IOSR Journal of Environmental Science, Toxicology and Food Technology (IOSR-JESTFT)
e-ISSN: 2319-2402, p- ISSN: 2319-2399.Volume 19, Issue 12 Ser. 1 (December 2025), PP 07-15
www.iosrjournals.org

Remote Sensing And GIS Mapping And Assessment Of LULC And Urban Heat Island (UHI) Of Lafia, Nasarawa State, Nigeria

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Abstract
Urban Heat Island (UHI) is the occurrence of higher temperatures in metropolitan areas with noticeable impact on human comfort. The objectives of the study were to (i) map and examine the Landuse Landcover (LULC) changes in Lafia, (ii) map, measure and examine the level of Normalize Differential Building Index (NDBI), (iii) assess the distribution changes in Land Surface Temperature (LST) and UHI, and (iv) examine the impact of UHI in Lafia. Satellite images comprising of Landsat 7 TM (2002), ETM+ (2012) and OLI 30m (2024) covering the study area were obtained from the achieves of USGS website. Erdas Imagine Software was used to examine the LULC, LST and NDBI. Five classes of LULC (Vegetation, Built-up area, Rock Outcrop, Bare Surface, and Water Body) were selected through training sample, supervised digital image classification method (using the maximum likelihood algorithm) was used to group spectral signatures with similar DN values into the five (5) different spatial classes identified. Map creation was carried out using ArcGIS 10.5 software. The impact assessment of UHI on the residents/inhabitants of Lafia was obtained from 400 copies of questionnaires sampled to residents using Purposive and Random sampling techniques and responses analyzed using the SPSS software. The study revealed that in 2002, the dominant landuse (LU) was vegetation which occupied the largest area of 83,106 Ha (30%), it then decreased to 43,453 (15.7%) in 2012, and finally increased slightly to 55,311 Ha (20%) in 2024 due to intense farming activities in Lafia. However, the decrease in vegetation cover is attributable to rapid urbanization. Thus, Built-up area more than double from 52,635 (19%) in (2002) to 122.196 Ha (44.2%) 2012, and finally increased to 150,645 Ha (54.3%) in 2024. Bare land, Rock Outcrop and Water Body also fluctuated due to anthropogenic activities. The study further revealed most extensive UHI occurred in the central part of the CBD which is Central Cinema and then transverse to other areas over the period of the study. The study also showed that, in 2002, the maximum temperature was between 32.69^{0}C and 39.66^{0}C; between 33.93^{0}c and 41.58^{0}C in 2012; and between 35.36^0 and 42.68^0 in 2024 respectively. Similarly, the changes in the minimum and maximum values of NDBI were -0.17 and 0.32 in 2002; 0.33 and -0.24 in 2012; and 0.36 and -0.19 in 2024. Majority (37%) of the respondents affirmed negative impact of UHI in terms of health challenges and discomfort. There is the need to ensure that further development conserve the vegetal covers with a view to reducing the increasing temperature in Lafia. This is aimed at reducing sensitivity to heat exposure and health challenges such as meningitis, stroke, skin rashes, and neurological challenges in Lafia.
Keywords: *LULC, LST, UHI, NDBI, GIS, Remote Sensing, Mapping*

Date of Submission: 01-12-2025 Date of Acceptance: 11-12-2025

I. Introduction

Weather and climate are essential component of the environment that have always been of significant importance to man and and his health (Sufiyan, Mohammed, Bello & Zaharaddeen, 2020). Conceptually, Metropolitan Hotness Island (MHI) or Urban Heat Island (UHI) is the name given to the trademark warmth of both the environment and the lithosphere in urban communities (metropolitan) contrasted with their provincial (non-urbanized) environmental elements (Santamouris, 2013). In other, words, UHI is the occurrence of higher temperatures in metropolitan areas in comparison to temperatures of suburban and rural areas, which means; the higher the urbanization level, the more prominent the UHI process (Pickett, *et al.,* 2011; Santamouris, 2013). UHI develops when a large fraction of the natural land cover in an area are replaced by built surfaces that trap incoming solar radiation during the day and then re-radiate it at night (Aderoju, Samakinwa & Ibrahim, 2013).

The importance of Space Science and Technology (Remote Sensing and Geographic Information System) in climate and environmental conservation includes the capability to measure, capture, understand and study the spatial variability in both natural phenomenal and man-made infrastructure on Earth - all aimed at meeting the socio-economic, infrastructure, political and industrial challenges of man in his environment (Bello & Itam, 2025).

Cleared streets, parking garages, and structures assimilate and hold heat during the day and then spread that hotness back into the encompassing air. Furthermore, heat-related effects fall inconsistent with generally under-served populaces confronting more prominent well-being dangers (Sun, Tan, Xu, 2010). With increase in global temperatures occasioned by the increment in Green House Gases (GHG, such as carbon, methane, etc.), there is now a worldwide acceptance of emerging UHI mainly orchestrated by the activities of man (anthropogenic). For instance, there are increases in fumes - air pollution from vehicles, airplanes, industries, bush burning, mining sites, among others (Bello & Omoyajowo, 2015). All these activities are gradually altering the normal temperature regimes within ecological zones with noticeable input from human activities. Remote Sensing and GIS is now been adopted to study UHI as reliable technologies for data acquisition, analysis and visualization of impacted environment. This is due to the importance of having good health in all ramifications (Bello & Dogara, 2025; Sufiyan, Mohammed, Bello & Zaharaddeen, 2020).

With an assessed populace of 167 million (NPC, 2006), Nigeria is encountering one of the most phenomenal paces of urbanization around the world. The public normal metropolitan development rate is around 11% with a base of more than 5.3% per annum. Some singular urban areas have higher metropolitan development rates than the public normal (Christian & Ugoyibo, 2013). Lafia's location as a rising urban space since the establishment of the Federal University of Lafia in the capital city of Nasarawa State, in the Central region of Nigeria, suggest that increase in the activities of man in terms of cooking, vehicular traffic, and bush burning for agriculture as well as the cutting down of trees for urbanization will invariably impact the people. Consequently, it is important to specifically note that With an assessed population of 167 million, Nigeria is encountering one of the most phenomenal paces of urbanization around the world. This has greatly impacted the rural and urban spaces as illustrated in Figure 1, for which Lafia is a case to study deeply.

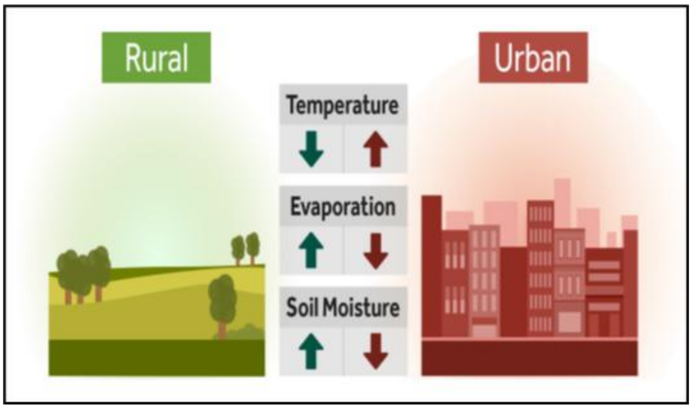


Figure 1: Rural Area with Vegetation cover & Urban Area with effects of UHI
Source: Peng *et al., (2012)*

Environmental pollution has altered the natural equilibrium of our natural habitats. As the number of humans increases in cities due to migration, urbanization and population expansion (Edobor & Bello, 2017), the city attraction increases the rate of growth in the introduction of pollutants which makes complex environmental issues. This can be in the form of automobile exhaust that produces noise, carbon monoxide (Co). Sulfur dioxide, radioactive substances and particulate matter (Bello, Bello, Edobor & Kabiru, 2022). Likewise, with increasing global temperature, the fear is that if left unattended to, the possibility of having uncomfortable living space and endless disasters such as flooding, desertification and, consequently, hunger, etc., might increase as a result of climate change induced challenges. UHI might be up to 10 - 15^0C under ideal conditions. For very nearly 200 years, climatic contrasts among metropolitan and rustic conditions have been perceived of which temperature is the most self-evident (Unger *et al.,* 2001). There is, therefore, the need to undertake this studies with a view to demonstrating the importance and processes of data collection and analysis of UHI indicators using Satellite Remote Sensing data and Geographic Information System (GIS) mapping techniques. It will also avail the researchers the ability to model case scenarios from prevailing trend of spatial occurrence and variability.

Thus, the justification for this study arose from the fact that, in urban or semi urban areas like Lafia Local Government Area of Nasarawa State, Nigeria, there exist the problem of urban smoke and an increase in environmental temperatures. This study, therefore, focused on the level of Landuse Landcover (LULC) change and temperature variability in Lafia using 2002, 2012 and 2024 time period for change assessment. The specific objectives are to: (i) map and examine the Landuse Landcover (LULC) changes in Lafia, (ii) map, measure and examine the level of Normalize Differential Building Index (NDBI), (iii) assess the distribution changes in Land Surface Temperature (LST) and UHI, (iv) examine the impact of UHI in Lafia.

II. Materials And Method

Figures 2 and 3 illustrates the adopted methodology workflow in this study. Table 1 shows the datasets used and their sources. Using Satellite Remote Sensing technology and GIS data analysis techniques, this study is geared towards assessing Urban Heat Island in Lafia. Using Landsat images of 2002, 2012 and 2024 respectively and other ancillary datasets (Table 1), the study modeled the LULC change and Land Surface Temperature (LSF) variability using supervised digital image classification by adopting the maximum livelihood algorithm in Erdas Image Software, and then calculating and visualizing the changes in NDBI in Lafia between 2002 and 2024. Ways to scientifically mitigate the challenges posed by increase in Green House Gases (GHGs) in the study area were articulated.

Table 1: Type of Data, Method and Sources

S/N	DATA TYPE	DATA FORMAT	DATA SOURCE	METHOD
1	Administrative Map	.shp(Shape file)	NAGIS	Delineate study area
2	Satellite Images	Tiff: Landsat 7 TM (2002), Landsat 7 ETM + (2012) and Landsat 8 OLI/TIRS (2024)	USGS	Analysis and observation
3	LST data	tiff	glcf	Derived
4	Temp. Data	Tabular (ºC)	Field	Field sampling
5	Erdas Imagine & ArcGIS (Version 10.5)	Software	Hexagon Geospatial & ESRI	Image analysis & GIS Mapping and analysis

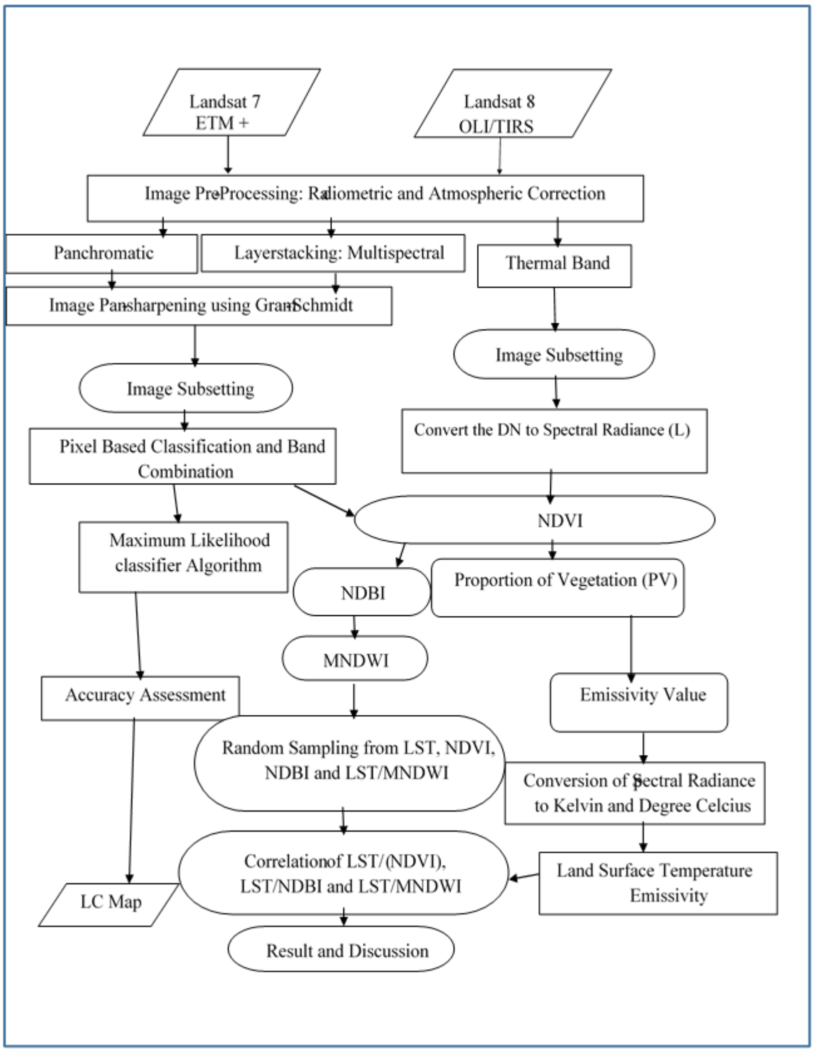


Figure 2: Study methodology workflow

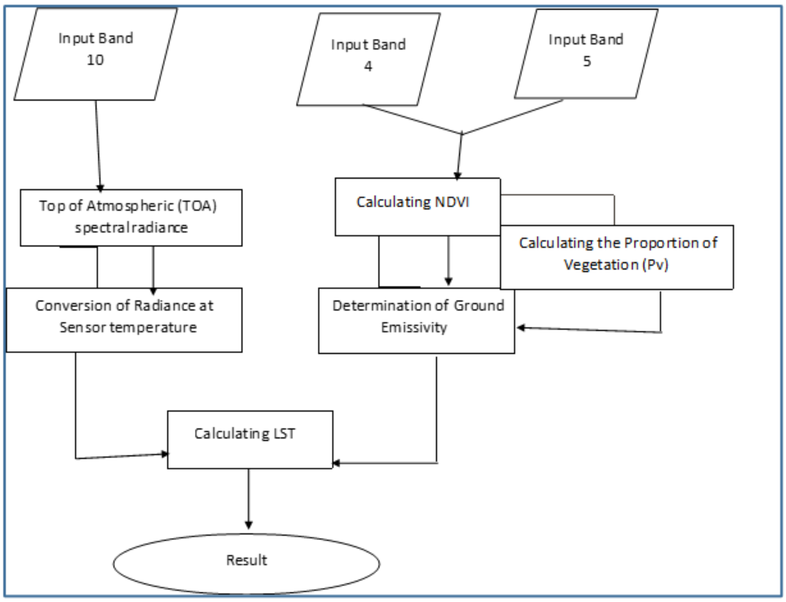


Figure 3. Algorithm for SUHI Evaluation And Assessment
Source: *Avdan & Jovanovska (2016)*

In addition, the problems and proper solutions on how to tackle the issue of UHI in the study area are assessed. New adoptive measures of recycling, reducing and reusing of waste as well as controls of emission of harmful gasses such as the greenhouse gasses are evaluated for informed knowledge and decision making.

III. Results And Discussion

Mapping of LULC and Impact of Urban Dynamics in Lafia

For year 2002, from the result shown in Table 2 and Figure 4 respectively, the landuse landcover (LULC) in Lafia indicates that Vegetation occupies the largest area of 83,106 hectares (30%), followed by Bare-surface, 74520 Hectares (26.9%); Rock Outcrop, 63,162 Hectares (22.8%); Built-up Area, 52,635 Hectares (19%); and Water body, 3,602 Hectares (1.3%) and thus ranked 5th (the least) in decreasing order of area coverage. Thus, it is safe to conclude that the highest LULC in terms of area coverage in 2002 was vegetation with about 30% (ranked 1st) of the total land cover in Lafia.

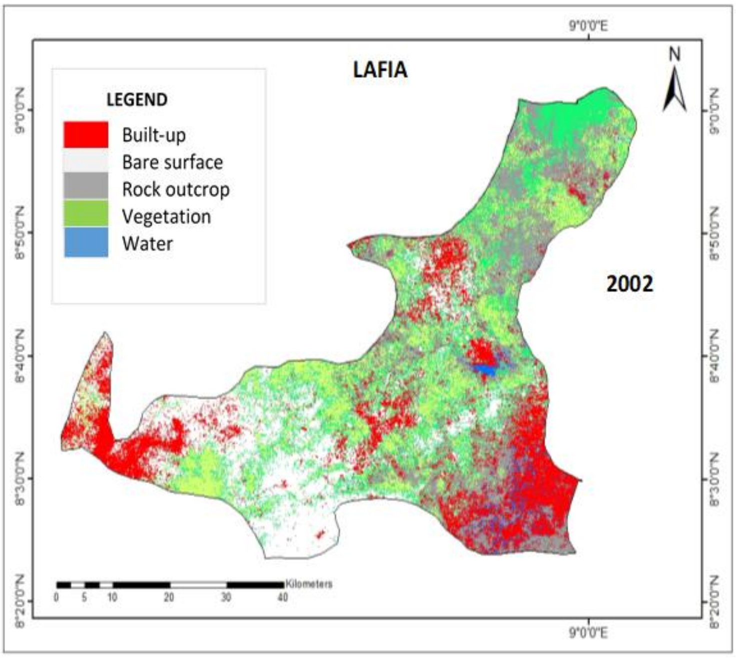


Figure 4: Land use/Land cover of Lafia in 2002
Source: *Author's GIS Analysis, (2025)*

Table 2: 2002 LULC of Lafia, Nasrawa State, Nigeria

LULC Classes	Area(Hectares)	Percentage (%)	Rank
Build-Up	52635	19	4th
Vegetation	83106	30	1st
Rock Outcrop	63162	22.8	3rd
Bare surface	74520	26.9	2nd
Water Body	3602	1.3	5th
Total	**277025**	**100**	

However, there were noticeable changes in 2012 (10 years later) as illustrated in Figure 5 and Table 3 respectively. The study revealed that Built-up area increased to occupy the largest area with 122,196 Hectares (44.2%) in 2012 from 52,635 Hectares (19%) in 2002. This is followed by Rock Outcrop with 95,666 Hectares (34.5%) which increased slightly due to excavation of minerals and clearing. This is followed with drastic decrease in vegetation cover to 43,453 Hectares (15.7%) from 83,106 Hectare (30%) in 2002. Similarly, Bare Surface also decreased to 13,417 Hectares (4.8%), while water Body also decreased from 1.3% in 2002 to 0.8% (2,293 Hectares) in 2012. The increase in Built-up area with 44.2% as LULC change in Lafia indicate massive increase in urban activities in Lafia within the 10-year period of study. This can also be said to have increased human activities and consequently led to significant Land Surface Temperature (LST) and urban Heat Island Island.

In 2024, same trajectory of increase followed in Built-up area as illustrated in Figure 6 and Table 4 (150,645 Hectares, 54.3%). However, Vegetation cover increased somewhat to 55,311 Hectares (20%) and then ranked 2nd as against 3rd in 2012. This is can be attributed to increase in farming activities for food production. Bare-surface 44,501 Hectares (16.1%); Rock Outcrop and Water Body occupied 25,091 Hectares (9.1%), and 14,77 Hectares (0.53%) respectively. This result shows that, for built-up area to have the highest percentage of the total area (277,025 Hectares) within the period under review, Lafia has undergone serious urban development in terms of infrastructures like buildings, good road networks, and increase in Bare Surface due to construction activities. Thus, it is empirical to conclude that in terms of LULC of Lafia between 2002 and 2024, urban development and other anthropogenic activities have increased and contributed immensely to increase in Land Surface Temperature and, by extension, the Urban Heat Island in Lafia.

Table 3: 2012 LULC of Lafia, Nasrawa State, Nigeria

LULC Classes	Area(Hectares)	Percentage (%)	Rank
Build-Up	122,196	44.2	1st
Vegetation	43,453	15.7	3rd
Rock Outcrop	95,666	34.5	2nd
Bare surface	13,417	4.8	4th
Water Body	2,293	0.8	5th
Total	**277025**	**100**	

Table 4: 2024 LULC of Lafia, Nasrawa State, Nigeria

LULC Classes	Area(Hectares)	Percentage (%)	Rank
Build-Up	150645	54.3	1st
Vegetation	55311	20	2nd
Rock Outcrop	25091	9.1	4th
Bare surface	44501	16.1	3rd
Water body	1477	0.53	5th
Total	**277025**	**100**	

Source: *Authors' GIS Analysis (2025)*

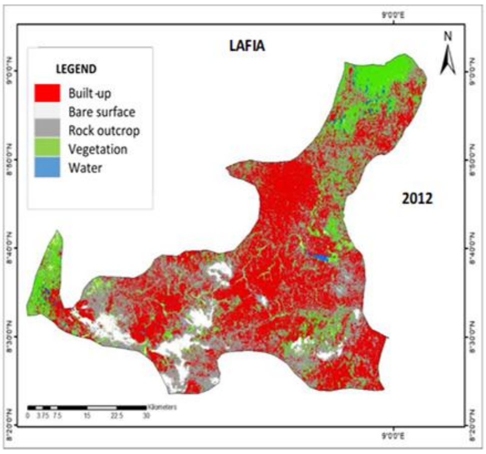


Figure 5: 2012 LULC of Lafia

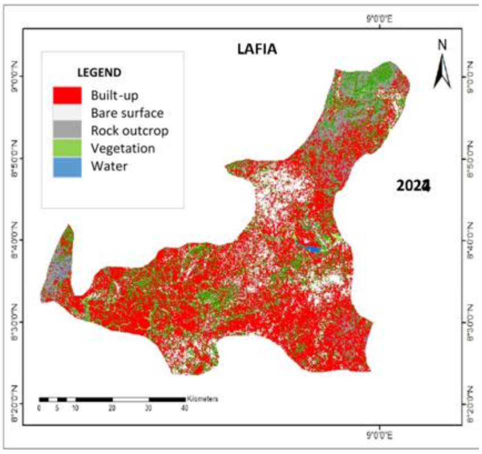


Figure 6: 2024 LULC of Lafia

Normalized Difference Built-Up Index (NDBI) Distribution

The Normalized Difference Built-up Index NDBI maps of the study area for the years within the period of study revealed that areas with green pigments on the NDBI maps were classified as having low values which represent places with vegetation cover and has low built-ups/pavements, areas with red/yellow pigment were classified as areas with high built-ups/pavements. The result also shows that in 2002 the minimum and maximum values of NDBI were -1 and 1 (-0.17 and 0.32) (see Figure 7). At this point, vegetation shows to have higher values than the built-up areas. In the year 2012, the minimum and maximum values of NDBI were 0.33 and -0.24 (see Figure 8); while in 2024, the NDBI minimum and maximum values were 0.36 and -0.19 respectively (see Figure 8).

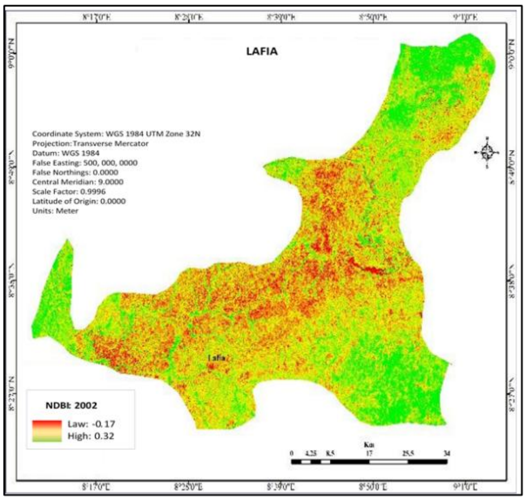


Figure 7: NDBI of Lafia 2002

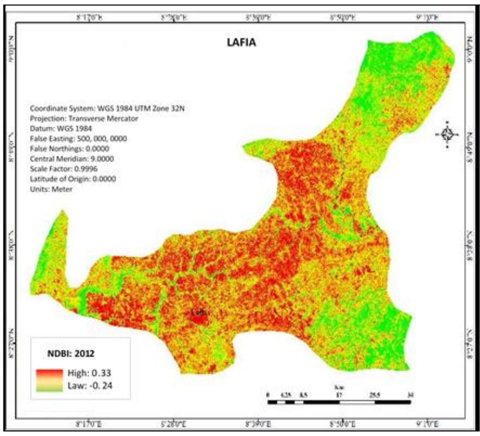


Figure 8: 2012 NDBI of Lafia

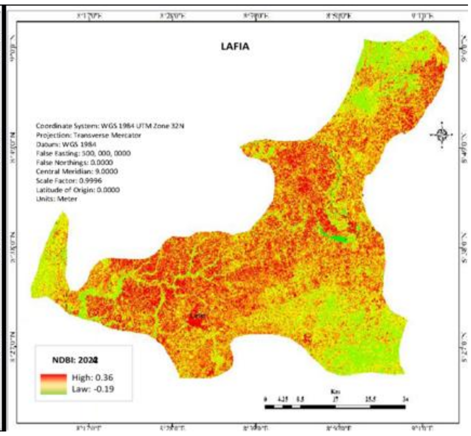


Figure 9: 2024 NDBI of Lafia

According to Zha *et al.* (2003), positive values of NDBI represent urban land areas while negative values of NDBI represent non-urban land area. These values were derived in accordance with the set standard for measuring NDBI of an area.

Urban Heat Island Distribution and Temperature Variation in Lafia

The spatio-temporal mapping and assessment of Land Surface Temperature (LST) of the Lafia shows that the study area has been continuously changing over the years. For instance, in the year 2002, the maximum and minimum temperature of Lafia was between 32.69^0C and 39.66^0C, and between 23.33^0C and 25.53^0C respectively (Figure 10). In 2012, the maximum and minimum temperature of Lafia was between 33.93^0c and 41.58^0C, and between 21.26^0C to 26.88^0C respectively (Figure 11). And lastly, in the year 2024, the maximum and minimum temperature were between 35.36^0C - 42.68^0C, and between 25.38^0C and 27.82^0C respectively (Figure 12). These results further confirm that the temperature in Lafia has been on a steady increase within the period of study due to urbanization process as corroborated in the LULC assessment maps in Figures 4, 5 and 6, and tabulated in Tables 2, 3 and 4.

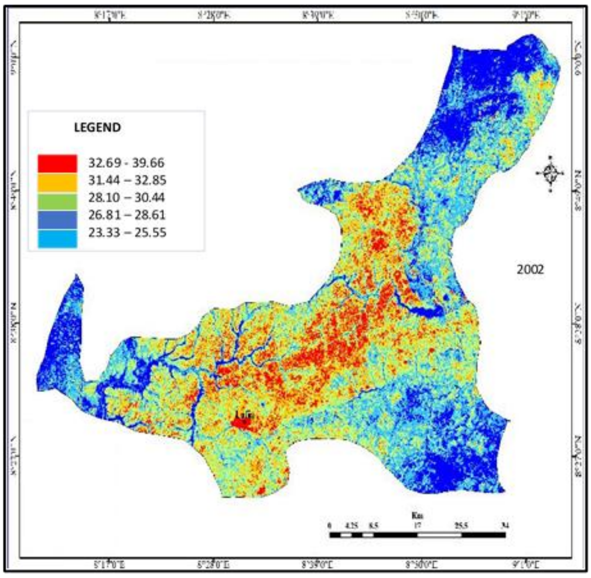
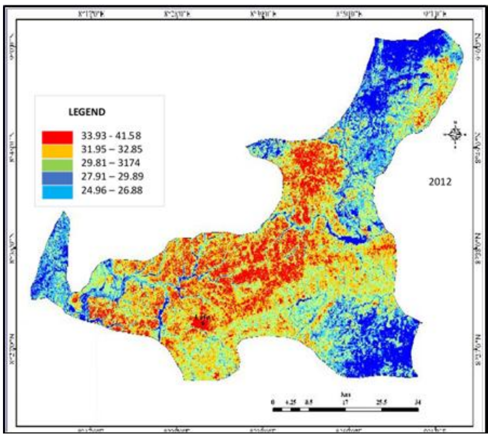


Figure 10: 2002 LST of Lafia



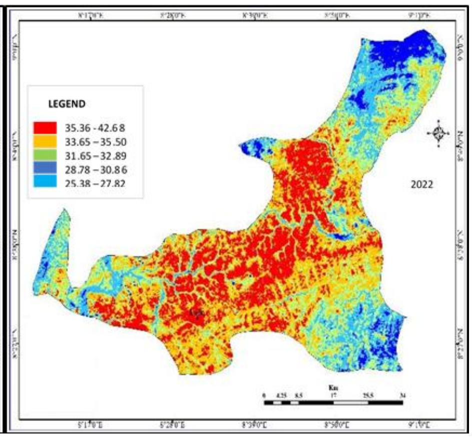


Figure 11: 2012 LST of Lafia **Figure 12:** 2024 LST of the Lafia

Source: *Author's GIS Analysis, (2025)*

The Impact of Urban Heat Island in Lafia, Nasarawa State

Thus, Urban Urban Island (UHI) occur when cities replace natural land cover with dense concentrations of pavement, buildings, anthropogenic activities and other surfaces that absorb and retain heat. The impact of this phenomenon cannot be over emphasized. This has been the case in Lafia. Thus, the study shows that the same condition has been in Lafia, the study area. UHI keep increasing massively due to infrastructural development and anthropogenic activities and, as such, it poses different challenges or impacts to the inhabitants in the study area as Tabulated in Table 5.

Table 5: Impacts of Urban Heat Island UHI in Lafia

S/N	Variables	Frequency	Percentage (%)
1	Air pollution level	29	9.3
2	High daytime temperature	40	12.9
3	Reduced night cooling	33	10.5
4	Mortality	7	2.3
5	General discomfort	24	7.7
6	Energy cost (air conditioning etc.)	25	8.0
7	Respiratory difficulties	5	1.6
8	Heat cramps	21	6.8
9	Heat exhaustion	33	10.6
10	Non-fatal heat stroke etc.	12	3.9
11	All of the above	82	26.4
Total		**311**	**100**

The study further shows that majority of the inhabitants in Lafia (58%) perceived temperature condition of the area to be very high due to massive urbanization in Lafia as urbanization is associated to UHI. The study further revealed that as the temperature of the study area grows higher due to UHI as confirmed in Figures 10, 11 and 12, there are health challenges associated with UHI and so, majority (37%) of the respondents also agreed to have been affected by both environmental and health challenges such as air pollution level, high daytime temperature, reduced night cooling, heat exhaustion, heat cramps, respiratory difficulties, etc. All been associated with UHI.

Finally, this finding conforms with the assertion that the hottest parts in cities and towns are generally those with numerous tall buildings without green spaces. The study also revealed that the reason for the UHI hotspot in the outskirt of the town was mainly because of the urban expansion and the new development sites. The new developing sites destroyed the original ground land cover and increased the land surface temperature (LST).

Figure 13 presents information on the respondent's experience of UHI heath-related challenges in the study area. From the findings, 115(37%) of the respondents indicate having health challenges related to UHI, 108 (34.7%) fall under the categories who said no, while more than one-quarter 83(26.7%) of the respondents were undecided on the decision whether they are affected by the prevailing temperature condition of the area due to UHI or not. This implies that majority of the respondent's experience any of the UHI related-health challenges listed in Table 5. The implication of the findings in section 3 is that urbanization is primarily responsible for the increase in Land Surface Temperature (LST) which ultimately leads to Urban Heat Island (UHI). This will persist if no meaningful measures are taken to plant trees and flowers as well as graces and gardens to green the Lafia. There is the need to ensure that further development conserve the vegetal covers with a view to reducing the increasing temperature in the study area.

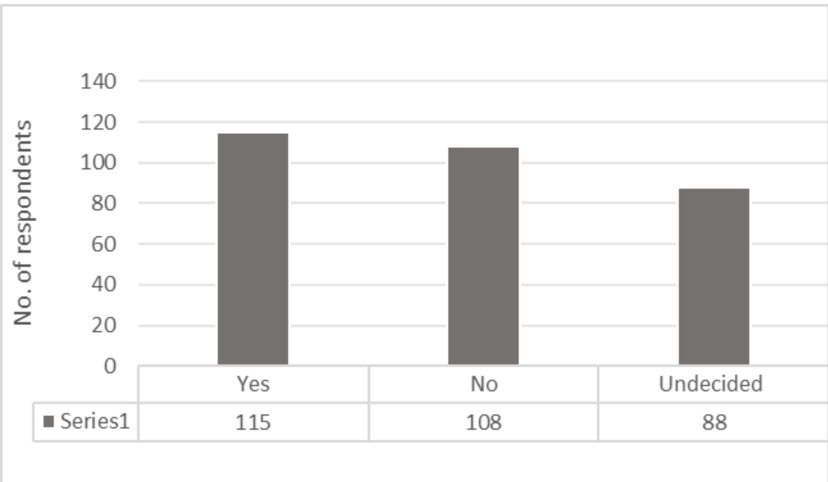


Figure 13: Respondents' Aware of UHI Related Health Challenges
Source: *Author's Analysis, (2025)*

IV. Conclusion And Recommendation

The aim of this study is to map and examine the Landuse landcover (LULC) change as well as assess the impact of urbanization on increase in Land Surface Temperature and Urban Heat Island in Lafia using three epochs of Remote Sensing LandSat Images and Geographic Information System GIS techniques in mapping and carrying out analysis of changes. The study shows that as the vegetation cover decreased due to urbanization, built-up area increased significantly from from 52,635 Hectare (19%) in 2002, and from 122,196 (44.2%) in 2012 to 150,645 Hectares, 54.39% in 2024. Consequently, the study also revealed a great variation in temperature in Lafia from 2002 to 2012, and from 2012 to 2024. In 2002, the temperature of the area was between 32.69^{0}C and 39.66^{0}C; 33.93^{0}c and 41.58^{0}C in 2012, and between 35.36^0 and 42.68^{0}C in 2024. Thus, the study shows pocket of Urban Heat Island (UHI) scattered all over places due to high infrastructural development and anthropogenic activities in Lafia. Based on the findings of the study, the following recommendations are articulated for improved environmental management and health: i. Increasing vegetation cover through afforestation and gardening, ii. Creation of green roofs, iii. Creation of high albedo pavements, iv. Pervious pavements creation, v. Shade trees, and vi. Awareness should be created to the local population regarding effects of excessive heat on human health coupled with information on simple measures to prevent excessive heat stress and health challenges.

Declarations: No Conflict of interest in this paper and no financial support whatsoever from any source.

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