and objectives of cities and countries.

As indicated in Table 4, Odopetu recorded the highest degree of green space depletion, with an estimated urban green space share of 0.38% in 2022 compared to the non-green space ratio of 99.62%. followed by Oshodi/Isolo, Ijomu/Obanla, and Lisa wards with 4.18%, 7.13%, and 9.36% urban green space share, respectively, with non-green space. The three ward areas are spatially located in the traditional core area of Akure metropolis, where there are relatively few green elements, a high level of demand for land spaces, high competition for spaces for land use developments, and land use conversion, particularly for commercial and residential uses. This is revealed in Fig. 7 and Fig. 9.

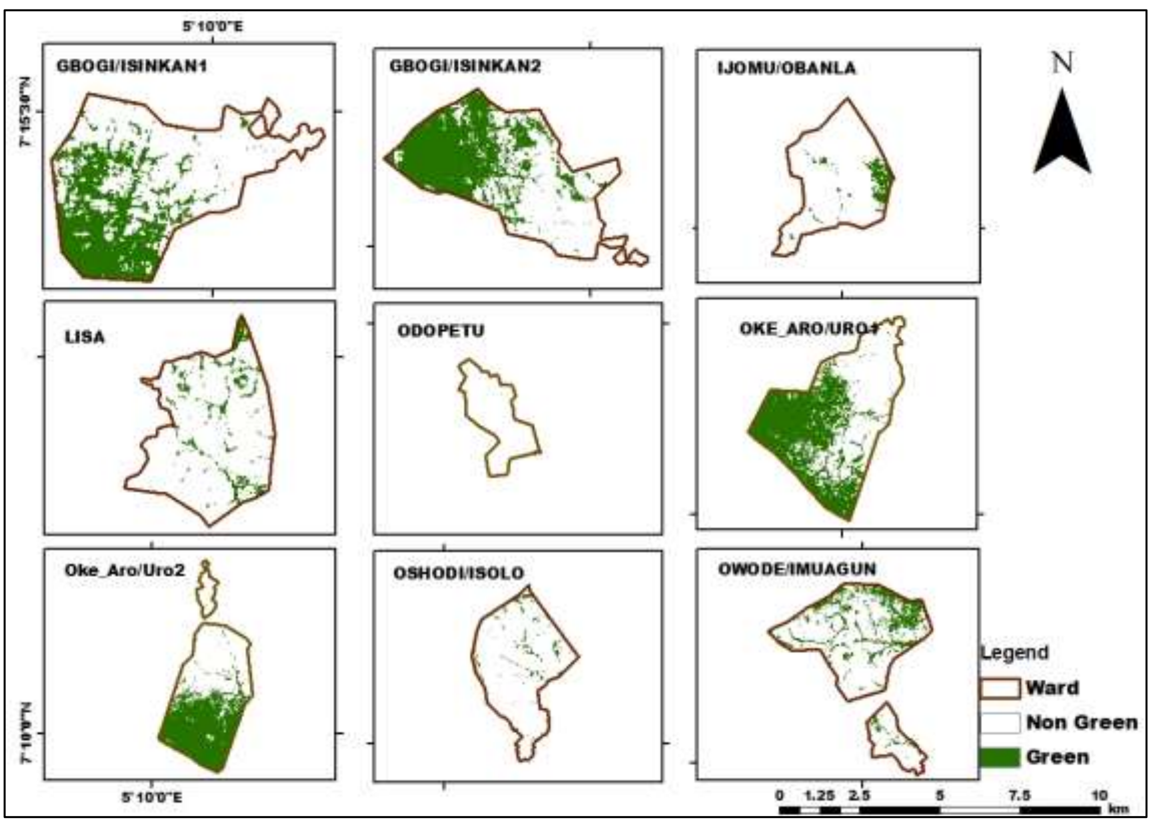

Fig. 7: Distribution of Urban green space at ward scale in Akure Metropolis
Source: Authors, 2023

Table 4: Indicates the Urban green space ratio/index of Akure metropolis.

Ward	Classes	Area (m2)	Area in Sq.km	Area (ha.)	Green space ratio/index = (Green Space Area / Total Land Area) * 100
Gbogi/Isinkan1	Non-Green space	11976300	11.9763	1197.6300	63.74
	Green space	6814800	6.8148	681.4800	36.26
Gbogi/Isinkan2	Non-Green space	16910100	16.9101	1691.0100	54.36
	Green space	14198400	14.1984	1419.8400	45.64
Ijomu/Obanla	Non-Green space	6890900	6.8909	689.0900	92.87
	Green space	529200	0.5292	52.9200	7.13
Odopetu	Non-Green space	1178100	1.1781	117.8100	99.62
	Green space	4500	0.0045	.4500	0.38
Oshodi/Isolo	Non-Green space	15833000	15.833	1583.3000	95.82
	Green space	690300	0.6903	69.0300	4.18
Owode/Imuagun	Non-Green space	18561800	18.5618	1856.1800	76.39
	Green space	5737500	5.7373	573.7500	23.61
Lisa	Non-Green space	15914700	15.9147	1591.4700	90.64
	Green space	1643400	1.6434	164.3400	9.36
Okearo/Uro1	Non-Green space	17343900	17.3439	1734.3900	50.66
	Green space	16890300	16.8903	1689.0300	49.34
Okearo/Uro2	Non-Green space	15037200	15.0372	1503.7200	53.16
	Green space	13247100	13.2471	1324.7100	46.84
	Grand Total	179401500	179.4013	17940.1500	-

Oke-Aro/Uro Ward I has the highest total green space index at 49.34%; this is followed by Oke-Aro/Uro Ward II with a total index of 46.84% space share. Publicly accessible green areas exhibit a relatively substantial share of total green space in the two wards; hence, accessible green space accounts for more than 40% of the city area. Besides, the estimated index observed is above the permissible standard of most developed cities like London, Washington, and Los Angeles. The two wards are located in the southwestern part of Akure, where an array of forest resources such as canopy trees, iron trees, timbers, and cocoa plantations predominate. Gbogi/Isinkan Ward II has a moderate share of urban green space at 45.64%, while Gbogi/Isinkan Ward I has a considerable share of urban green space at 36.26% of the total land area in the ward. Owode/Imuagun Ward has a total green space index share of 23.61% of the total ward area, while the non-green space share was estimated at 76.39%. Table 4 indicates the urban green space ratio/index of the Akure metropolis.

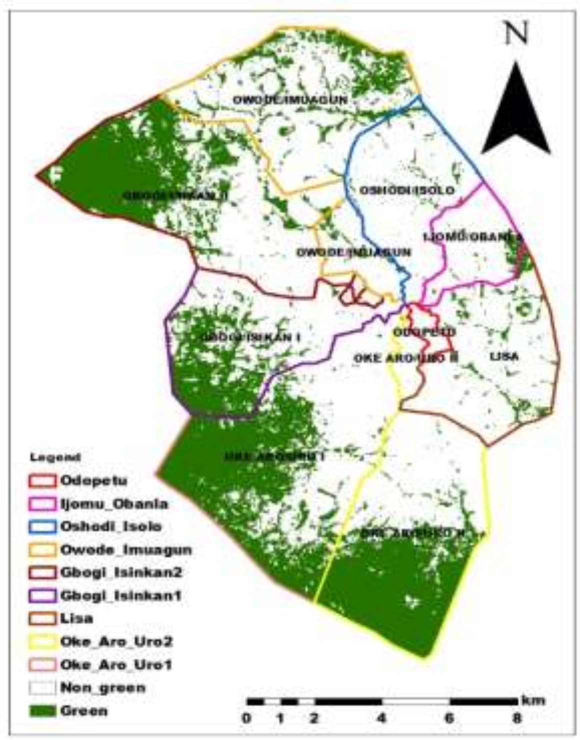

Fig. 8: Spatial Distribution pattern of Urban green spaces in Akure metropolis in 2022;
Source: Author, 2023

6.3. Urban Green space provision in Akure metropolis

Urban green space (UGS) has many environmental, health, and social benefits. Its provision and access are increasingly considered in urban policies, and must rely on data and indicators that can capture variations in the distribution of urban green spaces within cities [30]. The study made use of the standard approach to determine the level of provision of urban green spaces in the nine political wards in Akure metropolis. The total urban green space provision per person within the given area is reported in square metres. Findings revealed the amount of urban green space provision in Akure at ward scale; however, Odopetu ward and Oshodi/Isolo
recorded the lowest amount of green space provision at 0.12m2 per person and 8.57 m2 per person respectively, compared to London's conventional standard of 40m2/person; Washington (38 m2/person), and Los Angeles (46 m2/person), as shown in Tables 2 and 5. The observed green space provisions in these wards are expressively below the minimum requirement for an environmentally sustainable ecosystem that promotes the physical and mental well-being of man in a city.

According to the WHO, an ideal amount of urban green space can be generously provided at up to 50 square metres per person [31]. However, political wards in the Akure metropolis should strive for a sufficient and generous provision of urban green spaces above the minimum requirement. [32] asserted that ensuring minimum requirements in the provision of urban green spaces in cities is important because the most livable cities are those that provide ample green space for their residents. On average, Owode/Imuagun Ward, Gbogi/Isinkan Ward I, and Okearo/Uro Ward II wards exhibit above the minimum requirement of 40 m2/person for developed cities like London, Washington, and Cambridge at 53.56m2, 74.50 m2 and 158.04m2 per person respectively, but the rate of depletion is significantly high at 10.32% (see Table 3). Going by the observed rate of depletion in Akure, Gbogi/Isinkan Ward II, which has an average provision of urban green space at 363.50 m2/person, would lose more than 25% of its green space coverage in a decade.

Fig. 9: Section of Akure metropolis showing depleted ecosystem of Oshodi/Isolo ward
Source: Author, 2023

Table 5: Provision of green space per person (sqm) in Akure at ward scale.

Ward	Area (m2)	Area (ha.)	Resident Population	Green space provision/person London: [40m^2/Person] Washington: [38m^2/Person] Cambridge: [46m^2/Person] Los Angeles: [48.5m^2/Person]
Gbogi/Isinkan1	6814800	681.48	91476	74.49823
Gbogi/Isinkan2	14198400	1419.84	39060	363.5023
Ijomu/Obanla	529200	52.92	33236	15.92249
Odopetu	4500	0.45	37044	0.121477
Oshodi/Isolo	690300	69.03	80584	8.566217
Owode/Imuagun	5737500	573.75	107128	53.55743
Lisa	1643400	164.34	62104	26.46206
Okearo/Uro1	16890300	1689.03	106876	158.0364
Okearo/Uro2	13247100	1324.71	72352	183.0924

Source: Author, 2023

It is noteworthy that the spread and distribution of available urban green spaces in these wards are compact in pattern and skewed in one direction. The skewness of green space is evident in Okearo/Uro Ward I and Okearo/Uro Ward II, Gbogi/Isinkan Ward I and Gbogi/Isinkan Ward II as shown in Fig. 7 and 8. The amount of available green space in Lisa Ward is relatively low and tentacular in shapes and patterns arranged along water lines (riparian corridors) and street roads/main arteries. The pattern is characterised by a skewed distribution of greens, which has been attributable to the intense encroachment of physical landuse development onto available dry lands near water paths. Prospective builders tend to maximise construction around the riparian corridors. The uniqueness of this pattern is its ability to penetrate certain parts of the city, creating a star-like urban landscape. Along the waterlines, vegetated buffers of varying distances can improve and maintain water quality, control stream temperatures, reduce stream bank erosion, filter non-point source runoff, and provide habitat.

6.4 Urban green space and Environmental Implications

According to this study, creating urban green spaces is a crucial way to reduce the ecological impact of metropolitan regions in terms of energy resources consumption, garbage recycling, and food production. This is in agreement with [33] ‘Urban green space is a significant strategic tool in the fight against the urban heat island effect, which may increase temperatures by up to certain degrees Celsius over the urban neighbourhood. It is one of the world’s largest carbon sinks as it absorbs CO2 from the urban atmosphere, causing a reduction in total measured emissions in the atmosphere [34]; It also impacts the environment by enhancing evaporative cooling, decreasing heat retention, reducing pollution, and providing shade.

Although [35] argued that urban green spaces promote physical well-being, it is worth noting that urban green spaces provide suitable sites for renewable energy sources such as biomass, wind, and solar. The majority of factories in developed cities run on energy generated from renewable sources, such as wind, solar, and biomass. Urban green spaces provide enabling environments for renewable energy production, particularly biomass energy. Biomass is referred to as a clean, renewable energy source whose initial energy comes from the sun, plants, or algae. However, biomass resources have the ability to regrow in a relatively short time, hence their rapid renewable rate.

7. Conclusion

The study revealed intense pressure on green spaces from urban physical development and other anthropogenic activities, resulting in the persistent deterioration of green spaces. These developments are a trade-off between green spaces and complete losses of renewable energy sources which can be exploited to generate sustainable energy. Environmental regulations and actions are critical for protecting, conserving, and preserving urban green spaces in order to achieve long-term support and program for urban renewable energy sources. The impact of urbanisation has revealed cases of extreme heat that pose an increasing threat to public health, particularly in the urbanised areas. Akure is an urban area; the study revealed that larger proportion of its urban green spaces disappeared at an increasing rate of 1.05, 1.28, and 10.32 percent between 2002, 2015, and 2022. Largely, green space (vegetation) coverage was 166.38 sq km in 1984; as of 2022, urban green space available was 31.55 sq km, recording an absolute change of 134.83 sq km loss in 38 years.

This reflects an enormous loss of a substantial ecosystem and results in green spaces occupying a very small proportion of the total land area. Consequently, the implication of this is the destruction of both biomass components that are useful for generation of renewable energy such as delicate flora and fauna components of ecosystems. As reported in this study, almost all the vegetation covers in Odopetu Ward, Oshodi/Isolo Ward, and the extension of Owode/Imuagun Ward, have disappeared and are being taken over by non-green spaces. This observation is in agreement with [36] 'The amount of land covered by forests worldwide has decreased by 2 million square miles (3.1 million square kilometres) since 1990. As "carbon sinks," forests absorb CO2 and convert it into the oxygen we breath'. Besides, more than one billion acres of forest have been removed to make space for strip mining, cattle grazing, and industrial sprawl, it further emphasized that deforestation is one of the main causes of rising greenhouse gas emissions [37].

Additionally, the destruction of green spaces has exacerbated the erosion of exposed fragile soils and lands, earthen roads, and the building foundations of the majority of traditional buildings, especially in the core area of the Akure metropolis. The loss of ecological values in the study area's green space component is a critical implication of green space depletion. Conclusively, there is no fair or even distribution of green spaces in the Akure metropolis. At the ward scale, a few wards like Okearo/Uro I and II have green spaces clustered on one side of the ward, and communities that have very few green spaces are located in the centre area of the metropolis. It is expedient to restructure and review the master planning of Akure Metropolis, taking cognizance of revitalising urban areas and ensuring the implementation of sustainable, environmentally friendly planning projects. This will accompany an urban renewal scheme involving the demolition of blighted areas, particularly in the city centre and the corridors of main road arteries.

The study recommends raising awareness of the climatic implications of greening through social media to sensitise the residents of Akure metropolis about the social, health, and environmental benefits of urban green spaces. Local and relevant authorities should be more interested and proactive in educating the resident population of Akure on the importance and environmental implications of urban green spaces.

The study creates awareness on the continual depletion of green areas in Akure metropolitan area as at the year 2022, and this is likely to continue as demand for land rises owing to urbanisation and accompanying activities. It is noteworthy that, if urban physical developments are well guided, controlled and administered with necessary regulations and actions, urban areas will continue to gain all benefits associated with green spaces and renewable energy sources. In Contrary, depletion of urban green spaces (vegetative covers) will have a substantial detrimental impact on the functioning and integrity of urban natural ecosystems, as well as sustainable energy potentials.

References

[1] UNDESA., U. N. (2019). *The 2018 Revision of the World Organisation Prospects.* New York: Population Division of UNDESA.

[2] Liu, S., Zhang, X., Feng, Y., Xie, H., Jiang, L., & Lei, Z. (2021). Spatiotemporal Dynamics of Urban Green Space Influenced by Rapid Urbanization and Land Use Policies in Shanghai. (E. Salvatori, Ed.) *Forests Journal*, 12, 476. Retrieved from https://doi.org/10.3390/f12040476

[3] Sanjana, A., Mahbubur, M., & Ashraful, A. (2019). Designing a Blue-Green Infrastructure (BGI) Network: Toward Water-Sensitive Urban Growth Planning in Dhaka, Bangladesh. *Land 2019, 8(9), 138;* . Retrieved from https://doi.org/10.3390/land8090138

[4] Teodoro, S., Aurelia, S., Riccardo, B., Angelo, S., & Eeva, A. (2021). Planning of Urban Green Spaces: An Ecological Perspective on Human Benefits. *MDPI Journal-Land, 10*(2). Retrieved from https://doi.org/10.3390/land10020105

[5] MHCLG. (2021, June 13). National Planning Policy Framework;. *Area of outstanding natural beauty.*

[6] José, G. V.-H., & Justyna, Z.-W. (2020). Urban green infrastructure as a tool for controlling the resilience of urban sprawl. *springer,Environment, Development and Sustainability*. Retrieved from https://doi.org/10.1007/s10668-020-00623-2

[7] Dushkova, D., Maria, I., Hughes, M., Konstantinova, A., Vasenev, V., & Dovletyarova, E. (2021). Human Dimensions of Urban Blue and Green Infrastructure during a Pandemic. Case Study of Moscow (Russia) and Perth (Australia). *Sustainability*, 13, 4148. Retrieved from https://doi.org/10.3390/

[8] Coutts, C., & Hahn, M. (2015, August 18). Green Infrastructure, Ecosystem Services, and Human Health. *Int J Environ Res Public Health. 2015 Aug;, 12(8):*, 9768–9798. doi:doi: 10.3390/ijerph120809768

[9] Kathryn, J. B., & Yvonne, L. (2017). The public health benefits of green infrastructure: The potential of economic framing for enhanced decision-making. *Journal of Environmental Sustainability*, 25.

[10] Oyinloye, M. (2013). Monitoring Spatial Growth of Educational Institution using GIS: A Focus on Federal University of Technology Akure, Nigeria. *American Journal of Humanities and Social Sciences*, Vo1. 1, No. 3, 2013, 163-173. doi:DOI: 10.11634/232907811301364

[11] Balogun, I. A., & Ishola, K. A. (2017). Projection of Future Changes in Landuse/Landcover Using Cellular Automata/Markov Model over Akure City, Nigeria. *Journal of Remote Sensing Technology, Vol. 5 Iss. 1*, PP. 22-31. doi:DOI: 10.18005/JRST0501003

[12] Elizalde, P. L. (2013). *Planning and Designing Urban Open Spaces for Low-Income Neighborhoods in Chilie (Case Study: Alto Hospicio Chilie).* Vancouver, Canada: Unpublished thesis submitted in partial fulfillment of the requirements of the degree of Master Advanced Studies in Landscape Architecture, The Faculty of Graduate Studies, The University of British Columbia, .

[13] Erini, S., Arnis, R. H., & Yasmina, N. F. (2013). The application of pedestrian ways design concepts as an implementation of sustainable urban open spaces. *Procedia-Soc. Behav. Sci.*, v85, pp. 345-355.

[14] Olajuyigbe, A., Osakpolor, S., & Adegboyega, S. (2013). Assessment of Quality of Life Using Geographial Information System Approach for Poverty Alleviation Decision-Making. *International*

Jornal of Sustainable Land Use and Urban Planning,1(1)., 1-20.

[15] Habeebullahi, N. (2022, July 5). Green Spaces and Their Environmental Significance. *Green Spaces*, p. 1.

[16] United Nations. (2020). *Department of Economic and Social Affairs Sustainable Development; 2030 Agenda;division for Sustainable deveolpment goals.* United Nations. Retrieved from http://www.un.org/sustainabledevelopment/news/communications-material/

[17] Bureau of Stat. (2022). *Akure, Nigeria Metro Area Population 1950-2022".* . Akure: Bureau of Statatics.

[18] National Population Commission. (2006). *Population Census Data, 2006.* Akure: NPC.

[19] Fadairo, G. (2018). *Impact of Flooding on Urban Housing: A Focus on Ala River in Akure, Nigeria.* Ph.D. Thesis, Federal University of Technology, Akure, Nigeria, , Akure.

[20] PEAS Associates. (2019). *Map of Akure in its National Setting.* Akure: Peas Professional Co.

[21] Google Earth Map source . (2023). *Map of Akure showing* . AKURE.

[22] Lou, J., Xu, G., Wang, Z., Yang, Z., & Ni, S. (2021). Multi-Year NDVI Values as Indicator of the Relationship between Spatiotemporal Vegetation Dynamics and Environmental Factors in the Qaidam Basin, China. *Remote Sens.*, 13, 1240. doi:https://doi.org/10.3390/rs13071240

[23] Fasakin, J. (2000). *A Land-use Analysis of the Operational Characteristics of Commercial Motorcycles in Akure, Nigeria.* Federal University of Technology Akure, Unpublished PhD Thesis Submitted to the Department of Urban and Regional Planning,.

[24] Owolabi, O. B. (2020). Consequences of Residential conditions on Psychological well-being of communities in Kwara State, Nigeria. *Quantum Journal of Engineering, Science and Technology, 1*(1), 21-32.

[25] Khan, A. M. (2012). *Planning Standards for Recreational Facilities and Open Space in the Context of Urban Areas of Bangladesh in Khan, A. M. (2014). Revisiting Planning Standards for Recreational Facilities in Urban Areas.* Retrieved from http://www.bip.org.bd/SharingFiles/journal_book

[26] World Health Organization. (2010). *Urban Planning, Environment and Health: From Evidence to Policy Action.* WHO. Retrieved March 22, 2023, from From http://www.euro.who.int/__data/assets/pdf_file/0004/114448/E93987.pdf?ua=1.

[27] Maryanti, M. R., Khadijah, H. A., Uzair, M., Megat, M., & Ghazali, M. A. (2016). The urban green space provision using the standards approach: issues and challenges of its implementation in Malaysia. *WIT Transactions on Ecology and The Environment, Vol 210*, 369. doi:10.2495/SDP160311

[28] Moatamed, A. (2021, March 1). Impact of anthropogenic activities on natural vegetation cover of Aseer Region, Saudi Arabia. *The Egyptian Journal of Environmental Change, 13*(1). doi:DOI: 10.21608/ejec.2021.149017

[29] Gu, C. (2019). Urbanization: Processes and driving forces. *Sci. China Earth Sci., 62*((9)), 1351–1360.

[30] Le Texier, M., Schiel, K., & Caruso, G. (2018, October 17). The provision of urban green space and its accessibility: Spatial data effects in Brussels. (E. Arcaute, Ed.) *ACs Environmental Au Journal, 13*(10), 2. doi:10.1371/journal.pone.0204684

[31] Morar, T., Radoslav, R., Spiridon, L. C., & Păcurar, L. (2014). Assessing pedestrian accessibility to green space using GIS. *Transylvanian Review of Administrative Sciences, 10*(42), 116–139.

[32] Baaharash, B. (2015). *Liveable Cities: Greening for Success from*. Retrieved from https://www.linkedin.com/pulse/liveable-cities-greening-success-baharash-bagherian?trk=pulse-det-nav_art.

[33] Mohajerani, A., Bakaric, J., & Jeffrey-Bailey, T. (2017). The urban heat island effect, its causes, and mitigation, with reference to the thermal properties of asphalt concrete. *J. Environ. Manag.,, 197*, pp. 522-538,. doi:10.1016/j.jenvman.2017.03.095

[34] Pat, B., Ian, J., O'Neill, & Jane, J. L. (2020). Global Climate Chnage; Vital signs of the Planet. *Urban Green*.

[35] Rocque, R. J., Caroline, B., Ruth, N., Laura, C., Louann, P. B., Rose-Alice, P. R., . . . Witteman. (2021). Health Effects of Climate Change: an Overview of Systematic Reviews. *Google Scholar*.

[36] Ramesh, P. B. (2022). Impact on Forest and Vegetation Due to Human Interventions. *Journal of Green Energy and Environmental Technology*, 15. doi:DOI: 10.5772/intechopen.105707

[37] Nunez, C. (2022, september 29). *Climate 101: Deforestation*. Retrieved from National Geographic.com: https://www.nationalgeographic.com/environment/article/deforestation

Contribution of Individual Authors to the Creation of a Scientific Article (Ghostwriting Policy)

The authors equally contributed in the present research, at all stages from the formulation of the problem to the final findings and solution.

Sources of Funding for Research Presented in a Scientific Article or Scientific Article Itself

No funding was received for conducting this study.

Conflict of Interest

The authors have no conflicts of interest to declare that are relevant to the content of this article.