

Urbanization and Environmental Quality Assessment in the Abuja Municipal Area Council Using Lst, Ndvi, Ndbi and Ndwi

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ABSTRACT

Urbanisation is one of the main environmental changes in the twenty-first century that significantly changes landscapes and disrupts the ecological balance in various regions of the world. The most significant issue in Abuja Municipal Area Council (AMAC) is associated with the rate at which urbanisation tends to take place more rapidly without sufficient protective measures towards the natural ecosystems. This study assessed Urbanization and Environmental Quality in the AMAC using Land Surface Temperature (LST), Nominalised Difference Built-up Index (NDBI), Normalised Difference Vegetation Index (NDVI), and Normalised Difference Water Index (NDWI). Landsat 8 data for 2014, 2019 and 2024 were used to estimate LST, NDVI, NDBI and NDWI of the study area. Correlation analysis was used to assess the relationship between the indices. The results indicate a progressive rise in LST across the years, with mean values increasing from 35.15°C in 2014 to 39.11°C in 2024. The NDBI values remained relatively stable but slightly increased in maximum values from 0.403 in 2014 to 0.463 in 2024. The NDVI showed moderate vegetation presence throughout the period, with mean values ranging between 0.22 and 0.24. The NDWI values increased over time, with the mean shifting from -0.23 in 2014 to 0.06 in 2024. The standard deviations for all indices were low, implying minimal variability within each dataset. The correlation analysis reveals that In 2014, LST exhibited a strong positive correlation with the NDBI ($r = 0.69$) and a strong negative correlation with the Normalised Difference Vegetation Index (NDVI) ($r = -0.69$), indicating that built-up areas contributed to higher temperatures while vegetation had a cooling effect. NDWI also showed a positive relationship with LST ($r = 0.56$). By 2019, the correlation between LST and NDBI remained positive ($r = 0.64$) but slightly weaker, while the relationship with NDVI remained negative ($r = -0.71$). However, the association between LST and NDWI became weakly negative ($r = -0.11$). In 2024, similar patterns persisted with LST positively related to NDBI ($r = 0.63$) and negatively related to NDVI ($r = -0.59$). The moderate positive correlation between NDVI and NDWI ($r = 0.47$) in 2024 reflects that vegetated areas retained more surface moisture. The study recommended that Abuja Municipal Area Council impose more stringent development restrictions to prevent the spread of impervious materials in the recently urbanised areas and encourage the use of permeable surface designs.

Key Words: Urbanisation; Environmental Quality; Land Surface Temperature (LST); Nominalised Difference Built-up Index (NDBI); Normalised Difference Vegetation Index (NDVI); Normalised Difference Water Index (NDWI)

INTRODUCTION

Urbanisation is one of the main environmental changes in the twenty-first century that significantly changes landscapes and disrupts the ecological balance in various regions of the world (Qian et al., 2022; Zhang et al., 2023; Sufiyan et al., 2023). Increased urban population growth has resulted in increased land use, spatial enlargement of urban areas, and significant changes in vegetation cover and water supply (Mandal et al., 2019; Ogunbode et al., 2025). Increase urbanization activities and governance has resulted to shift towards smart

urban city development in most countries, including Nigeria (Bello, Usman & Abubakar, 2022). These changes are directly linked to development of urban heat islands, worsening the state of air and water quality and general harm of the environment (Ku & Tsai, 2024; Vujovic et al., 2021). In African cities, including those located in Nigeria, the pressures of urbanisation are augmented by poor planning and inadequate infrastructure and are therefore a serious problem to sustainable urban development (Cirolia, 2020; Kamana et al., 2024).

Abuja Municipal Area Council (AMAC), the administrative and political centre of the Federal Capital Territory of Nigeria, has experienced unprecedented urbanisation over the last few decades, making it an interesting case study in explaining the connection of urban growth with environmental quality (Chukwurah et al., 2022; Rowland & Ebuka, 2024). The most significant issue in AMAC is related to the increased speed at which urbanisation often occurs without appropriate protective measures for the natural ecosystems (Amaechi et al., 2023; Mshelia et al., 2024). The development of new residential, commercial and industrial areas simultaneously leads to loss of vegetative cover and encroachment of anthropogenic activities on wetlands (Assefa et al., 2021; Das & Mehrotra, 2023). These changes lead to increased land surface temperatures, which increases stress in urban areas through heat, and on the other hand, alters local climatic conditions and living conditions (Halefom et al., 2024; Portela et al., 2020). The ecological sustainability of the area is compromised by the degradation of the water resources and the decline of the green areas worsening the environmental quality on which the urban life depends (Ogunbode et al., 2025; Wang & Wang, 2024). The growing tension between the demands of urban development and the preservation of the ecological systems (Hu et al., 2023; Pauleit et al., 2021; Yu et al., 2025) represents a topical issue to the urban administrators and policy makers in AMAC.

LITERATURE REVIEW

Urbanisation refers to the organized process of conversion of rural settings to urban settlements due to demographic growth, proliferation of infrastructure, and changes in the land-use systems (Bebi & Iyambo, 2025; Bikis, 2023). It is characterized by the geographical expansion of constructed network and industrialization, natural landscape transformation into residential, business and administrative areas (Asabere et al., 2020). Although urbanisation is traditionally associated with economic progress and the increased availability of services, it also has a significant ecological cost, which has led to the emergence of such phenomena as increased land-surface temperatures, vegetation loss, and reduced water bodies (Mallick & Alqadhi, 2025; Nimish et al., 2020; Patel et al., 2024). The urbanisation path in high growth metropolises like Abuja Municipal Area Council (AMAC), owing to its capital city status, attracts migrants, businesses and government quarters, creating complex environmental dilemmas, which require systematic evaluation (Achuenu & Ayuba, 2025; Enoguanbhor et al., 2021; Momoh et al., 2024).

Assessment of environmental quality in urban settings is often based on remotely sensed indices that reflect land cover and surface condition changes (Sari et al., 2025; Shi & Li, 2021). Land Surface temperature (LST) is a critical parameter indicating thermal implication of urbanization, especially replacement of green areas with hard surfaces like asphalt and the concrete (Kara & Yavuz, 2025; Naserikia et al., 2023; Portela et al., 2020). The Normalised Difference Vegetation Index (NDVI) is a value used to measure vegetation density and vigor; when the NDVI is high, it implies that there is excess vegetation of healthy condition, and when the NDVI is low, it indicates that the vegetation has been depleted (Li et al., 2024; Martinez & Labib, 2022). The Normalised Difference Built-up Index (NDBI), is a measure of the percentage of built-up land, which is used to identify urban sprawl and the degree of impervious covers (Ali Shah et al., 2022; Prasomsup et al., 2020). At the same time, the Normalised Difference Water Index (NDWI) is used to detect and track water bodies and moisture level, which will help to see changes in hydrological characteristics in urban landscapes (Ghalehtimouri et al., 2024; Gupta et al., 2024). All these combined indices provide a compound view of the urbanisation modifying the quality of the environment.

Urban environmental studies employs a series of analytical methods to determine how the indices can be related to larger urban processes (Hess, 2022; Kong et al., 2020; Okacha et al., 2024). Correlation analysis is usually used to identify all interrelationships between LST, NDVI, NDBI and NDWI, which can explain all interactions between vegetation loss, built-up expansion, water scarcity and thermal variation. Mapping and

quantification of these indices in time and space cannot be accomplished without spatial analytic techniques such as Geographic Information Systems (GIS) in addition to the use of more elaborate remote sensing methods (Dapke et al., 2025; Kimothi et al., 2023). Some advanced methods, including regression modelling, machine-learning algorithms, and multi-criteria decision analysis, can also be used to predict the relationship between urban and environmental interactions and how this affects the livability and sustainability of urban areas (Antolín-López et al., 2024; Aulia & Marpaung, 2025). These approaches enable investigators to assess the temporal and spatial aspects of urbanization and the impacts of urbanization on the environment.

Previous studies (Chukwurah et al., 2022; Gilbert & Shi, 2023; Ilo & Ezeodili, 2025) on urban growth in Nigeria have largely focused on physical expansion patterns and socioeconomic aspects, with limited integration of geospatial indices that directly capture environmental quality. While research has examined urban sprawl and its implications in cities such as Lagos, Ibadan, and Kano (Koko et al., 2022; Lawal & Akanbi, 2024; Onilude & Vaz, 2020; Taiwo et al., 2021), fewer studies (Koko et al., 2021; Obateru et al., 2024) have addressed the specific dynamics within Abuja Municipal Area Council, despite its role as a rapidly expanding administrative hub. Moreover, limited attention has been paid to the combined analysis of land surface temperature (LST), vegetation condition (NDVI), built-up intensity (NDBI), and water presence (NDWI), which together provide a comprehensive understanding of environmental changes induced by urbanisation. This gap underscores the need for an integrated approach to assess how urbanisation affects key environmental parameters in AMAC over time.

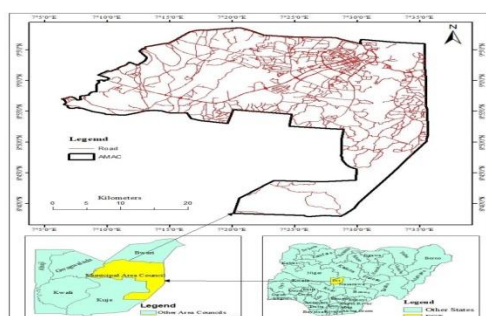
There is currently a lack of detailed, spatially explicit evidence to support the connection between rapid urbanisation and the changes in environmental quality of the Abuja Municipal Area Council (AMAC). Without such evidence, urban planners and policy makers are limited in their ability to make informed decisions regarding sustainable development and environmental management. An extensive analysis using geospatial tools and indices, such as Land Surface Temperature (LST), Normalized Difference Vegetation Index (NDVI), Normalized Difference Built-up Index (NDBI), and Normalized Difference Water Index (NDWI), will provide the essentials on how urban growth is transforming the urban form. This study is vital in finding out the trends and forces where the environment is degraded and hence helps in determining the strategies which should be put in place to reduce the negative effects of urbanisation and improve the livability of the Abuja Municipal Area Council.

Materials and Method

Study Area

The vegetation and urbanization within Abuja Municipal Area Council (AMAC) demonstrates a dynamic interaction between the high rate of urbanization and the slow disappearance of natural landscapes. In the last decade, AMAC has undergone high infrastructural development owing to population growth and administrative centrality leading to the development of large areas of the vegetated land into built-up surfaces. This change can be observed in the increasing percentage of impervious surfaces and a resultant decrease in vegetative cover in the urban periphery despite average vegetation indices depicting moderate stability. The proliferation of residential estate, roads, and commercial areas has disrupted the green spaces, reduced the ecological balance, and increased the surface temperature of land by the Urban Heat Island effect.

Figure 1. Location of Abuja Municipal Area Council (AMAC), FCT, Nigeria



Source: FCDA

METHODOLOGY

Types and Sources of Data

Table 1 provides the types and sources of data that were used to analyse the relationship between LST and NDVI, NDBI and NDWI.

Table 1: Type and Sources of Data

SN	Name	Sources	Date
1	Landsat 8	http://glovis.usgs.gov/	2014, 2019 and 2024

Calculation of LST, NDVI, NDBI and NDWI

The approach to estimating Land Surface Temperature (LST), Nominalised Difference Built-up Index (NDBI), Normalised Difference Vegetation Index (NDVI), and Normalised Difference Water Index (NDWI) in ArcGIS commenced with the preprocessing of satellite imagery through projection of all the raster datasets to Universal Transverse Mercator (UTM) Zone 32N coordinate system to provide spatial consistency. Imagery was subsequently resampled to a common spatial resolution of 30m so that different sensors could be harmonized and more easily compared. The rasters were then clipped to the shapefile of Abuja Municipal Area Council to only obtain the area of interest to be analysed. All indexes were computed with the help of the Raster Calculator tool in ArcGIS using the following formula.

Calculation of Land Surface Temperature (LST)

LST estimation was done using the following formula(Panigrahi & Sharma, 2025):

$$LST = \left[\frac{\tau}{1 + \omega \left(\frac{\tau}{\rho} \right) \times \ln(\varepsilon)} \right] \quad (1)$$

where, τ is at-sensor brightness temperature;

ω is the wavelength of emitted radiance (for Landsat 7 Band 6 and Landsat 8 Band 10 is approximately 11.5 μm)

$\rho = h \times c/s$ (1.438×10^{-2} m.K);

h being the Plank's constant (6.626×10^{-34} J.s);

s is the Boltzmann Constant (1.38×10^{-23} J/K);

c is the velocity of light (2.988×10^8 m/s);

ε is the land surface emissivity; and

$\rho = 14380$

The land surface emissivity (ε) was calculated using the following Equation(Tiwari & Kanchan, 2024):

$$\varepsilon = nP_v + m \quad (2)$$

where, $n = 0.004$ and $m = 0.986$; and P_v denotes the vegetation proportion, also referred to as fractional vegetation cover.

The vegetation proportion (P_v) was obtained from the following Equation (Tiwari & Kanchan, 2024):

$$P_v = \left[\frac{NDVI - NDVI_{\min}}{NDVI_{\max} - NDVI_{\min}} \right]^2 \quad (3)$$

where, $NDVI_{\min}$ and $NDVI_{\max}$ are the minimal and the maximal values of the NDVI (calculated according to the following Equation (Tiwari & Kanchan, 2024):

$$NDVI = \frac{NIR - RED}{NIR + RED} \quad (4)$$

where, NIR and RED are the infrared and red bands of Landsat 7 and 8, respectively.

The temperature value at the sensor (brightness) was extracted using the following Equation (Panigrahi & Sharma, 2025):

$$\tau = \left[\frac{K_2}{\ln \left(\frac{K_1}{L} + 1 \right)} \right] \quad (5)$$

where, K_1 and K_2 are the thermal conversion constants provided in the Landsat metadata. Radiance for Landsat 8 TIR band will be obtained from Equation (Panigrahi & Sharma, 2025):

$$L = ML \times DN + AL \quad (6)$$

where, L is the top-of-atmosphere radiance, ML is the radiance multiplicative scaling factor, and AL is the radiance additive scaling factor (these are found in the metadata of the Landsat image).

Convert the temperature from Kelvin to Celsius by subtracting 273.15 from the result (Panigrahi & Sharma, 2025):

$$LST_C = LST_K - 273.15 \quad (7)$$

Calculation of Normalized Difference Builtup Index (NDBI)

The NDBI of the study area was calculated using the map algebra function (raster calculator) of ArcMap 10.8. It is represented mathematically using the formula as follows (Roba & Tabor, 2025):

$$NDBI = \frac{MIR - NIR}{MIR + NIR} \quad (9)$$

where, MIR and NIR are Band 6 and Band 5 of Landsat 8.

Computation of Normalized Difference Water Index (NDWI)

The NDWI of the study area was calculated using the map algebra function (raster calculator) of ArcMap 10.8. It is represented mathematically using the formula as follows (Ghalehtemouri et al., 2024):

$$NDWI = \frac{G - NIR}{G + NIR} \quad (10)$$

where, G and NIR are the band 3 and band 5 of Landsat 8.

Computation of minimum, maximum, mean and standard deviation, and Correlation Analysis

Following the generation of the indices maps, the Zonal Statistics tool in ArcGIS was used to derive the minimum, maximum, mean, and standard deviation of each variable within the Abuja Municipal Area Council boundary, which served as the zone layer. In addition, the Band Collection Statistics tool was applied to carry out pairwise correlation analysis among LST, NDVI, NDBI, and NDWI, producing a correlation matrix that illustrated the strength and direction of relationships among the variables across all pixels in the study area. These analyses provided valuable insights into the influence of land cover changes on surface temperature and the interactions between vegetation, built-up areas, water bodies, and urban heat across the three time periods.

RESULTS AND DISCUSSION

Statistical Results of LST, NDVI, NDBI, and NDWI

The descriptive statistics of the indices were calculated as shown in Table 2.

Table 2: Descriptive Statistics of LST, NDVI, NDBI, and NDWI

	LST	NDBI	NDVI	NDWI	Year
Minimum	25.294	-0.293	-0.211	-0.461	2014
Maximum	45.347	0.403	0.514	0.205	2014
Mean	35.145	-0.033	0.235	-0.230	2014
Standard Deviation	2.782	0.062	0.069	0.049	2014
Minimum	25.966	-0.309	-0.141	-0.473	2019
Maximum	48.050	0.370	0.470	0.481	2019
Mean	36.074	-0.014	0.220	0.011	2019
Standard Deviation	2.823	0.065	0.066	0.038	2019
Minimum	28.209	-0.337	-0.218	-0.633	2024
Maximum	48.319	0.463	0.513	0.626	2024
Mean	39.110	-0.018	0.228	0.061	2024
Standard Deviation	2.235	0.063	0.077	0.050	2024

Source: Author's (2025)

The descriptive statistics result of Land Surface Temperature (LST) in Table 2 indicate a substantial intensification of the Urban Heat Island (UHI) effect in AMAC over the decade. The mean LST has exhibited a clear and significant upward trend, rising from 35.145° C in 2014 to 36.074° C in 2019, and then spiking to 39.110° C in 2024, a net increase of nearly 4° C. This pronounced warming suggests that the urban expansion in Abuja Municipal Area Council is replacing natural, cooling surfaces with impervious materials that retain more heat. Furthermore, the maximum LST, which reached 48.319° C in 2024, indicates that extreme thermal hotspots are developing. Interestingly, the standard deviation for LST decreased in 2024, suggesting that the higher temperatures are becoming more uniformly distributed across the study area, rather than being confined to isolated pockets, posing a growing challenge for thermal comfort and public health.

While the heat indices show sharp change, the indices related to land cover composition suggest a relative stability in the spatial averages. The mean Normalised Difference Built-up Index (NDBI) has remained close to zero across all three years (ranging from -0.033 to -0.018). This low mean suggests that, on average, the entire study area is still not overwhelmingly dominated by dense, impervious surfaces. Similarly, the mean Normalised Difference Vegetation Index (NDVI) has been remarkably consistent, varying only slightly between 0.220 and 0.235 . This implies that while built-up areas may be expanding, the average greenness level for the whole Area Council has been maintained. However, the increase in both NDBI maximum (to 0.463) and LST maximum suggests a localised, intense conversion of natural land to high-density built-up structures in certain districts.

The Normalised Difference Water Index (NDWI) presents the most dramatic positive shift in the environmental dynamics. The mean NDWI has transitioned from being highly negative in 2014 (-0.230) to clearly positive in 2024 (0.061). This significant change, alongside the rising maximum NDWI value (from 0.205 to 0.626), strongly indicates a substantial increase in surface water bodies or heightened moisture content within the study area. Potential explanations for this include the expansion of water impoundments, changes in local hydrological regimes, or perhaps increased seasonal flooding captured in the 2024 imagery. This increase in water presence is a critical finding, as water bodies can act as a local cooling influence, yet their emergence has clearly not been sufficient to mitigate the overwhelming warming trend identified in the LST data, suggesting the LST drivers (urbanisation/impervious surfaces) are dominant.

The statistics paint reveal a rapidly urbanising environment in AMAC that is struggling to balance development with environmental sustainability. The primary challenge is the pronounced and accelerating Urban Heat Island effect, evidenced by the mean LST increase. This warming is likely being driven by unmitigated urban expansion, as commonly observed in the Abuja metropolis. While the average vegetation cover (NDVI) appears stable, this masks the conversion of land at the urban fringe which is contributing to the high LST maximums. The notable increase in water presence (NDWI) is a critical anomaly that warrants further investigation to determine if it is due to beneficial hydrological management or an increase in problematic waterlogging and flood-prone areas. Ultimately, the data serves as a strong evidence base for policymakers to implement more stringent urban planning regulations focused on increasing green spaces (cool roofs, urban parks) and managing impervious surfaces to curb the severe UHI effect.

Correlation Results of LST, NDBI, NDVI and NDWI

The correlation analyses for LST, NDBI, NDVI and NDWI was generated in ArcGIS software and the results are presented in Table 3.

Table 3: Correlation Analyses Results

	LST	NDBI	NDVI	NDWI	2024
LST	1.000	0.690	-0.694	0.559	2014
NDBI	0.690	1.000	-0.751	0.659	2014
NDVI	-0.694	-0.751	1.000	-0.876	2014
NDWI	0.559	0.659	-0.876	1.000	2014
LST	1.000	0.637	-0.708	-0.112	2019
NDBI	0.637	1.000	-0.667	-0.088	2019
NDVI	-0.708	-0.667	1.000	0.255	2019
NDWI	-0.112	-0.088	0.255	1.000	2019
LST	1.000	0.634	-0.590	-0.166	2024
NDBI	0.634	1.000	-0.668	-0.166	2024

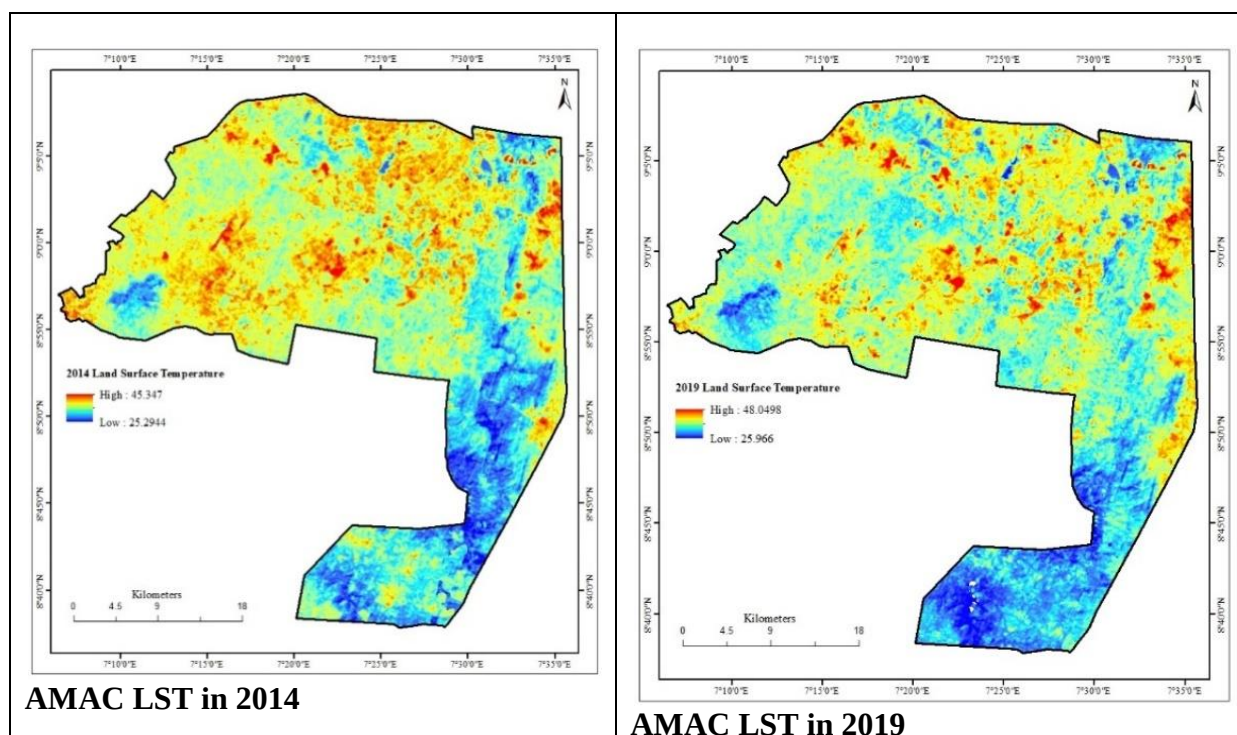
NDVI	-0.590	-0.668	1.000	0.469	2024
NDWI	-0.166	-0.166	0.469	1.000	2024

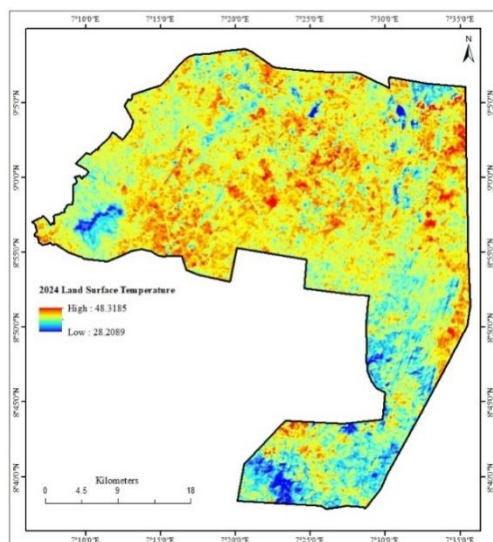
The correlation analysis result for AMAC in 2014 reveals that built-up area was a major driver of surface heating, as shown by the strong positive correlation between LST and NDBI (0.690). At the same time, vegetation played a significant cooling role, with LST showing a strong negative correlation with NDVI (-0.694). Vegetation also had strong negative associations with both NDBI (-0.751) and NDWI (-0.876), suggesting that urban expansion was directly linked to vegetation and water loss. Interestingly, LST correlated positively with NDWI (0.559), implying that water features in 2014 may not have provided effective cooling, possibly due to shallow or degraded water bodies that absorbed heat more readily.

By 2019, the relationships shifted slightly. The LST–NDBI correlation (0.637) remained strong but weaker than in 2014, indicating that built-up areas still influenced surface heating, though less sharply. The LST–NDVI correlation grew stronger (-0.708), showing that vegetation became even more crucial for cooling as urbanisation intensified. Meanwhile, the correlation between NDVI and NDWI moved from strongly negative in 2014 to weakly positive (0.255), reflecting some recovery or overlap between vegetation and water. Notably, the relationship between LST and NDWI declined sharply to -0.112, suggesting that water surfaces had become less relevant in controlling temperature compared to vegetation.

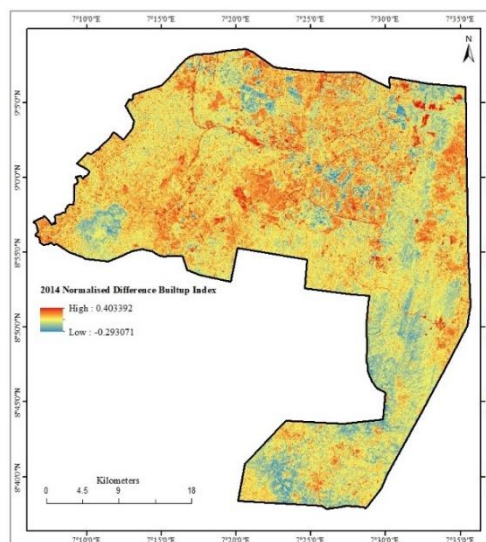
In 2024, the patterns suggest further urban transformation. The LST–NDBI relationship (0.634) remained stable, showing the continued role of urban expansion in driving higher temperatures. The negative link between LST and NDVI weakened slightly (-0.590), implying that while vegetation still provided cooling, its influence was reduced compared to 2019, possibly due to restoration projects that stabilised vegetation cover. NDVI and NDWI showed a moderate positive correlation (0.469), stronger than in 2019, highlighting a more integrated relationship between vegetation and water in the urban landscape. On the other hand, the LST–NDWI correlation remained weakly negative (-0.166), reinforcing the idea that water bodies are still not acting as effective cooling features. Together, these results demonstrate that urbanisation continues to intensify land surface temperature in AMAC, but vegetation has remained the most consistent factor in mitigating heat, while water features have shown unstable and limited cooling influence over time. Figure 2 shows the spatio-temporal visualization of LST, NDBI, NDVI and NDWI in 2014, 2019 and 2024 respectively.

Figure 2. Spatio-temporal Visualization of LST, NDBI, NDVI and NDWI (2014, 2019 & 2024)

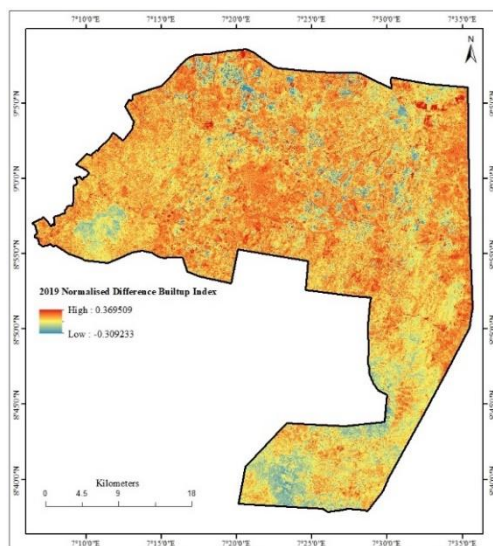




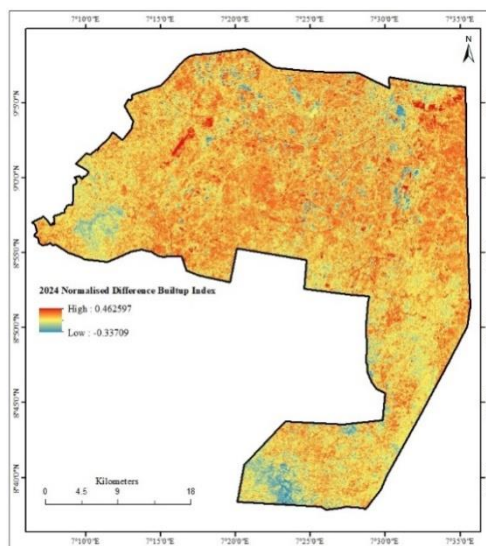
AMAC LST in 2024



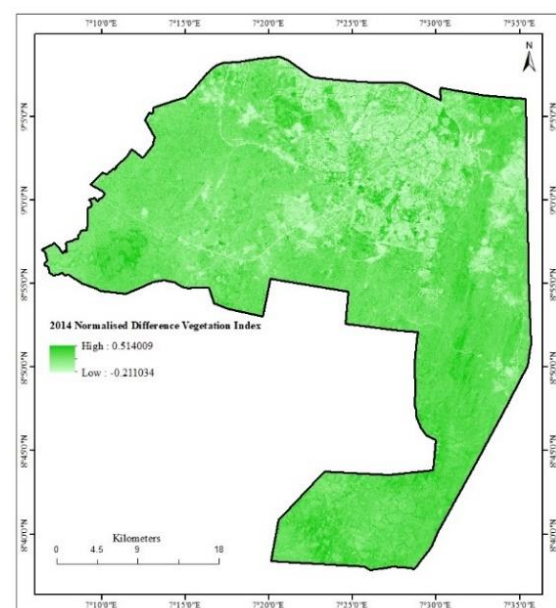
AMAC NDBI in 2014



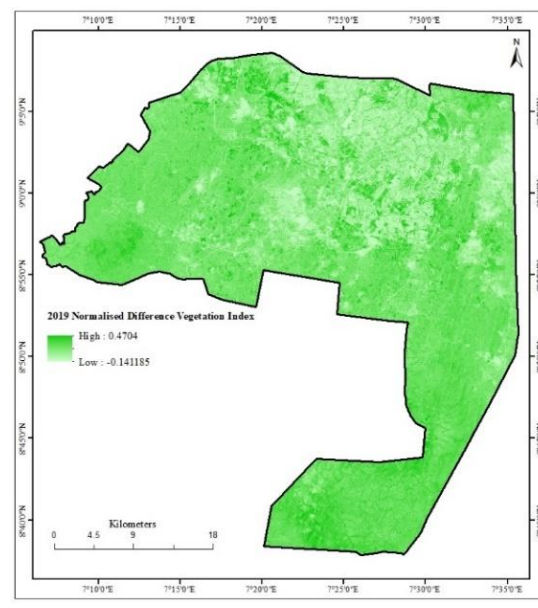
AMAC NDBI in 2019



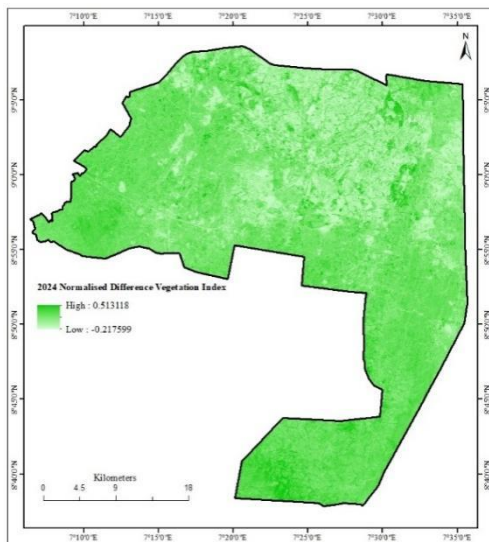
AMAC NDBI in 2024



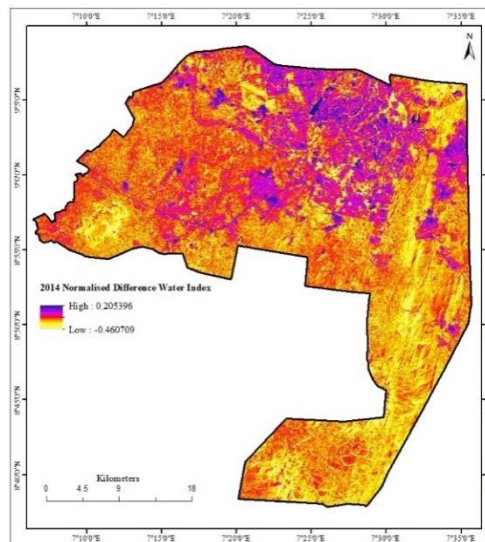
AMAC NDVI in 2014



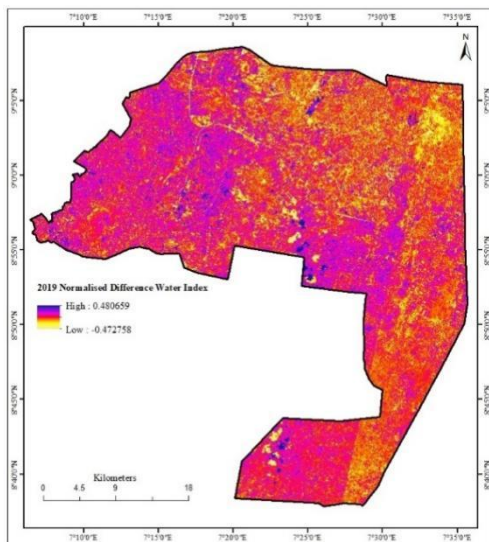
AMAC NDVI in 2019



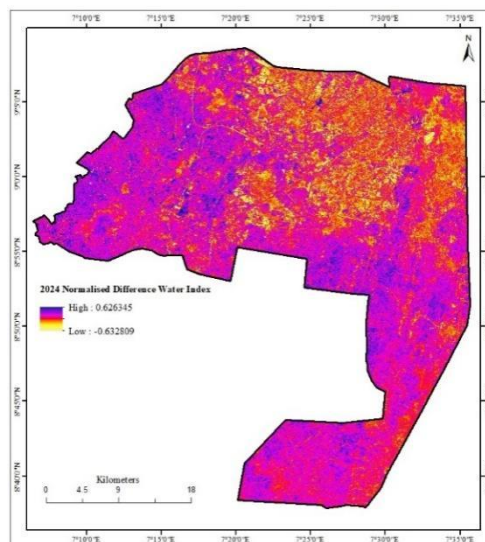
AMAC NDVI in 2024



AMAC NDWI in 2014



AMAC NDWI in 2019



AMAC NDWI in 2024

CONCLUSION AND RECOMMENDATIONS

The evaluation of urbanisation and environmental quality in Abuja Municipal Area Council (AMAC) by means of LST, NDBI, NDVI and NDWI indicates a definite tendency to increase the urban heat and spatial transformation throughout the ten years. The constant increase in mean and maximum values of LST shows the increasing impact of the Urban Heat Island effect that is mainly caused by the substitution of natural surfaces with impermeable materials. Though the average NDVI and NDBI values show apparent stability, the rising max NDBI and LST values depict localised and high density developments which contribute to the intensification of surface heating. Concurrently, the significant increase of NDWI suggests the growth of the surface moisture or water bodies, but, in its turn, has not alleviated the prevailing warming trend. Correlation studies also support the same fact that urban expansion (NDBI) and vegetation (NDVI) are still the primary thermal source and cooling respectively, and water bodies (NDWI) have exhibited mixed thermal moderation functions. All these indicate that AMAC is experiencing a fast urbanisation process whereby development is taking place at the cost of environmental balance and thermal comfort.

The most important consideration that the urban planners and policymakers must adopt to address the increasing Urban Heat Island effect is the incorporation of green infrastructure, as in the form of urban parks, vegetated corridors, and rooftop gardens. Plant vegetation coverage is important to maintain and increase because NDVI has consistently shown a significant negative correlation with LST, which indicates that it

moderates urban temperatures. Abuja Municipal Area Council needs to impose more stringent development restrictions to prevent the spread of impervious materials in the recently urbanised areas and encourage the use of permeable surface designs. Also, it should be explored why the NDWI has grown since it is important to understand whether it is positive hydrological development or water pooling in floods. The combination of sustainable drainage systems and better management of water bodies can be used to provide equilibrium between the presence of moisture in the urban environment and the presence of effective heat regulation.

Declaration: The authors declare that there is no conflict of interest in this paper.

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