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Assessment of Urban Heat Island in the Niger Delta Region of Nigeria

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Abstract- ***Mapping temperature zones in urban centers is an important reference for urban planning and construction but has received limited attention in the Niger Delta Region of Nigeria. This study investigates and maps temperature zones within selected cities in the region. Ambient and land surface temperature (LST) measurements were taken during wet and dry seasons across seven states using Landsat 8 satellite imagery and weather stations installed in the study areas. For Yenagoa, Bayelsa State, dry-season LST readings were highest at Point 9 near the FGN Medical Centre (31.12 °C) and lowest at Point 4 near the State Entrance Gate in Igbogene (28.32 °C), with other areas ranging from 28.24 °C to 30.65 °C. Wet-season LST varied from 24.87 °C to 35.15 °C, with Emiringi Road, Okutukutu, Amasoma Road, Okaka, and Oxbow Lake identified as high-temperature zones. Additional hotspots included Ekeki Motor Park, Swali Market, Opolo, and Okutukutu. In Calabar, Cross River State, the wet-season peak was recorded at Point 3 (Mbukpa, a densely populated residential area) at 30.57 °C higher than in the dry season, while the lowest reading occurred at Point 8 on Target Road (28.10 °C). In Asaba, LST ranged from 25.56 °C to 29.88 °C. Ambient temperatures in the dry season ranged from 26.40 °C to 37.20 °C, with relative humidity between 51.78% and 77.52% and north-easterly winds at 1.01–3.25 m/s. In the wet season, temperatures ranged from 24.33 °C to 32.00 °C, relative humidity from 58.50% to 92.16%, and southerly winds at 0.63–2.51 m/s. Several sites, including Asaba Bridge Head and Inebisi Junction, recorded comparatively lower LST and ambient temperatures during the wet season.***

Key words: Land surface temperature (LST), Ambient Temperature, Combined Heat Stress Map, Niger Delta.

I. INTRODUCTION

Heat stress maps are specialised charts that use colour variations to represent data values in tables or physical maps, often in diagram form. Their quality largely depends on the GIS software used for mapping. Despite their name, heat stress maps do not necessarily depict temperature directly; instead, they display the amount or concentration of certain temperature-related measurements. These maps are especially useful for visualising large, complex datasets, such as those used in Earth science, allowing researchers to view entire datasets at once (NASA, 2022). Heat maps may take the form of a rectangular chart with numerical values in each cell, or more commonly in Earth science applications colour overlays on a geographic map. In such overlays, the colors represent variations in data values, as indicated in the map legend. These legends can use either a continuous color gradient or discrete color categories. For example, NASA uses heat maps to study changes such as land surface temperature, fire and carbon monoxide emission rates, chlorophyll concentration, and sea surface temperature (NASA, 2022).

Land surface temperature (LST) indicates how warm the Earth's surface appears from a satellite's perspective. "Surface" in this context refers to whatever the satellite detects through the atmosphere, whether it is snow, ice, grass, a building's roof, or forest canopy. While LST and ambient temperature are not identical, they are related and can influence one another. The LST maps in this study were generated using Landsat 8 data collected during both the dry and wet seasons for the study period. Map temperatures ranged from 4.74 °C (deep blue) to 53.42 °C (brownish red). In equatorial regions, LST typically remains consistently warm. Elevation also affects temperature, with higher terrain generally cooler than surrounding lowlands at the same latitude. Monitoring LST is crucial because heat emitted from Earth's surface both affects and is affected by weather and climate patterns. Scientists track these changes to study the effects of increasing greenhouse gas concentrations and to assess how rising LST impacts vegetation and ecosystems. Beyond research, LST mapping has practical applications for instance, commercial farmers can use

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it to determine crop water needs during the dry season, when plants are prone to heat stress. LST also influences human comfort, especially during power outages, when high surface temperatures can significantly affect living conditions.

II. METHODOLOGY

The Niger Delta Region of Nigeria, located at approximately latitude 5°19′20.40″ N and longitude 6°28′8.99″ E, is a geopolitical zone comprising the nine states of Akwa Ibom, Bayelsa, Cross River, Delta, Edo, Abia, Imo, Ondo, and Rivers. It is bordered by Anambra State to the southeast, the Atlantic Ocean to the south, and Ekiti and Osun States to the southwest. As Nigeria's major oil and gas producing region, it holds a central role in the country's economy. This study employed a quantitative research approach. Sampling stations were purposively selected within urban centers in the seven states forming the study area. Data collection utilized specialized meteorological instruments, including a pole-mountable or standing RF433 MHz Meteorometer with a 100 m coverage range, equipped with weather history and alarm monitoring capabilities, and a BTMETER model 866AP handheld weather station as backup. These two instruments were used for ground-based data collection across the study sites.

Weather monitors were mounted at a height of 6 m above ground level in open spaces to prevent interference from surface heat sources. Data were recorded on the same day that the Landsat 8 satellite passed over the study area. The RF433 MHz Meteorometer measured air temperature, wind speed and direction, and relative humidity. A Garmin 72H GPS device was used to geo-reference sampling points. Land surface temperature (LST) data were obtained from Landsat 8 imagery, which is critical for studies in areas such as climate change, hydrology, geophysical and biophysical processes, and urban land-use/land-cover analysis. LST for any Landsat 8 image can be retrieved by first processing Band 10. In this study, LST was computed following the method proposed by Avdan and Jovanovska (2016), which was applied to all imagery collected during the research period:

I. Computation TOA (Top of Atmospheric) spectral radiance
II. Conversion of TOA to Brightness Temperature conversion
III. Calculation of the NDVI
IV. Calculation of the proportion of vegetation
V. Calculation of Emissivity
VI. Calculation of the Land Surface Temperature

LST = (Brightness Temperature T / (1 + (0.00115 BT / 1.4388) Ln (Emissivity)

III. RESULTS AND DISCUSSION OF FINDINGS

Land Surface Temperature (LST) is a key environmental parameter in evaluating heat exchange between the Earth's surface and the lower atmosphere (Aniekan & Akwaowo, 2017). Across the seven selected cities in the Niger Delta Region, both wet and dry season analyses revealed significant spatial and seasonal variations in LST, influenced by urbanization, land cover type, and proximity to vegetated or water-dominated zones.

Yenagoa, Bayelsa State

The Landsat-derived maps showed marked differences between seasons. In the dry season, LST ranged from 28.24 °C to 31.12 °C, with the highest value recorded at Point 9 near the FGN Medical Centre, and the lowest at Point 4 near the State Entrance Gate in Igbogene. In the wet season, LST values ranged from 24.87 °C to 35.15 °C, with high-temperature zones including Emiringi Road, Okutukutu, Amasoma Road Okaka, Oxbow Lake, Ekeki Motor Park, Swali Market, and Opolo. As show in figure1, the average LST in green areas was 17.57 °C, while the city center recorded 30.72 °C, indicating a pronounced urban heat effect.

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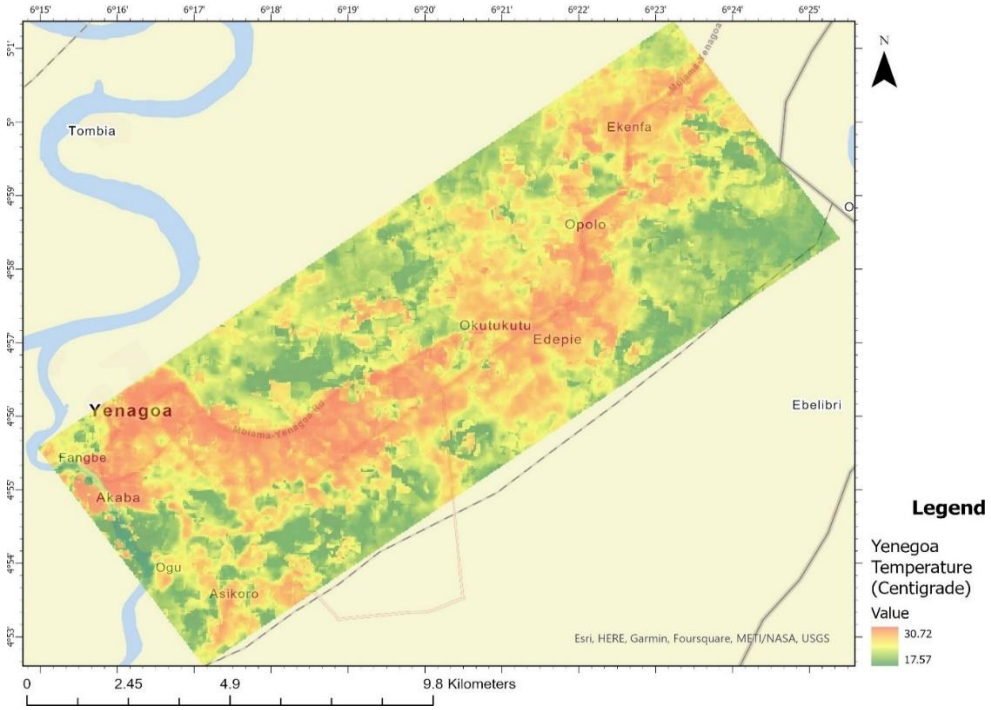

Figure 1: Combined Heat Stress Map for Yenagoa City, Bayelsa State Niger Delta Region

Calabar, Cross River State

Five temperature zones were identified in the study area figure 2. In the wet season, LST ranged from 7.87 °C to above 32.51 °C, with the highest temperatures concentrated in the southern city and urban core. In the dry season, LST ranged from 37.78°C to above 44.70 °C, with urban hotspots such as Ikot Omin, Esuk Utan, and Adiabo Ikot Mbo showing elevated values. Rural zones like Akpabuyo recorded much cooler conditions. The difference between rural and urban areas was 8.74 °C (urban: 29.50 °C; rural: 20.76 °C).

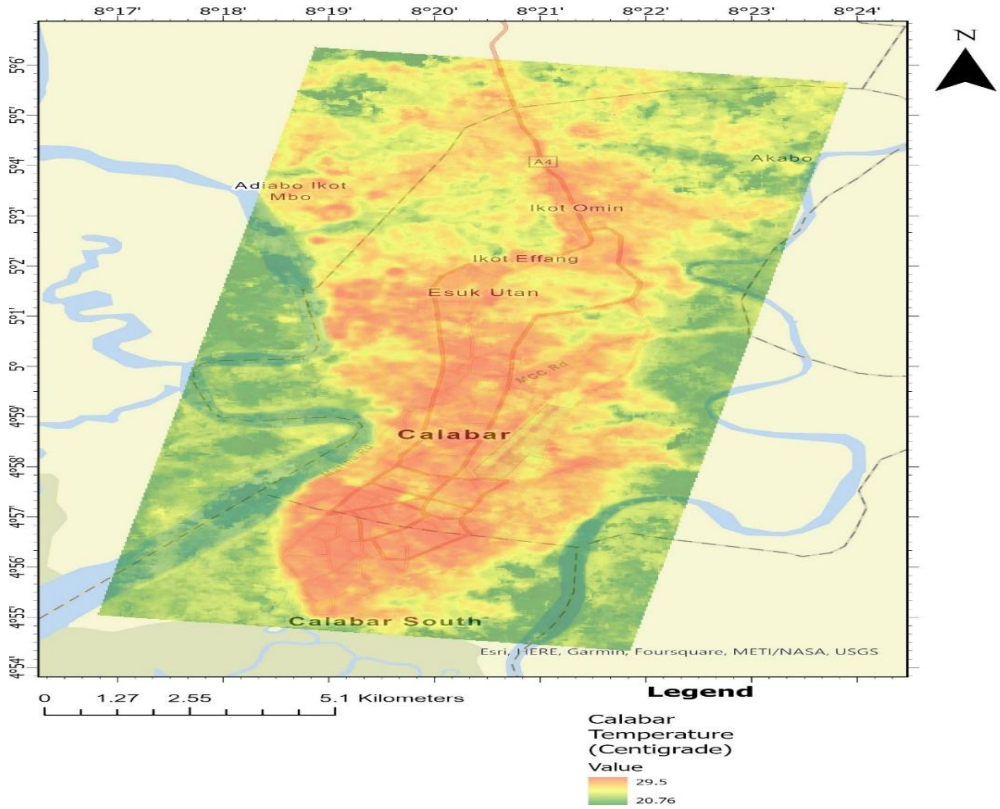

Figure 2: Combined Heat Stress Map for Calabar City in Cross State Niger Delta Region

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Asaba, Delta State

In the wet season, LST ranged from 4.73 °C to above 33.07 °C, with higher temperatures concentrated along major transportation corridors such as the bridgehead through Inebis Road to the airport. Dry season LST values ranged from 37.03 °C to above 42.94 °C, with the urban center recording 32.55 °C compared to green zones averaging 20.01 °C.

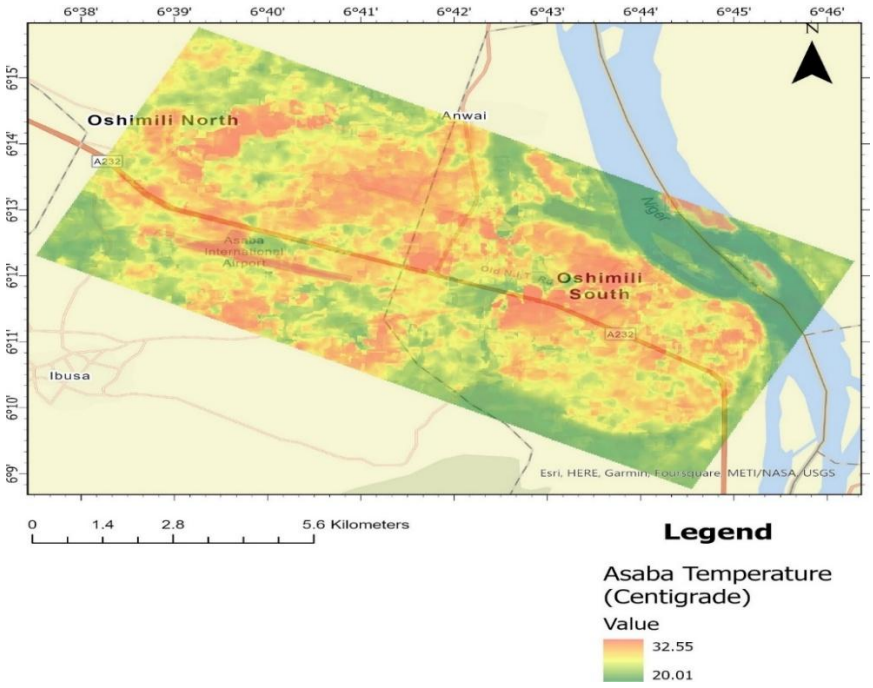

Figure 3: Combined Heat Stress Map for Asaba City, Delta State, Niger Delta Region

Benin, Edo State

Thermal patterns indicated elevated LST in built-up areas as shown in figure 4, with urban hotspots recording around 33.64 °C in Egor, Oredo, Ikpoba Okha, Ekodei, Ring Road, and Ikiadolo. Cooler zones (22.94 °C) were found near Akure–Benin Road, extreme east of Ikiadolo, and Oredo's outskirts. Rural vegetated areas along the Benin Bypass toward Agbor Road also exhibited reduced heat stress.

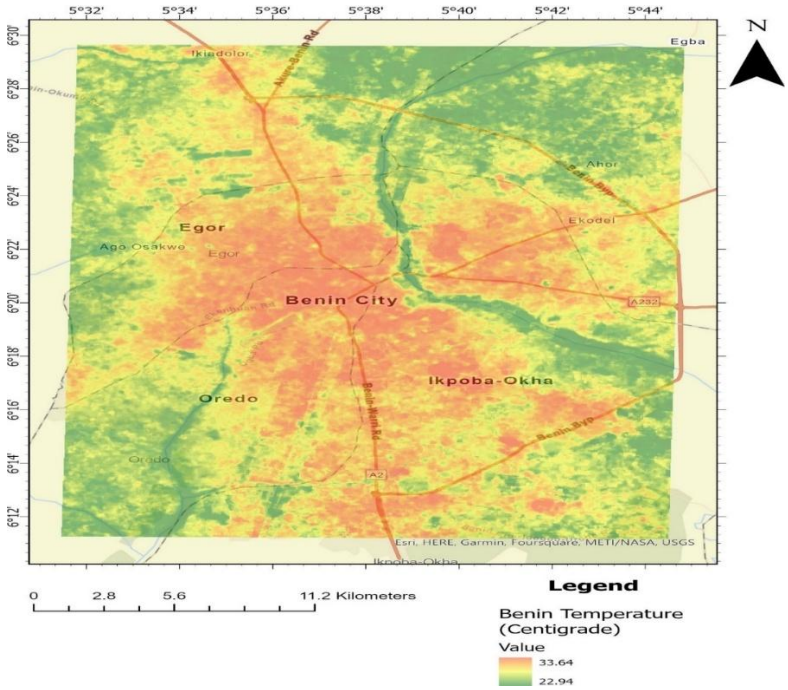

Figure 4: Combined Heat Stress Map for Benin City, Edo State Niger Delta Region

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Owerri, Imo State

The LST map showed extensive heat stress coverage within the urban core area, figure 5, with cooler green zones located 3.5–6.5 km from the city center. Urban hotspots included the Divisional Police Headquarters, Port Harcourt Road, Imo State House of Assembly, Douglas Road, and the Control area. LST values reached 30.73 °C in these hotspots, while cooler areas recorded 22.58 °C.

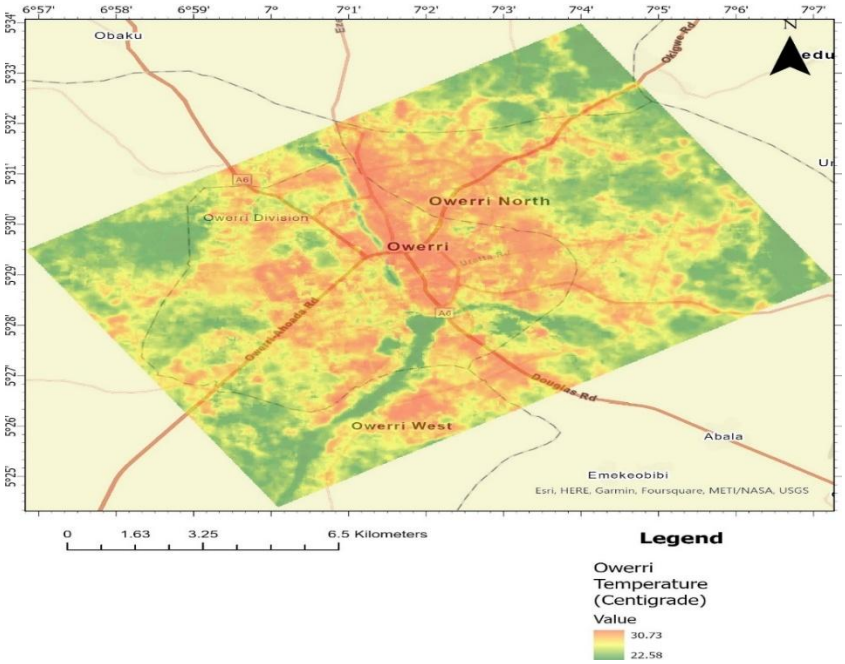

Figure 5: Combined Heat Stress Map for Owerri City Imo State Niger Delta Region

Port Harcourt, Rivers State

The city displayed widespread heat stress across built-up zones as shown in figure 6. In the dry season, the urban core recorded 31.83 °C, compared to 19.84 °C in surrounding rural zones, a difference of 11.99 °C High-stress areas included the East–West Road (Choba to Eleme Junction), Port Harcourt–Aba Expressway (Oyigbo to the city center), Ikwerre Road (Iguruta to Education area in Mile 1), Eagle Island, and the Trans Amadi Industrial Layout.

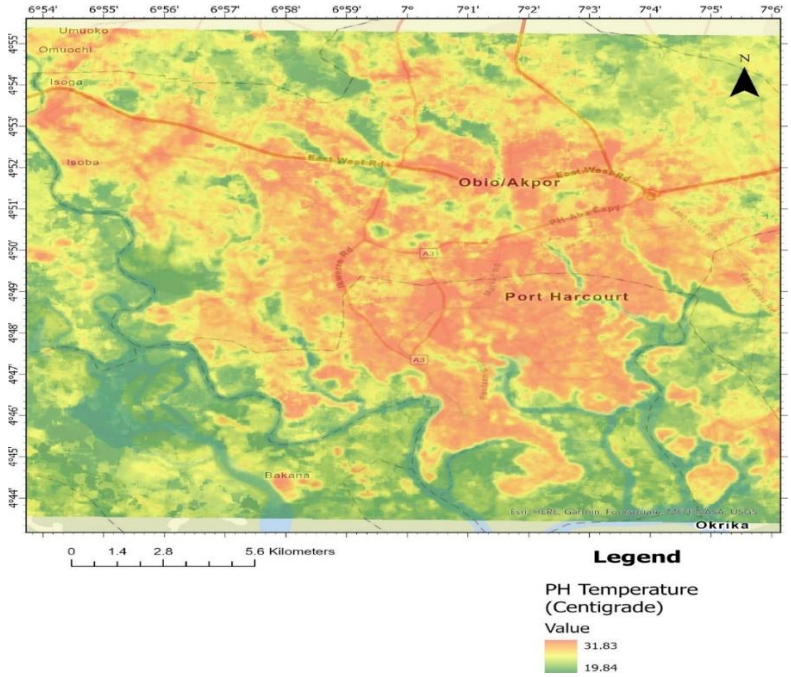

Figure 6: Combined Heat Stress Map for Port Harcourt City Rivers State Niger Delta

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Uyo, Akwa Ibom State

LST map in figure 7 showed widespread urban heat coverage extending from Oron Road to Etoi, Ikot Ekpe Mbiribit, Ikot Okon, and Ibiabong. Even outskirts such as Ikot Akpan Abia recorded elevated heat stress. In the dry season, the urban core averaged 29.92 °C, while green areas around Abak–Itu Road, Uruan, and Mbak recorded cooler averages of 22.24 °C.

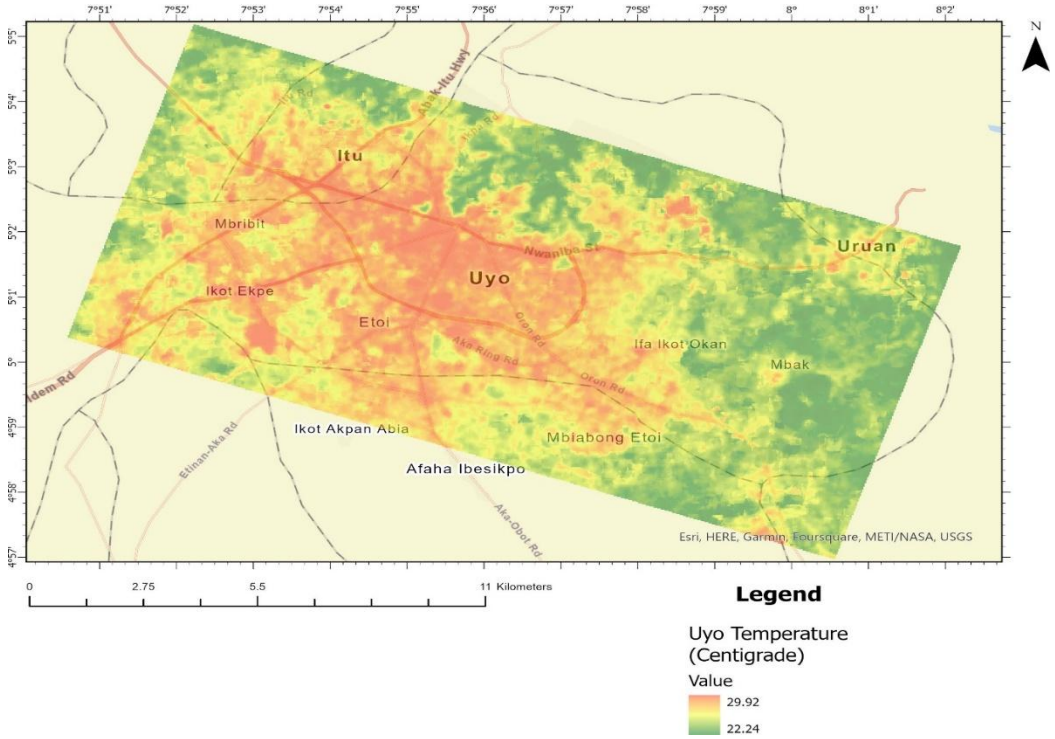

Figure 7: Combined Heat Stress Map for Uyo City Akwa Ibom State Niger Delta Region

Regional Trends and Implications

Across all the Niger Delta cities studied, the dry season temperatures were consistently higher than wet season values, reflecting seasonal variations in solar radiation and evapotranspiration. The most heat-stressed zones corresponded to areas with high building density, impervious surfaces, and limited vegetation. Conversely, cooler temperatures were found in rural and vegetated areas, underscoring the mitigating influence of green infrastructure. The consistent temperature gaps ranging from 7 °C to nearly 12 °C between rural and urban areas indicate a pronounced Urban Heat Island (UHI) effect across the Niger Delta Urban Centres.

IV. CONCLUSION

This study mapped and analyzed land surface temperature patterns across seven urban centers in the Niger Delta Region of Nigeria using Landsat 8 satellite data and ground-based meteorological observations for wet and dry seasons. The results demonstrate significant spatial and seasonal variations in LST, with dry season values consistently exceeding wet season values. Urban centers exhibited substantially higher temperatures than surrounding rural or vegetated zones, confirming the presence of strong Urban Heat Island effects. Key factors contributing to elevated LST include high building density, impervious surfaces, limited vegetation cover, and concentration of heat-retaining materials.

Conversely, areas with dense vegetation or proximity to water bodies showed markedly lower temperatures. The documented temperature differences between urban and rural zones (up to 11.99 °C) highlight the urgent need for heat mitigation strategies in city planning. Mitigation measures such as expanding urban green spaces, promoting reflective and permeable building materials, preserving peri-urban vegetation, and integrating climate-sensitive planning policies can help reduce heat stress in the Niger Delta's growing cities. These interventions will not only improve thermal comfort for residents but also enhance climate resilience in the face of global warming.

V. RECOMMENDATIONS

Based on the research findings, several targeted interventions are recommended to address heat stress and strengthen climate resilience in the Niger Delta Region. Expanding urban green infrastructure is critical, with the establishment of parks, green belts, and roadside vegetation corridors in high-LST zones such as Yenagoa's city center, Calabar's southern district, and Port Harcourt's industrial layouts. This should be complemented by large-scale tree planting along major transport corridors, including the Benin–Warri Expressway, Port Harcourt–Aba Expressway, and Oron Road in Uyo. Building codes should be updated to promote reflective and permeable materials such as cool roofing, permeable pavements, and light-colored surfaces—while offering subsidies or tax incentives for retrofitting public buildings with heat-reflective materials.

Protecting and restoring peri-urban vegetation is equally vital, including halting the conversion of green belts into impervious developments, particularly in cooler zones like Akpabuyo (Calabar), Anwai (Asaba), and Uruan (Uyo), and advancing community-driven afforestation and mangrove restoration projects to enhance evapotranspiration. Land surface temperature data should be fully integrated into urban planning, guiding zoning, ventilation corridor design, and shaded public space allocation, while requiring Environmental Impact Assessments (EIAs) for major projects to include heat impact projections. Public awareness and climate literacy programs are also essential to educate residents and planners about the Urban Heat Island effect and its health risks, encouraging household-level greening initiatives like rooftop gardens and courtyard vegetation. Finally, seasonal heat stress management programs should be adopted during peak dry-season months, including shaded rest stops, increased watering of urban trees, and the provision of public cooling centers to safeguard vulnerable populations.

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