Geospatial Assessment of Urban Blue and Green Spaces in Abuja Municipal Area Council

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Key words: Urban Cooling Effect, Urban Heat Islands (UHIs), Green and Blue Spaces, Geospatial analysis, Land surface temperature.

SUMMARY

Urbanization and greenhouse gas accumulation have intensified global temperature trends, with the Urban Heat Island (UHI) effect significantly impacting cities. In AMAC, landscape indices revealed moderate vegetation cover, with green spaces concentrated in Karshi, Gwi, and the National Arboretum, while built-up areas in Lugbe, Garki, and Wuse exhibited lower NDVI values. MNDWI analysis showed limited water bodies, with key blue spaces like Jabi Lake and the Gurara and Usuma rivers.

Land Surface Temperature (LST) analysis from Landsat 8 imagery showed temperatures ranging from 30.36°C to 49.50°C, with an average of 40.93°C. Vegetated and water-covered areas exhibited lower temperatures due to evapotranspiration, while built-up zones experienced higher temperatures. UTFVI analysis identified thermal hotspots, with Karu, Gwagwa, and Gwi recording the highest temperatures, while the city center, Garki, and Wuse were cooler due to green and blue spaces.

Jabi Lake exhibited the strongest cooling effect, with temperatures rising from 29.73°C at the lake to 40.74°C at 300 meters away. Zonal statistics confirmed the critical role of green and blue spaces in mitigating urban heat. These findings emphasize the need for urban planning strategies that expand and preserve green and blue spaces to combat the UHI effect and enhance climate resilience in AMAC.

1.0 INTRODUCTION

Urbanization, coupled with the intensified accumulation of greenhouse gases in the Earth's atmosphere, has led to profound changes in global temperature trends and climate patterns. Rapid urbanization has placed about 55% of the global population in urban areas, projected to increase to 60% by 2030 (United Nations, Department of Economic and Social Affairs, Population Division, 2018,).This urbanization has led to several undesirable environmental changes, including the replacement of natural surfaces with urban fabrics characterized by higher temperatures than surrounding rural environments, a phenomenon known as the Urban Heat Island (UHI) effect (Feyisa *et al*., 2014).

The UHI effect primarily stems from rapid urbanization, which replaces natural landscapes with heat-absorbing, non-reflective, water-resistant, and impermeable artificial surfaces that absorb solar radiation during the day and release it at night (Ramakreshnan *et al*., 2018). Furthermore, the waste heat produced by human activities, such as energy consumption and transportation, acts as a secondary factor contributing to the Urban Heat Island (UHI) effect (Aghamohammadi *et al*., 2022).

International bodies, such as the Intergovernmental Panel on Climate Change (IPCC ,2017), have underscored UHI as a global phenomenon posing substantial challenges to human health, safety, and economic stability. The U.S. Global Change Research Program (2017) has noted that UHI exacerbates heatwaves and increases energy consumption. Addressing UHI aligns with the Sustainable Development Goals (SDGs), particularly (SDG 11), which aims to foster inclusive, safe, resilient, and sustainable cities and communities. Failure to meet climate targets, as outlined in the Emissions Gap Report 2021 by the United Nations Environment Programme (UNEP,2017), could lead to a substantial increase in average worldwide temperatures by the close of the century.

In Nigeria, UHI is not a recent occurrence, with cities like Abuja experiencing rapid growth and land-use changes over time. Initiatives such as "Greening Abuja" and "Operation Green Lagos" emphasize efforts to enhance urban green infrastructure and promote sustainable urban development (Enoguanbhor, 2022). Universal endeavors to moderate UHI are being rendered in the shape of stream reclamation and green framework development, as cases. Green spaces and blue spaces, in particular, can provide comfortable environments for citizens while also serving as means to control urban temperature (Lee *et al*., 2016). The concept of "cool cities" emerges as a central theme, emphasizing the importance of urban blue and green spaces in reducing heat emissions and promoting climate resilience.

Scholars such as Taha *et al*., (1991) and Oke (1976) have extensively studied UHI effects, demonstrating temperature differentials ranging from 0.5°C to 6.0°C between urban and non-urban regions using land surface temperature (LST) only, without quantifying UHI. Mathew *et al*., (2018) and Wang *et al*. (2021) have emphasized alarming temperature differentials between urban centers and rural areas, reaching up to 12°C, but did not consider cooling effect strategies as solutions for reducing temperature. Studies by Moisa and Gemeda (2022) assessed the extent of urban thermal field variance index (UTFVI) and thermal comfort levels of Addis Ababa city using geospatial techniques, providing robust evidence of UHI effects, overlooking the cooling influence of green and blue spaces. Cruz *et al*., (2019) assessed the spatiotemporal Urban Cooling Island (UCI) effect of Iloilo River and adjacent wetlands on the surrounding microclimate using geospatial techniques to understand the cooling effect of water bodies in UHI, but did not consider the effect on green spaces.

Despite the substantial body of research on UHI effects and mitigation strategies, there remains a notable gap in the literature concerning the use of UTFVI and UCI to assess the cooling effect of blue and green spaces on mitigating UHI, particularly within the context of Abuja, Nigeria. While studies have emphasized the importance of urban green and blue spaces in enhancing environmental quality and mitigating UHI effects, there is a need for further investigation.

This study aims to assess the influence of green and blue spaces in moderating urban heat islands (UHIs) in Abuja, Nigeria, by examining how these spaces moderate temperature variations across different land cover types. The specific objectives are, to assess the spatial distribution of green and blue spaces in the study area, to determine the spatial pattern of temperature in the study area, to evaluate the urban cooling effects of green and blue spaces and their surroundings across various zones within the study area.

2.0 MATERIALS AND METHODS

2.1 Study Area

Abuja City is situated in the North Central region of Nigeria within the Guinea Savanna. Geographically, it is positioned between latitude 8° 25’ - 9° 25’ N and longitude 6° 45’ - 7° 45’ E, encompassing approximately 8,000 square kilometers of land mass. The Federal Capital City itself occupies an area of about 250 square kilometers, with its center at latitude 9° 04’ and longitude 7°.

2.2 Data

The study utilized Sentinel-2 data from the MSI sensor with a 10-meter resolution for the year 2023, sourced from Copernicus and the European Space Agency (ESA). Landsat 8 data were obtained from the OLS/TIRS sensor with a 30-meter resolution for the year 2023, provided by the US Geological Survey (USGS). An administrative map of Amac was acquired from AGIS. Air temperature data for the year 2023 were collected from ground-based weather stations, provided by the Nigerian Meteorological Agency (NIMET).

2.3 Methods

The study follows a multi-step methodology to analyze the spatial distribution and thermal dynamics of blue and green spaces within the study area. The workflow is illustrated in Figure 2.

First, spectral indices were derived from Sentinel-2 MSI data to extract blue and green spaces using the Modified Normalized Difference Water Index (MNDWI) and the Normalized Difference Vegetation Index (NDVI). The NDVI and MNDWI thresholds used were 0.3 and 0.2, respectively. These thresholds were selected based on a combination of relevant studies and visual examination of the data (Pritipadmaja *et al*., 2023; Sharma *et al*., 2021). Built-up areas and impervious surfaces were identified using the Normalized Difference Built-up Index (NDBI).

NDVI = (NIR Red)/ (NIR + Red)………………….. (1)

MNDWI = (Green - SWIR) / (Green + SWIR) ………….. (2)

NDBI = (SWIR- NIR)/ (SWIR + NIR)…………………. (3)

Secondly, Land Surface Temperature (LST) estimation from satellite imagery is essential for understanding UHI effects. In this study we integrated approaches from several authors such as (Cai *et al*., (2022),Moisa and Gemeda, (2022) Pritipadmaja *et al*., (2023). Thermal data from

Landsat 8 were processed using Google Earth Engine (GEE) to estimate Land Surface Temperature (LST). The Radiative Transfer Equation (RTE) was employed, incorporating at-sensor brightness temperature, wavelength of emitted radiance, Planck's constant, and surface emissivity. NDVI-based emissivity correction was applied to enhance LST accuracy, following the formula:

$\varepsilon = 0.004Pv + 0.986$…………… (4)

The relationship between air temperature from NIMET and LST was established through correlation analysis to validate the satellite-derived temperature data. This analysis helped to analyze LST values using NIMET air temperature measurements, ensuring high accuracy for the validation of LST with NIMET data, we sampled the data by creating a fishnet for the cell rows, using a 20 by 30 grid to capture samples of blue and green spaces thoroughly. We extracted multiple points from the LST information, then calculated the mean LST, buffered these points, and calculated the zonal statistics to determine the mean, maximum, and minimum temperatures. Using the mean LST, we conducted a correlation analysis to validate the temperature data.

The relationship between LST and spectral indices was also conducted to understand the impact of urban blue and green spaces on UHI can vary significantly based on geographic, climatic, and urban design factors. Scientific research benefits from repeated studies that validate and reinforce findings. research contributes to the robustness and reliability of existing knowledge by confirming whether established relationships hold true in this specific context. This will provide context-specific insights that are directly relevant to the area of study.

Thirdly, Urban Thermal Field Variance Index (UTFVI) and Urban Cooling Indices (UCI) were calculated to assess the impact of blue and green spaces on urban heat islands (UHI). (Isioye *et al*., (2020) ,Sharma *et al*., (2021) and Waleed *et al*., (2023) used UTFVI to evaluate the overall strength of UHI effects based on LST data, categorizing values into six classes indicating the level of UHI presence and its influence on ecological quality and thermal comfort. The UTFVI formula is:

$UTFVI = (Ts - Tmean) / Ts$, …………… (5)

where Ts is the LST of a pixel and

Tmean is the mean LST.

To quantify the cooling effect of blue spaces and green spaces, several cooling indicators were employed as described by (Lee *et al.* (2016) Du *et al.* (2017) and Ekwe *et al*. (2020)**.** Urban cooling effects were quantified using UCI, which includes the UCI scale, temperature difference, and UCI intensity. These indicators measure the cooling impact of blue and green spaces, with buffer zones ranging from 30 meters to 300 meters to capture the spatial extent of cooling. Cai *et al.*, (2022) UCI analysis methodology presents a compelling approach for studying the cooling effects of water bodies and green spaces within Urban Heat Islands (UHI). Regression analysis was employed to compare the cooling effects of green and blue spaces and understand their influence on the surrounding environment.

Spatial analysis of UHI involves identifying urban hot spots, areas with elevated LST values, based on land use land cover (LULC) conversion around urban areas. This conversion is the root cause of increased LST in many cities, attributed to the replacement of vegetation and other LULC with impervious surfaces. Hot spots are defined as regions where LST values exceed the mean LST by two standard deviations ($\mu + 2*s$), facilitating the mapping and characterization of areas experiencing high thermal stress. The study performs zonal statistics in GIS to analyze spatial data within specific zones, calculating metrics such as mean, median, maximum, minimum, standard deviation, sum, majority, and minority for each zone.

3.0 RESULTS

3.1 Landscape Indices Analysis

The examination of landscape indices offers significant understanding regarding the vegetation, water, and built-up features in AMAC. This section presents visual depictions (Figure 4.1,4.2 and 4.3) of three specific landscape indices: NDVI, MNDWI, and NDBI. These indices are essential tools for evaluating the dynamics of Land Use and Land Cover (LULC).

The NDVI findings revealed moderate vegetation coverage in the AMAC area, particularly in green patches concentrated in the southeastern region near Karshi waterfall, and higher vegetation density in the National Arboretum in the city center and Gwi regions compared to surrounding areas. The study area predominantly features land rather than water bodies, resulting in mainly negative mean MNDWI values, especially in Kaura and Iddo. High MNDWI values are primarily found in the northern part of AMAC, with the Gurara and Usuma rivers providing water supply and irrigation for Abuja, and Jabi Lake serving as a reservoir for rainwater runoff. The NDBI ranged from -0.551 to 0.660, with a mean value of 0.122 and a standard deviation of 0.083, indicating a mix of built-up and non-built-up areas with moderate built-up intensity. The low standard deviation suggests limited variability in the distribution of built-up areas, indicating minimal disparity in built-up intensity across the study area. Despite variations, recent trends show urban sprawl and heightened structural intensity near the city center, consistent with findings from previous research on urban growth over the past two decades.

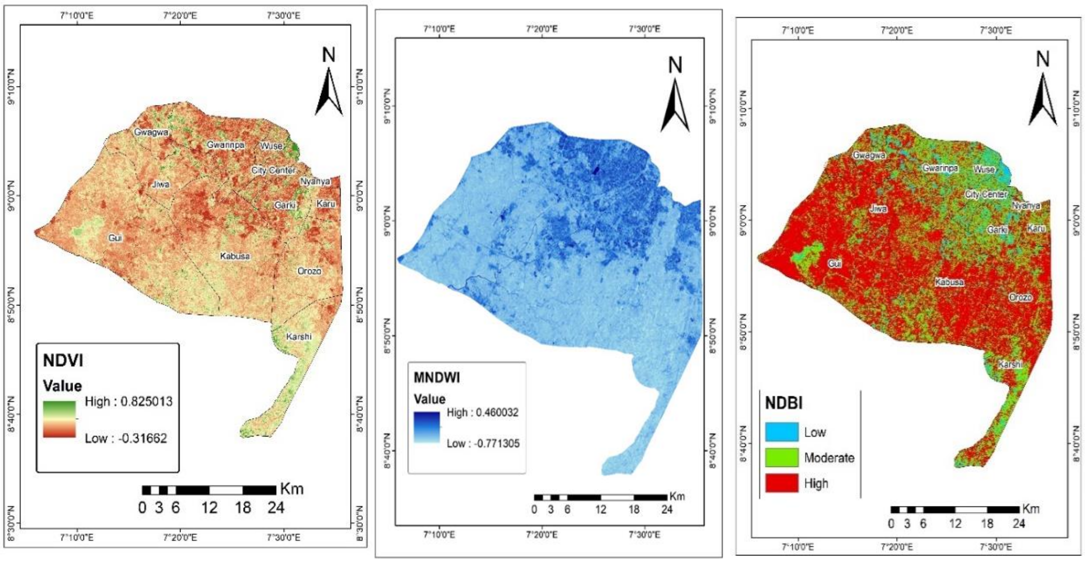

Figure 4.1,4.2.4.3: NDVI, MNDWI, NDBI across AMAC showing high and low values

The extraction of green and blue spaces is a critical aspect of urban and environmental planning, providing insights into vegetation cover and water bodies. In this study, we employed the Normalized Difference Vegetation Index (NDVI) to identify and quantify green space while MNDWI for blue spaces within our region of interest.

To identify green spaces, we used the NDVI, for this specific study area, we refined our criteria to enhance accuracy: NDVI values greater than 0.3 was selected to represent significant vegetation. This threshold ensures that only areas with substantial vegetation cover are considered, excluding sparse or unhealthy vegetation. For the extraction of water bodies, we used an MNDWI threshold of 0.2. Upon applying these thresholds to the land indices of our study area, several observations were made regarding the distribution of green and blue spaces masked out blue green space in figure 4.4.

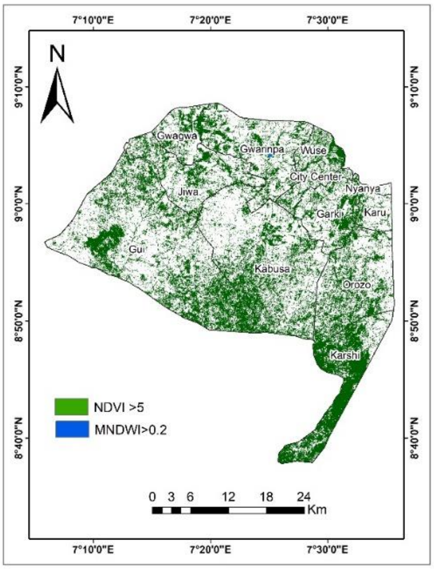

Figure 4.4: Masked Blue and Green spaces

In terms of green spaces, areas such as Tunga Jankua, Gwi, and the regions surrounding Karshi Waterfall exhibited significant clusters of green spaces. These areas demonstrated NDVI values well above the 0.3 threshold, indicating dense and healthy vegetation. In contrast, urban regions such as Lugbe, Garki, and Wuse showed fewer green spaces. The NDVI values in these areas were generally lower, reflecting the higher density of built-up areas and lower vegetation cover as reflected in the NDBI map (figure 4.3).

For blue spaces, the MNDWI analysis identified several water bodies across the study area. The regions with MNDWI values above 0.2 were accurately mapped as water bodies, confirming the presence of blue spaces with the MNDWI.

3.2 Spatial pattern of temperature /Retrieved LST

The thermal data utilized in this study was obtained from the thermal band of Landsat 8 satellite imagery, which encompasses a range of wavelengths within the electromagnetic spectrum, including thermal infrared, facilitating the derivation of Land Surface Temperature (LST). Analysis of the LST values extracted from Landsat 8 imagery revealed a spectrum of temperatures within the study area, ranging from 30.36 °C as the minimum to 49.50 °C as the maximum. These findings underscore the significant temperature diversity across the region, with certain areas exhibiting cooler temperatures around 30.36°C, while others reach considerably higher temperatures up to 49.50°C as seen in figure 4.5.

The average (mean) LST across the study area was calculated at 40.93°C, providing a central reference point around which the majority of observed temperatures are distributed. Furthermore, the standard deviation of the LST values, at 2.08°C degrees Celsius, indicates the extent of temperature dispersion from the mean.

Areas characterized by vegetation cover and water bodies exhibited relatively lower temperatures, indicative of cooler microclimates. These regions benefit from the cooling effects of evapotranspiration and shading provided by vegetation, as well as the presence of water, acting as a natural heat sink. Such green and blue spaces play a crucial role in alleviating Urban Heat Island (UHI) effects and fostering more comfortable living environments.

Conversely, areas featuring bare land and impervious surfaces, such as sand patches, urban structures, roads, and pavements, displayed higher LST values. These locales experience elevated temperatures due to the absorption and re-emission of solar radiation by artificial materials and the limited presence of vegetation.

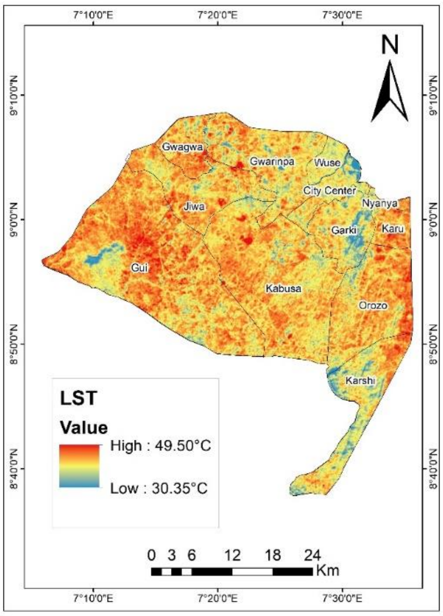

Figure 4.5: LST values across AMAC.

The positive correlation of r value of 0.83 strong positive relationship between the Landsat-derived LST and NIMET temperature data. For validating Land Surface Temperature (LST) data, correlation analysis is generally more suitable as it directly handles continuous data, provides a clear quantitative measure of the relationship, and is straightforward to interpret (White-Newsome *et al*., 2013; Cruz *et a*l., 2019). Chi-square statistics might be used in specific categorical analysis but are less common for continuous data validation like LST.

A correlation analysis was also conducted utilizing the Correlation Coefficient (r) and R-squared (R^2) statistic to directly measure the strength and direction of the linear relationship and evaluate the association between the Land Surface Temperature (LST) and various landscape indices. The R^2 value indicates the degree to which the landscape indices account for the variance observed in LST values.

Approximately 32% of land surface temperature (LST) fluctuations are attributed to vegetation, with a negative correlation between the Normalized Difference Vegetation Index (NDVI) and LST. NDVI values, ranging from 0.1 to 0.7, generally indicate that higher vegetation density correlates with lower LST values, which vary between 49°C and 30°C. The correlation coefficient of -0.57 and an R^2 of 0.32 indicate a moderate negative association. The Normalized Difference Built-up Index (NDBI) shows a moderate positive correlation with LST, suggesting

that as built-up areas increase, LST also rises. With LST values between 43°C and 35°C, the correlation coefficient is 0.53, and the R^2 is 0.28, indicating that built-up areas significantly influence LST, contributing to 28% of its changes.
In contrast, the Modified Normalized Difference Water Index (MNDWI) exhibits a very weak positive linear relationship with LST, with a correlation coefficient of 0.089 and an R^2 of 0.0081, indicating minimal association. The study's correlations between LST and landscape indices, such as NDVI and NDBI, underscore the impact of vegetation, built-up areas, and water content on the area's thermal characteristics. Notably, NDBI's pronounced effect on LST variations highlights urbanization's influence on local climate dynamics. Conducting this research validates established relationships within the specific context, offering valuable local insights.

3.3. Urban Hotspot and Cold Spot Analysis

A thermal hotspot map (Figure 4.5) was generated to identify areas with the highest and lowest temperatures, indicating thermal stress and cooler environments. The scattered nature of thermal hotspots away from the city center is a significant finding.

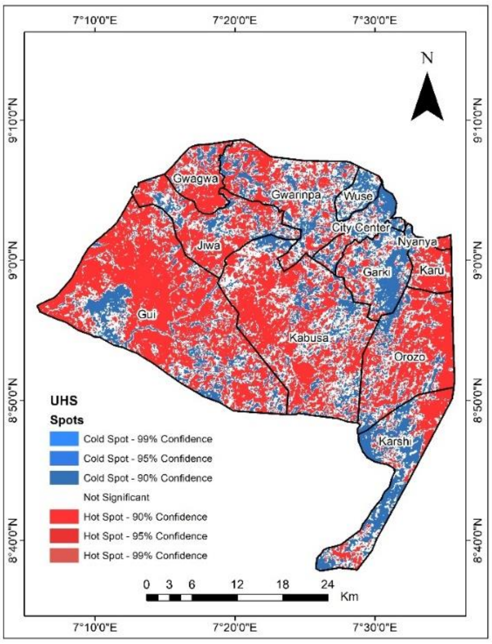

Figure 4.6: Urban Heat Island Hotspot and cold spot Map of AMAC

In this study, we analyzed the Urban Heat Island (UHI) effect using the Urban Thermal Field Variance Index (UTFVI). The UTFVI offers a detailed differentiation of hotspot regions within urban areas by employing direct Land Surface Temperature (LST) values. It also evaluates the thermal comfort of residents in the analyzed metropolitan area (AMAC) and examines the impact of urban blue and green spaces on the UHI phenomenon
The UTFVI values in our study ranged from -0.342 to 0.176. Based on this classification in table 4.1, and the UTFVI map in figure 4.6 indicated a strongest index representing the worst conditions for thermal comfort for hottest areas, while the coolest areas fell under the good thermal comfort category with a UTFVI of 0.005.

Table 4.1: UHI phenomenon and ecological evaluation index. (Mitiku Badasa Moisa 2022)

UTFVI Range	UHI Phenomenon	Ecological Evaluation Index	Area (sq km)
< 0	None	Excellent	554.08
0 - 0.0005	Weak	Good	692.03
0.005 - 0.01	Middle	Normal	64.84
0.01 - 0.015	Strong	Bad	67.56
0.015 - 0.02	Stronger	Worse	68.71
> 0.02	Strongest	Worst	55.30

The table above illustrates the relationship between different levels of urban thermal variance (UTFVI) and thermal comfort (UTCI), along with the areas affected. The areas with the highest thermal comfort (excellent and good) cover more space than those with lower thermal comfort. The smallest area, associated with the worst thermal comfort (UTCI > 0.02), is only 55.30 sq km. This indicates that extreme thermal variance and discomfort are highly localized. The analysis of UTCI reveals the necessity for targeted interventions to improve thermal comfort in areas with the highest thermal variance. This study underscores the importance of urban blue and green spaces in reducing UHI impacts and enhancing ecological conditions. The city center demonstrated a good thermal comfort level, whereas areas such as GUI, Kabusa, Orozo and Jiwa experience the worst thermal comfort levels.

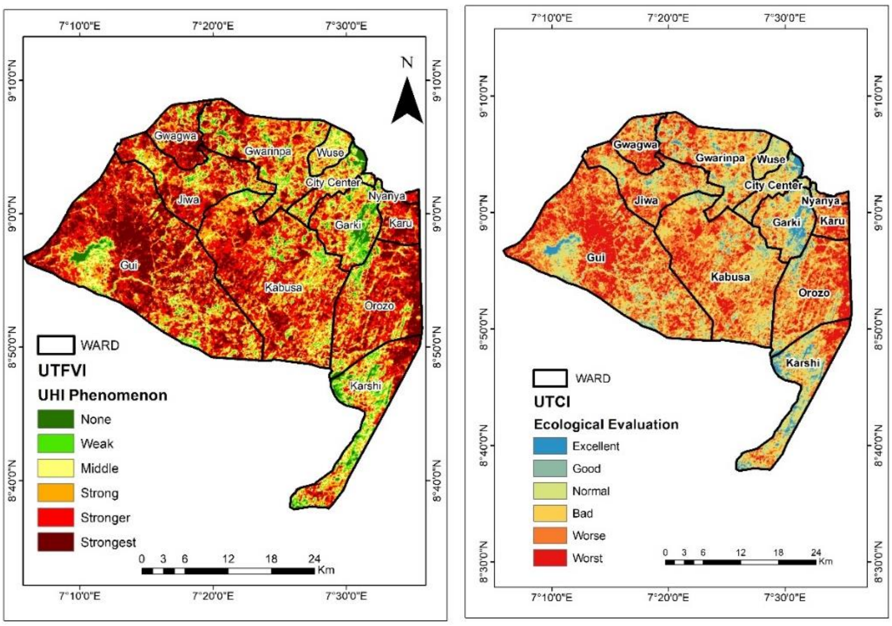

Figure 4.6: UTFVI and Ecological Evaluation of AMAC

3.4 Cooling effect within different zones and its surrounding area

The Abuja Municipal Area Council (AMAC) covers a total area of 1,503 square kilometers. Within this expanse, several notable green and blue spaces contribute significantly to the region's ecological and climatic balance. Table 4.2 lists these spaces and their respective areas:

Table 4.2: Area Distribution of green and blue spaces

Rank	Area Name	Type	Size (sq km)
1	Karshi	Green	48.23
2	Apo Resettlement and Gzape	Green	29.67
3	Gwi	Green	10.05
4	National Arboretum	Green	5.83
5	Jabi Lake	Blue	2.62

These green and blue spaces play a crucial role in mitigating urban heat and contributing to the cooling effect in the region. To quantify this effect, surface temperature distribution was assessed across various buffer distances from these spaces using a multiple ring buffer approach at 30-meter intervals extending up to 300 meters. This method allows for a detailed examination of how surface temperature (Land Surface Temperature, LST) varies with distance from the space, providing insights into the cooling impact of the space. As seen in Figure 4.7

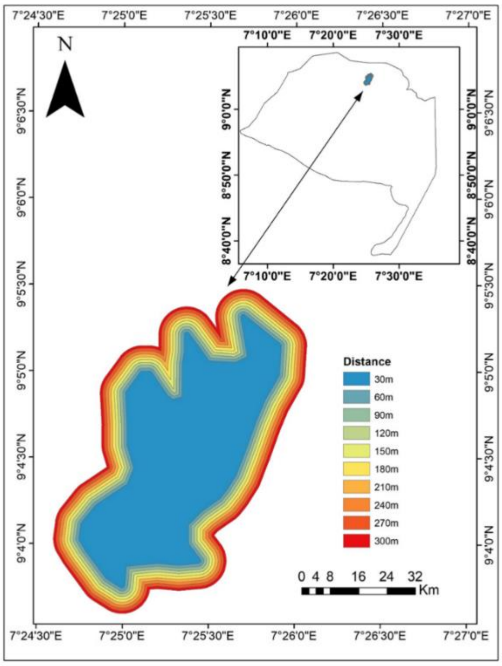

Figure 4.7: Spatial Distribution of Temperature Around Jabi Lake

This figure illustrates the surface temperature distribution around Jabi Lake Reservoir and its surroundings across various buffer zones and isotherm lines. The analysis reveals a clear thermal gradient, with the lake itself exhibiting the lowest mean surface temperature at 29.73°C. As the distance from the lake increases, the surface temperatures rise accordingly: at the 30-meter buffer, the mean temperature is 30.37°C, increasing to 34°C at 210 meters, and reaching a peak of 40.74°C at the 300-meter buffer.

This trend indicates a significant cooling effect exerted by the lake, which diminishes with increasing distance. To further validate this observation, an isotherm map was created, delineating temperature lines that confirm the consistency of the thermal gradient. The isotherm lines attest to the fact that the buffers accurately represent the thermal influence of the lake, illustrating the spatial distribution of cooler temperatures surrounding the lake and reinforcing the findings of the buffer zone analysis.

Zonal statistics was used to further analyze the Land Surface Temperature (LST) distribution across different wards within AMAC figure 4.8 shows the map of the hottest and coldest part of AMAC. LST ranged from 30°C to 40°C. By applying zonal statistics, we observed the surface temperatures directly, helping to understand the cooling effect more precisely.

The analysis revealed that the hottest areas are Karu, Gwagwa, and Gwi, primarily due to their larger ward sizes with a lot of settlements as its cheaper for vast population in abuja and absence of blue or green space. In contrast, the city center, Garki, and Wuse exhibited cooler temperatures.

This indicated that vegetation and water bodies play a critical role in cooling urban areas, emphasizing the importance of preserving and expanding these spaces. The assessment of surface temperatures across different buffer distances from Jabi Lake confirms the substantial cooling effect of blue spaces within urban settings. The presence of Jabi Lake helps mitigate urban heat island effects in its vicinity, making it a crucial component of urban climate regulation strategies. Integrating more green and blue spaces, like those detailed in table 4.5, could enhance this cooling effect, contributing to a more sustainable and livable urban environment in the Abuja Municipal Area Council.

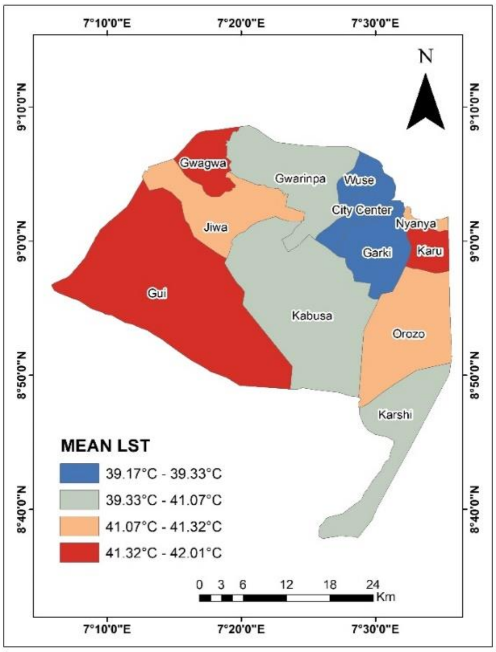

Figure 4.8: Map of cool zones in AMAC

The Urban Cooling Island (UCI) indices used in this study are defined according to the work of Sun et al. (2012). These indices include the UCI scale, temperature difference, and UCI intensity. The UCI indices are crucial for understanding the cooling effects of urban green and blue spaces on their surrounding environments. The already existing Ten buffer zones around these spaces at 30-meter intervals to determine the UCI scale was used. The average temperature was calculated for each buffer zone, and the zone with the highest average temperature was identified as the Urban Cooling Intensity (UCI) scale.

The highest UCI intensity was observed at 30m with a value of 0.0833°C/m at the National Arboretum, coupled with a temperature difference of 4.995°C There were noticeable decreasing effects on areas within 120m buffer zone (0.0033°C/m), then it increased again from 180-300 effect on places within the 500m buffer zone (0.0122°C/m -0.0221°C/m).Conversely, the lowest UCI intensity values, near zero, were noted at multiple distances (90m, 180m, 210m, 240m, 270m, and 300m), with minimal temperature differences (ranging from 0.006°C to 0.022°C). The distribution of UCI intensity underscores that the cooling effects of blue and green spaces vary markedly with distance. The most significant cooling effect was observed near the boundaries (30m), and this influence wanes with increasing distance.

4.0 Discussion

4.1 Spectral indices/Green and Blue Space Extraction

The identification of densely vegetated areas can inform the development of green spaces and blue spaces, enhancing urban livability and biodiversity. Areas with significant green and blue spaces should be prioritized for conservation to maintain ecological balance and provide recreational spaces for the community. The findings from the NDVI and MNDWI-based extraction of green and blue spaces have several implications for urban planning and environmental management. The identification of significant green spaces, such as those in Tunga Jankua, Gwi, and Karshi Waterfall, highlights areas that could be prioritized for conservation efforts or urban greening initiatives. Conversely, regions with lower NDVI values, like Lugbe, Garki, and Wuse, may require targeted interventions to enhance urban green spaces. Comparatively, studies by Chibuike *et al*., (2018) and Moisa and Gemeda, (2022) used NDVI analysis to highlight the importance of green spaces in urban settings. Both studies emphasize the need for targeted urban planning and conservation efforts to sustain and enhance the ecological health of urban areas. However, Moisa's study over Jimma city in Ethiopia and Ekwe's study in Nigeria present different climatic contexts, demonstrating the versatility of NDVI in diverse environments.

4.2 LST Distribution

Singh *et al*., (2017) studied the spatial distribution of land surface temperature (LST) in Lucknow (Csa climate), revealing that LST is significantly influenced by LULC changes and anthropogenic activities. This is consistent with findings from studies by Moisa and Gemeda, (2022) in Jimma city, Ethiopia, and Mallick *et al*. (2008) in Delhi, India, which also found substantial increases in LST due to the replacement of green spaces with impervious surfaces. Pritipadmaja *et al*., (2023) used MODIS for LST validation instead of a more accurate sensor than Landsat 8. This methodological choice is debatable as both MODIS and Landsat 8 are sensor-based, potentially introducing similar inaccuracies.

4.3 Cooling Effect of Blue-Green Spaces

The heightened temperatures in city centers exert significant pressure on microclimate patterns, altering precipitation, air circulation, and exacerbating climate-related disasters, water quality deterioration, and increased levels of air pollutants Mathew *et al*., (2018) and Wang *et al*., (2021), in these studies regions outside urban areas were cooler. Interestingly, in this research study found that the city center is cooler than other outer urban areas, with blue spaces like Jabi Lake and Pedra Dam exhibiting the coolest temperatures at around 31 °C.

The latitude of the city affects the cooling intensity of water bodies, with lower latitude cities generally experiencing stronger cooling effects. For instance, in Hiroshima (34°N), the cooling effect extended nearly 100 meters from a riverbank (Murakawa *et al*., 1991).whereas in Sheffield (53°N), it did not exceed 30 meters (Hathway & Sharples, 2012) In this study, the cooling intensity extended up to about 180 meters, indicating a significant cooling effect.

4.4 Urban Heat Island

The Urban Thermal Field Variance Index (UTFVI) assesses urban heat stress and highlights that areas with higher thermal comfort are more extensive than those with lower comfort levels. The study emphasizes the role of urban blue and green spaces in reducing urban heat island (UHI) effects and improving ecological conditions, necessitating location-specific interventions. Green and blue spaces, such as Jabi Lake, significantly cool their surroundings, underscoring the need for more integration of these spaces in urban planning for a sustainable environment in AMAC. Areas like GUI, Kabusa, Orozo, and Jiwa experience the worst thermal comfort levels, indicating the need for targeted urban planning. The Urban Cooling Index (UCI) shows significant temperature pattern variations, with cooling effects of green and blue spaces being most effective near their boundaries. Despite a statistically significant correlation between buffer distance and UCI intensity, the weak relationship suggests that other factors, such as the shape and area of green spaces, also play a role, highlighting the need for further research with additional variables to fully understand urban cooling dynamics.

5.0 CONCLUSION

The geospatial assessment of urban blue and green spaces in AMAC, Abuja, underscores the importance of these natural elements in moderating urban heat islands. The study reveals that green and blue spaces significantly contribute to cooling effects, reducing land surface temperatures and enhancing thermal comfort. Vegetation and water bodies effectively lower surface temperatures through shading and evapotranspiration, highlighting their importance in urban climate regulation. Conversely, urbanization and impervious surfaces exacerbate the UHI effect, leading to higher local temperatures. These findings advocate for the strategic expansion and integration of green and blue spaces in urban planning to foster sustainable and resilient urban environments. Addressing the gaps identified in this study will enable policymakers and urban planners to effectively leverage natural spaces to mitigate the adverse effects of urban heat islands, thereby promoting a healthier and more sustainable urban future for Abuja and beyond.

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BIOGRAPHICAL NOTES

Surv. (Mrs)Angela Omamuyovwi Anyakora is a Registered ,highly skilled and passionate professional in the field of Surveying and Geo-Informatics. With her extensive expertise, she has made remarkable contributions to the industry while working with different organizations and supporting various projects. In recognition of her leadership abilities, Angela has been appointed as the Vice chair Technical for the FIG Young Surveyors Network and the
Chair of Generational Sustainability Working Group 3 under the FIG Diversity and Inclusion Taskforce . Through her dedication, she not only advances her own career but also uplifts other young professionals in the surveying and geo-informatics industry.

Currently employed at Sambus Geospatial limited Nigeria, Angela utilizes her skills to bolster numerous initiatives. Not limited to her professional pursuits, she exhibits a deep commitment to volunteer work and humanitarian services. Angela actively participates in the Volunteer Surveyors Community Program (VCSP), where she serves as the Co-Lead . VCSP, an initiative by the Young Surveyors Network for the International Federation of Surveyors (FIG), empowers young professionals to make positive impacts through volunteerism.Her dedication to addressing climate change led her to join the FIG Climate Compass Taskforce, where she advocates for the use of geospatial technologies to understand and mitigate the impact of climate change on humans. Through her work in the taskforce, Angela aims to raise awareness about key issues and contribute to sustainable solutions in combating climate change's effects.

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