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

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Abstract

Urbanization and greenhouse gas accumulation have intensified global temperature trends, with the Urban Heat Island (UHI) effect significantly impacting countries. 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. The analysis of Land Surface Temperature (LST) 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-blue spaces in moderating urban heat islands. These findings emphasize the intervention of urban planning strategies to expand and preserve green-blue spaces to combat the UHI effect and enhance climate resilience in AMAC.

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

1. Introduction

The rapid expansion of urban areas, combined with the increasing concentration of greenhouse gases in the atmosphere, has significantly influenced global temperature trends and altered climate patterns. Fast urbanization has made about 55% of the population of the world to live in urban areas, a figure which is expected to rise to 60% by 2030 (UNDESA 2018,). This urbanization has caused a number of undesirable impacts on the environment. Environmental changes are these replacing the natural surfaces with that of the urban fabrics which have higher temperatures than the surrounding rural environment that this fabric is in. This phenomenon which is most widely studied on urban photos is referred to as the Urban Heat Island (UHI) effect (Feyisa et al., 2014).

The Urban Heat Island (UHI) effect is a consequence of rapid urbanization. Urbanization leads to the replacement of natural landscape with artificial heat-absorbing, non-reflecting, water-resistant and impermeable surface materials that absorb the sun radiation during the day (Ramakrishnan et al., 2018). Besides, the heat that we produce while consuming energy or using our vehicles also contributes to the Urban Heat Island (UHI) (Aghamohammadi et al., 2022). Global issue UHI (urban heat island effect) is an issue that makes life difficult for mankind. Based on Inter-governmental Panel on Climate Change (IPCC ,2017), urban heat island effect is a global phenomenon which challenges the safety health and economy of man. 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 promote inclusive, secure, tenacious, 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 endeavours to moderate Urban Heat Islands are being addressed through strategies such as stream reclamation and the development of green frameworks. 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 nonurban regions using land surface temperature (LST) only, without quantifying UHI.

Mathew et al., (2018) and Wang et al. (2021) stressed worrying temperature differentials between urban centres and rural areas reaching as high as 12°C; however, they did not consider cooling effect strategies for temperature reduction. Moisa and Gemeda (2022) have assessed the intensity of urban thermal field variance index (UTFVI) and thermal comfort degree levels of Addis Ababa city using geo-spatial methods, which provide concrete evidence of UHI impacts ignoring cooling effect of green and blue spaces. Cruz et al., (2019) used geospatial techniques to assess UCI effect of Iloilo River and neighbouring wetlands on the surrounding microclimate to understand their cooling effect in UHI, but did not account for similar effect on green spaces.

Although the effects of UHI and its mitigation measures have been widely studied, there is a conspicuous gap in literature regarding the use of UTFVI and UCI to evaluate how blue and green spaces cool the UHI. This literature gap is particularly within Abuja, Nigeria. Research has shown how essential urban green and blue spaces are to improving environmental quality and mitigating UHI effects, but it still needs to be studied more. This research will determine how much green and blue spaces in Abuja, Nigeria, moderate urban heat islands (UHIs) and how they moderate temperatures 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. 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

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

Firstly, the spectral indices were gotten from Sentinel-2 MSI to obtain blue and green spaces using the Modified Normalized Difference Water Index (MNDWI) and the Normalized Difference Vegetation Index (NDVI) with 0.3 and 0.2 as the thresholds. These values were Assessed using an integration of visual data inspection and reference to pertinent research like (Pritipadmaja et al., 2023 and Sharma et al., 2021). The Normalized Difference Built-up Index (NDBI) was used to recognize impervious surfaces and built-up regions.

$NDVI = \frac{NIR-RED}{NIR+RED}$…………………. (3.1)

$MNDWI = \frac{GREEN-SWIR}{GREEN+SWIR}$………….. (3.2)

$NDBI = \frac{SWIR-NIR}{SWIR+NIR}$………………… (3.3)

Secondly, the estimation of LST from Sentinel 2 is vital for studying Urban Heat Island phenomena. In this research, we merged methods from various sources like Cai et al., (2022), Moisa and Gemeda, (2022) and Pritipadmaja et al., (2023). Google Earth Engine (GEE) was used to process thermal data from Landsat 8 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:

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

A connection was established between NIMET air temperature data and that of LST. This was determined 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 connection 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. To analyze UHI in the study area, we calculated Land Surface Temperature (LST) following the method described by Isioye et al. (2020), Sharma et al. (2021) and Waleed et al. (2023) using Equation:

$UHI=LST-LST\ mean/\ STD$……… (3.6)

After computing the UHI, The Urban Thermal Field Variance Index (UTFVI) was used to describe its effect. UTFVI is utilized to evaluate the overall strength of Urban Heat Islands (UHI) in the research area based on land surface temperatures (Isioye et al., (2020), Sharma et al., (2021) and Waleed et al., (2023).

The UTFVI equation is:

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

Where Ts represents the LST of a pixel and

Tmean denotes the mean LST.

Also, Urban cooling indices were applied to characterize the cooling effects of blue spaces and green spaces (Lee et al. (2016) Du et al. (2017) and Ekwe et al. (2020). The cooling effects in urban areas were quantified using UCI, which encompasses the UCI scale, temperature difference, and UCI intensity. These metrics gauge the cooling impact of blue and green spaces, employing buffer zones from 30 meters to 300 meters to capture the spatial extent of cooling. Cai et al., (2022) UCI analysis method offers a compelling approach for examining the cooling effects of water bodies and green spaces within Urban Heat Islands (UHI). Regression analysis was used to compare the cooling effects of green and blue spaces and comprehend their influence on the surrounding environment.

The spatial analysis of UHI involves identifying urban hot spots, which are areas with elevated LST values, based on land use land cover (LULC) changes around urban areas. This transformation is the primary cause of increased LST in numerous cities, attributed to the substitution of vegetation and other LULC with impervious surfaces. Hot spots are defined as regions where LST values surpass the mean LST by two standard deviations (μ + 2*s), enabling the mapping and characterization of areas experiencing high thermal stress. The research employs zonal statistics in GIS to examine spatial data within specific zones, computing metrics such as mean, median, maximum, minimum, standard deviation, sum, majority, and minority for each zone.

3. Results

3.1 Landscape Indices Analysis

Analysing landscape indices provides valuable insights into the vegetation, water, and built-up characteristics within AMAC. This section presents visual representations (Figure 4.1,4.2 and 4.3) of three specific landscape indices: NDVI, MNDWI, and NDBI. These indices serve as essential tools for evaluating the dynamics of land use and land cover (LULC). 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 varied between -0.551 and 0.660, with an average 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.

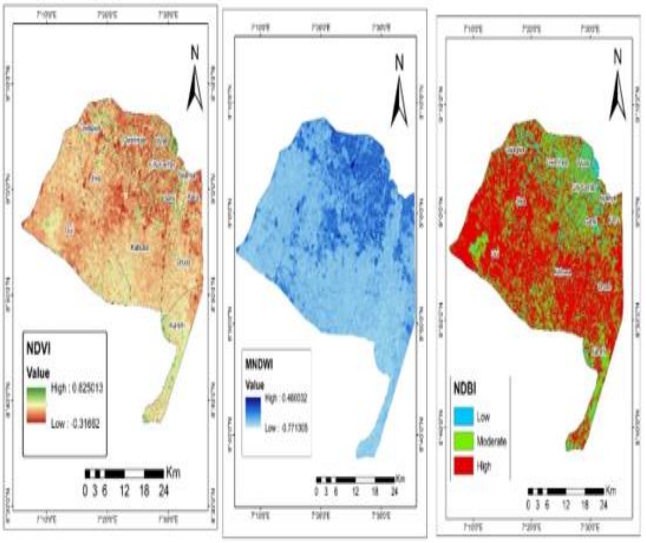

Figure 4.1,4.2.4.3: NDVI, MNDWI, NDBI across AMAC showing high and low values

The extraction of green and blue spaces is a critical aspect of urban and environmental planning, providing insights into vegetation cover and water bodies. This Research, we employed the 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.

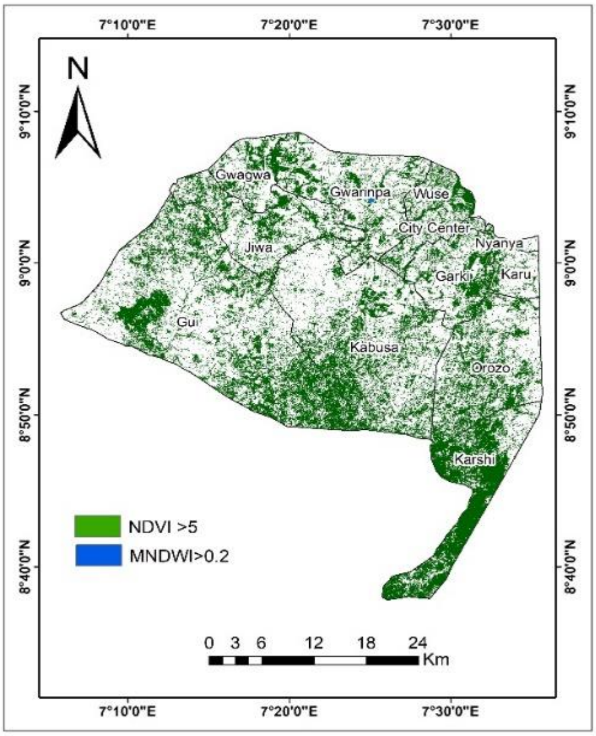

Figure 4.4: Masked Blue and Green spaces

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 with vegetation cover and water bodies showed relatively lower temperatures, suggesting cooler microclimates. These regions enjoy the cooling effects of evapotranspiration and the shade offered by vegetation, along with water's role 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 high temperatures due to the absorbing and re-radiation by artificial materials and lack of vegetation.

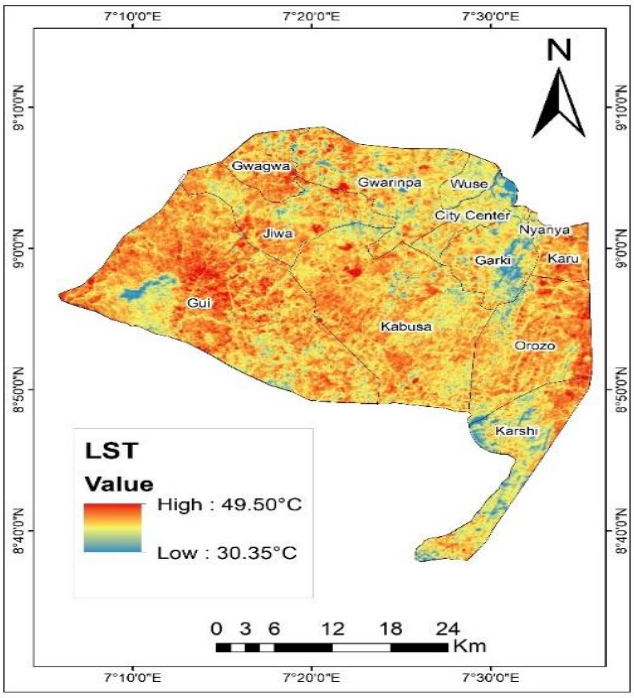

Figure 4.5: LST values across AMAC.

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 al., 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 (R2) statistic to directly measure the strength and direction of the linear relationship and evaluate the connection between the Land Surface Temperature (LST) and various landscape indices. The R2 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 NDVI and LST. NDVI values, 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 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 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. In this study the connection between LST and landscape indices, such as NDVI and NDBI, underscore the effect of vegetation, built-up areas, and water content on the area 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

To identify regions experiencing the highest and lowest temperatures, indicating areas of thermal stress and cooler zones, a heat map (Figure 4.5) was created. A notable observation from this analysis was the dispersed distribution of thermal hotspots beyond the urban core.

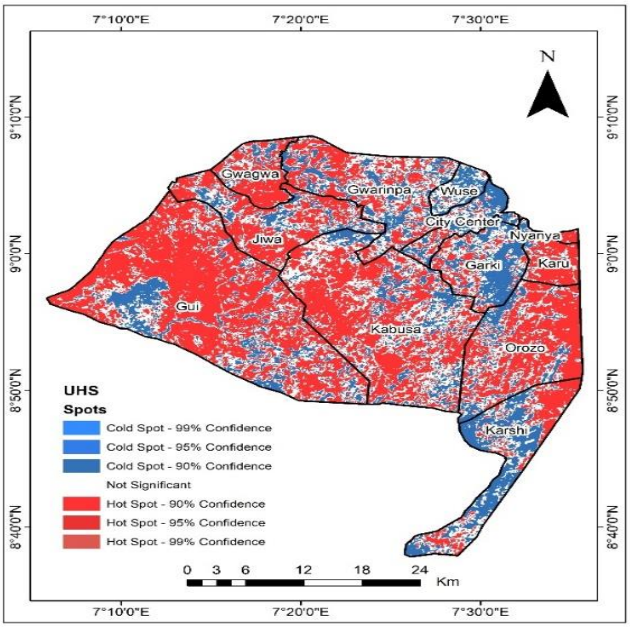

Figure 4.6: Urban Heat Island Hotspot and cold spot Map of AMAC

In this study, we analysed the UHI effect using the UTFVI. The UTFVI offers a detailed differentiation of hotspot regions within urban areas by employing direct LST values. It also evaluates the thermal comfort of residents in AMAC and examines the effect 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 UTFVI and 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 significance of urban blue and green spaces in reducing UHI impacts and improving 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.

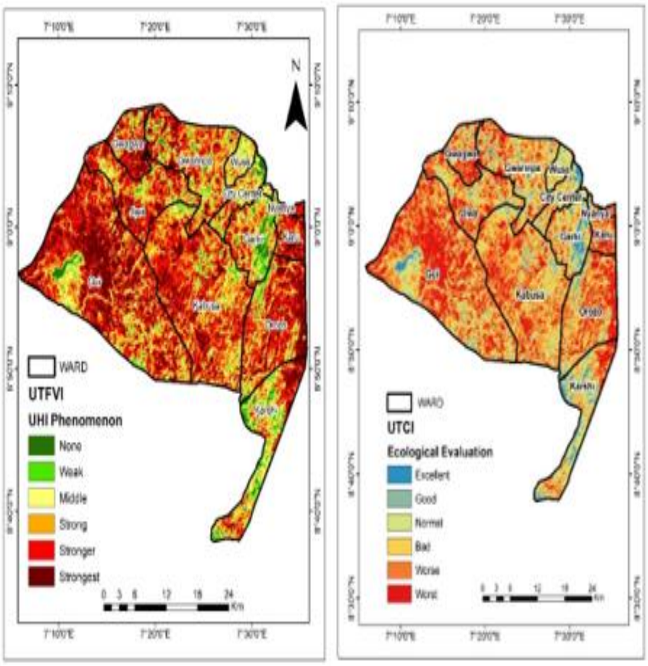

Figure 4.6: UTFVI and Ecological Evaluation of AMAC

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 vital role in moderating urban heat and contributing to the cooling effect in the region. To quantify this effect, land 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

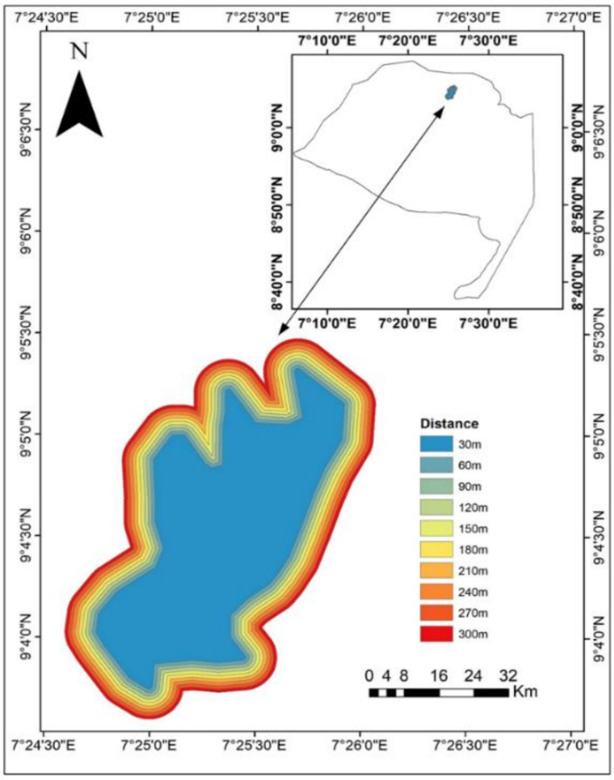

Figure 4.7: Spatial Distribution of Temperature Around Jabi Lake

The above 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 were used to further analyze the Land Surface Temperature (LST) distribution across different wards within AMAC figure 4.13 shows 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 us 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 assessment was conducted using mean, maximum, median, and count statistics around the buffer rings to determine the highest temperatures and the distances at which temperatures began to increase significantly. From the zonal statistics, it was found that areas with abundant vegetation or water bodies exhibited lower temperatures extending to about 300 meters.

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.

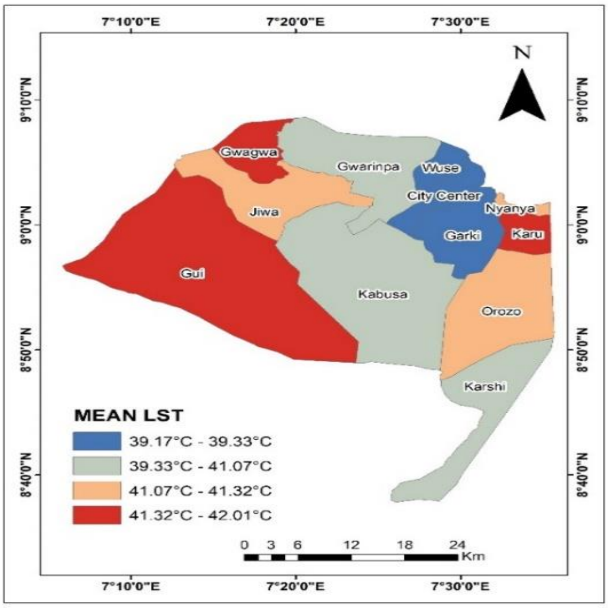

Figure 4.8: Map of cool zones in AMAC

The Urban Cooling Island indices employed in this investigation were defined based on the research conducted by Sun et al. These indices encompass the UCI scale, temperature differential, and UCI intensity. These UCI indices are pivotal in elucidating the cooling impacts exerted by urban green and blue spaces on their surrounding environments. The established ten buffer zones surrounding these spaces, at 30-meter intervals, were utilized to determine the UCI scale. The average temperature was computed for each buffer zone, and the zone exhibiting the highest average temperature was identified as the Urban Cooling Intensity 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. 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 liveability 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. The MNDWI analysis underscores the importance of managing and protecting water bodies within the study area. The accurate mapping of blue spaces provides essential data for water resource management, particularly in regions where water bodies are less prevalent.

Future research should focus on the temporal analysis of these landscape indices to monitor changes over time. Additionally, integrating these indices with socio-economic data could provide a more comprehensive understanding of the impacts of urbanization on environmental and human health and another can incorporate seasonal variations in NDVI and MNDWI values to monitor changes in vegetation and water bodies over time, aiding in dynamic environmental management.

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

The examination of geographic distribution of land surface temperature (LST) in Lucknow (Csa climate) in a research by Singh et al., (2017) shows that LST is greatly affected by changes in land use land cover (LULC) and human activities. The results from this study greatly aligns with those conducted by Moisa and Gemeda, (2022) in Jimma city, Ethiopia, and Mallick et al. (2008) in Delhi, India, which also observed significant LST increases resulting from the conversion of green areas to impermeable 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 elevated temperatures in urban centers exert considerable influence on microclimatic patterns, modifying precipitation, air circulation, and intensifying climate-related catastrophes, water quality degradation, and heightened air pollutant levels. Mathew et al., (2018) and Wang et al., (2021), found that regions outside of metropolitan areas exhibited cooler temperatures in their studies. 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. 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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