Impacts of Urban Sprawl on Urban Heat Intensity in East Baton Rouge Parish: A Remote Sensing Assessment

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Abstract

Urban expansion in East Baton Rouge Parish (EBRP) increasingly replaces vegetated, permeable land with heat-absorbing rooftops and pavements, reducing evapotranspiration and elevating land-surface temperatures (LST). This study quantifies how low-density, land-consumptive growth patterns amplify urban heat intensity (UHI) and frames that thermal signal as an indicator of land degradation relevant to planning and public health. We integrate multi-temporal USGS Landsat 8/9 Collection 2 Level-2 LST with vegetation metrics **(**NDVI, SAVI from Landsat/Sentinel-2) and a built-up proxy (NDBI/impervious fraction from land-cover products and local GIS) to map sprawl-related thermal hot spots, model relationships among imperviousness, vegetation condition, and LST, and summarize results to policy-relevant units (census tracts, corridors, and development fronts). Cloud and quality masking are applied, seasonal composites are generated for warm periods, and ΔLST is computed between urbanized pixels and nearby reference areas. We use robust trend estimation and spatial diagnostics (e.g., local clustering) to highlight persistent hot spots along major arterials, large parking complexes, and recently urbanized edges where vegetation loss and soil sealing co-occur. Findings show a consistent, spatially coherent coupling: higher imperviousness and lower vegetation indices align with higher LST**,** producing durable heat hot spots in spread-out, shade-poor districts. To support action, we propose a simple Heat & Degradation Index that blends ΔLST, % impervious, and vegetation change to prioritize cooling interventions, cool roofs and pavements, permeable retrofits, roadside green infrastructure, and parking-lot greening**,** with emphasis on corridors and neighborhoods exhibiting the most substantial thermal penalties. The workflow is transparent, reproducible with open data, and designed to be updated as new imagery and permitting records become available. By linking sprawl to thermal stress at decision scales, this work offers EBRP a practical, evidence-based path to monitor land degradation and target equitable cooling investments as the region grows.

1.0 Introduction

Urban sprawl, often manifested as low-density, auto-oriented expansion, continues to transform land cover across many U.S. metropolitan regions. As subdivisions, commercial strips, widened road networks, and large parking areas spread outward, they commonly replace vegetated, permeable landscapes with impervious materials such as asphalt, concrete, and rooftops (U.S. EPA, 2022). In East Baton Rouge Parish (EBRP), this pattern has implications beyond land consumption: the conversion of green cover to impervious surfaces reduces canopy shade, limits soil infiltration, and weakens evapotranspiration, while increasing heat storage and sensible heat flux from dark built materials. These land-surface changes intensify land surface temperatures (LST) and can widen spatial disparities in heat exposure across neighborhoods and development corridors.

The mechanisms linking sprawl to elevated urban heat intensity are well established. Vegetation moderates surface temperature through shading and evapotranspiration; when vegetation is removed or fragmented, the landscape loses key cooling pathways and becomes more responsive to solar loading. Built and impervious surfaces, by contrast, typically absorb and retain heat more efficiently and re-radiate energy, amplifying daytime thermal conditions and strengthening the surface urban heat island (SUHI) effect (Voogt & Oke, 2003; Weng, 2009). These thermal outcomes are not only environmental signals but also practical concerns, as higher surface temperatures are associated with increased cooling demand, reduced outdoor comfort, and heightened heat-related health risks, especially in shade-poor areas with limited green infrastructure.

Remote sensing provides a scalable and repeatable means to quantify these patterns and relate them to land-cover structure and development intensity. Thermal remote sensing enables spatially explicit mapping of LST, while vegetation and built-up metrics (e.g., NDVI/SAVI and imperviousness or NDBI) help diagnose how greenness loss and surface sealing contribute to thermal “penalties” across urban fabrics (Voogt & Oke, 2003; Weng, 2009). Public-sector environmental reporting also emphasizes that land development and impervious cover affect watershed function and environmental quality, reinforcing the value of

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tracking development-related surface change using decision-relevant indicators (U.S. EPA, 2022).

Importantly, emerging evidence suggests that the cooling benefits of vegetation, particularly trees, and the warming influence of impervious and built structures are not spatially uniform and may intersect with socioeconomic vulnerability. Studies have shown that vegetation cooling efficiencies can be more substantial in more deprived neighborhoods, while impervious features can sustain persistent warming that reinforces inequitable heat burdens (Gilligan, 2023; Lin et al., 2023). In EBRP, where growth continues along major arterials and along suburbanizing edges, this motivates a planning-focused assessment that identifies where sprawl-driven land conversion is producing durable thermal hot spots and where targeted interventions could yield the greatest benefits.

Although many UHI studies produce useful maps, local applications often remain limited to one-time snapshots or broad summaries that are difficult to translate into actionable priorities. EBRP needs a transparent, updatable workflow that integrates thermal intensity, imperviousness, and vegetation condition at decision scales to answer a practical question: where should cooling and restoration efforts be prioritized first? This gap is increasingly addressable because routinely updated, open datasets now support consistent monitoring. USGS Landsat 8/9 Collection 2 Level-2 products provide standardized surface temperature outputs and quality masks suitable for multi-temporal LST analysis (U.S. Geological Survey, 2024a; 2024b), and national land-cover initiatives are advancing annual land-cover and fractional impervious products for improved characterization of development dynamics (MRLC Consortium, 2024).

Accordingly, this study (1) estimates parish-wide temperature differences between urbanized areas and nearby non-urban reference areas using Landsat-derived LST (ΔLST), (2) maps the spatial distribution of thermal penalties and persistent hot spots across EBRP, (3) quantifies relationships between vegetation condition (e.g., NDVI/SAVI), imperviousness proxies, and LST variability, and (4) develops a composite Heat & Degradation Index that combines thermal intensity, impervious surface influence, and vegetation scarcity/change to support practical and equitable prioritization of cooling and land-restoration interventions.

2.0 Study Area Description

East Baton Rouge Parish (EBRP) is located in the Baton Rouge metropolitan region of Louisiana, USA (Figure 1). The parish contains a diverse urban, suburban landscape that includes a compact downtown core, major arterial and interstate corridors that structure regional mobility, and an extensive low-density suburban fringe. This mix of urban forms makes EBRP well suited for examining how development intensity and spatial configuration influence land surface temperature (LST) and surface urban heat island (SUHI) patterns.

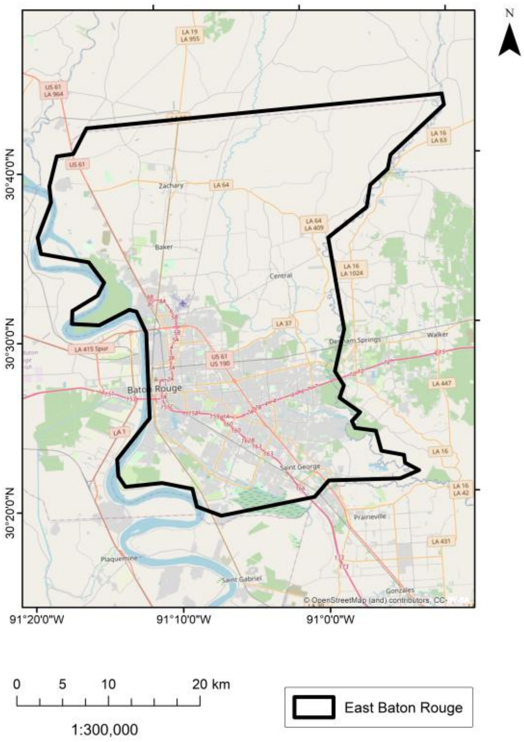

Fig 1. Location and boundary of East Baton Rouge Parish

Heat-relevant land-surface characteristics in EBRP include large parking complexes associated with commercial centers and institutions, wide multi-lane roadways and interchange infrastructure, extensive roof area (often dark, heat-absorbing materials), and heterogeneous residential neighborhoods with uneven street-tree canopy. These features create strong contrasts in surface energy balance, where impervious and built materials tend to store and re-radiate heat while vegetation patches provide localized cooling through shade and evapotranspiration. As a result, thermal “hot spots” are expected to align with highly paved corridors and large impervious footprints, whereas cooler conditions are more likely in well-vegetated neighborhoods and peri-urban areas with higher green cover.

The analysis is conducted at the Landsat-native spatial resolution (30 m) using parish-wide coverage, enabling consistent mapping of LST and related land-surface indicators across EBRP. To support planning and interpretation, pixel-based outputs are summarized to decision-relevant spatial units, including transportation corridors, census tracts, and developing edge/front areas where recent growth is occurring. Because SUHI intensity is typically strongest under warm, clear-sky conditions, the study emphasizes warm-period imagery and seasonal composites derived from quality-screened scenes to reduce cloud contamination and improve comparability across the parish.

3.0 Methods

This study applies a reproducible remote-sensing workflow to quantify urban heat intensity in East Baton Rouge Parish (EBRP) and relate surface temperature patterns to vegetation condition and impervious surface extent. Analyses were conducted at 30 m resolution and summarized to planning-relevant units where appropriate.

3.1 Data Sources

Thermal conditions were characterized using USGS Landsat 8/9 Collection 2 Level-2 Land Surface Temperature (LST) products. Vegetation condition was quantified using the Normalized Difference Vegetation Index (NDVI) derived from Landsat reflectance bands (red and near-infrared). Built-up intensity and surface sealing were represented using the NLCD/MRLC impervious fraction (%). All datasets were harmonized to a common spatial grid and clipped to the EBRP boundary.

3.2 Preprocessing and Quality Masking

Quality assurance steps were implemented to ensure comparability across space and time. For Landsat, pixels flagged as cloud, cloud shadow, or otherwise unreliable were removed using the Collection 2 Level-2 quality information. To reduce scene-to-scene noise and emphasize heat-relevant conditions, warm-period clear-sky composites were created (e.g., median or mean composites over selected warm-season months), producing spatially continuous fields of LST and NDVI across the parish. Impervious fraction data were resampled/aligned to the Landsat grid to support pixelwise integration.

3.3 Derivation of Vegetation and Imperviousness Indicators

Vegetation greenness was computed using NDVI:

$$NDVI = \frac{NIR - Red}{NIR + Red}, \qquad 1$$

where NIR and Red are near-infrared and red reflectance, respectively. NDVI values closer to 1 indicate denser, healthier vegetation, whereas values near 0 or negative typically correspond to built surfaces, bare ground, or water.

Imperviousness was represented as impervious fraction (%) from NLCD/MRLC products, reflecting the proportion of each 30 m pixel covered by impervious surfaces (roads, rooftops, parking). This variable serves as a direct proxy for surface sealing and development intensity.

3.4 Urban and Rural Reference Masks

To compute an interpretable measure of urban heat intensity, urban and rural reference areas were defined using combined thresholds of imperviousness and vegetation. An urban mask was generated by selecting pixels with an impervious fraction ≥ 10%, representing developed and development-influenced surfaces. A rural reference mask was defined using pixels with an impervious fraction < 5% and high vegetation cover (NDVI ≥ 0.5) to represent comparatively green, low-development reference conditions. These thresholds were applied parish-wide and provide a consistent basis for estimating a rural baseline temperature.

3.5 Urban Heat Intensity Metrics

Urban heat intensity was quantified in two complementary ways. First, a parish-wide reference temperature was computed as the mean LST of the rural reference mask. Second, thermal deviation was calculated for each pixel as the difference between pixel LST and the rural mean:

$$\Delta LST = LSTpixel - LSTrural, \qquad 2$$

Positive ΔLST values indicate surfaces warmer than the rural reference baseline, while negative values indicate cooler-than-reference conditions. This formulation provides a spatially explicit SUHI proxy that is comparable across the parish and supports mapping of thermal “penalties” associated with highly impervious, low-vegetation areas.

3.6 Relationship Between LST, Vegetation, and Imperviousness

To quantify how vegetation and imperviousness influence thermal patterns, pixel-wise relationships were evaluated among LST, NDVI, and the impervious fraction. Correlation and regression-based diagnostics were used to assess the direction and strength of associations, with the expectation that LST increases with imperviousness and decreases with higher vegetation greenness.

3.6.1 Correlation analysis

Linear associations were first summarized using the Pearson correlation coefficient between LST and each predictor (NDVI and Impervious fraction):

$$rXY = \frac{\sum_{i=1}^{n}(xi - xo)(yi - yo)}{\sqrt{\sum_{i=1}^{n}(xi - xo)^2}\sqrt{\sum_{i=1}^{n}(yi - yo)^2}}, \qquad 3$$

where xi represents NDVI*i* or Imp*i*, y*i* represents LST*i*, n is the number of valid pixels, and x*o* and y*o* are means.

3.6.2 Regression analysis

To estimate the independent contributions of vegetation and imperviousness to thermal variability, ordinary least squares (OLS) regression models were fitted. The primary multivariate model was:

$$Yi = \beta_0 + \beta_1 Imp_i + \beta_2 NDVI_i + \varepsilon_i, \qquad 4$$

where Yi is LST$_i$ β$_0$ is the intercept, β$_1$ and β$_2$ are regression coefficients, and ε$_i$ is the residual error term. Model performance was summarized using the coefficient of determination:

$$R^2 = 1 - \frac{\Sigma_{i-1}^{n}(y_1 - \boldsymbol{y_2})^{\mathbf{2}}}{\Sigma_{i-1}^{n}(y_1 - \boldsymbol{y_0})^{\mathbf{2}}}, \qquad \mathbf{5}$$

where y$_2$ is the predicted thermal response.

Correlation and regression results were summarized parish-wide and aggregated to key spatial units (e.g., corridors and census tracts) to support planning interpretation.

3.7 Heat and Degradation Priority Index

To translate thermal conditions into an actionable planning indicator, a composite **Heat & Degradation Index (HDI)** was computed by integrating thermal deviation (ΔLST), impervious fraction (Imp), and vegetation scarcity represented by low NDVI. All three components were scaled to a common 0–1 range (min–max normalization within the study area), so they contribute comparably to the index. The HDI increases where surfaces are hotter than the rural baseline, more impervious, and less vegetated, consistent with surface sealing, vegetation loss, and reduced ecosystem cooling function. The index was calculated as:

$$HDI_i = \frac{1}{3}N(\Delta LST_i) + \frac{1}{3}N(Imp_i) + \frac{1}{3}(1 - N(NDVI_i), \qquad 6$$

where N denotes min–max normalization and i indexes pixels. HDI values were then classified into priority categories to delineate intervention zones for heat mitigation and land-restoration actions.

4. Results and Discussion

4.1 Parish-wide UHI intensity and spatial thermal deviation

Warm-period Landsat land surface temperature (LST) composites indicate a pronounced surface urban heat island signal across East Baton Rouge Parish (EBRP). Mean LST within pixels classified as urban (impervious fraction ≥ 10%) was 36.27°C, while the rural reference mask (impervious fraction < 5% and NDVI ≥ 0.5) exhibited a mean LST of 28.26°C (See Table 1).

Group	Mean LST (°C)
Urban	36.27
Rural reference	28.26
ΔLST (Urban − Rural)	8.01 °C

Table 1. Urban Heat Intensity (ΔLST)

To localize where EBRP is hotter or cooler relative to the rural baseline, thermal deviation was computed.

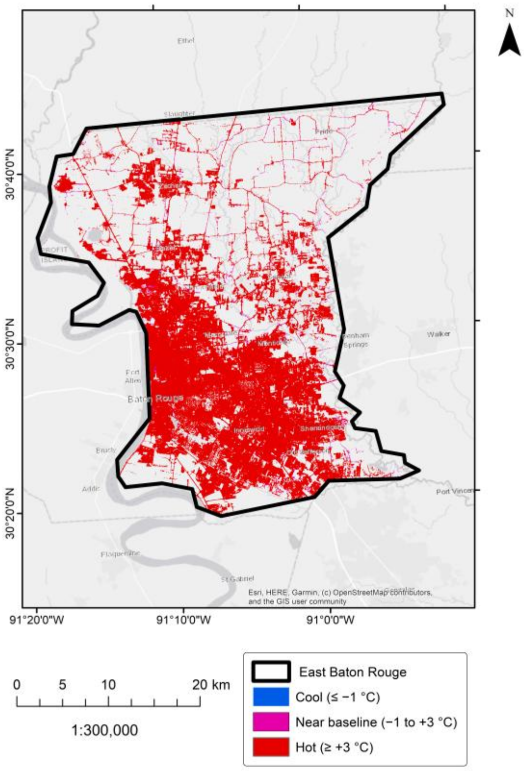

Fig 2. Thermal Deviation in EBRP

Thermal deviation values were grouped into three planning-oriented classes: **cool** (< -1°C), near baseline (−1 to +3 °C), and hot (≥+3°C). The resulting map shows that heat exposure is spatially clustered rather than uniform. Hot-class pixels concentrate across the urbanized core and extend along major arterial corridors and development nodes, forming dense clusters consistent with highly impervious landscapes. Cooler, near-baseline conditions occur predominantly in greener, less developed portions of the parish, reflecting the moderating influence of vegetation and lower surface sealing. Overall, the combined urban–rural contrast and the spatial pattern of thermal deviation indicate a coherent sprawl-related thermal “penalty” in EBRP, with the strongest heat signatures aligning with areas characterized by extensive paved surfaces, dense roof cover, and limited canopy (Voogt & Oke, 2003; Weng, 2009).

4.2 Relationship between LST, vegetation greenness (NDVI), and imperviousness

Pixelwise correlation results show that vegetation greenness is negatively associated with land surface temperature (LST), while imperviousness is positively associated with LST (Figure 3).

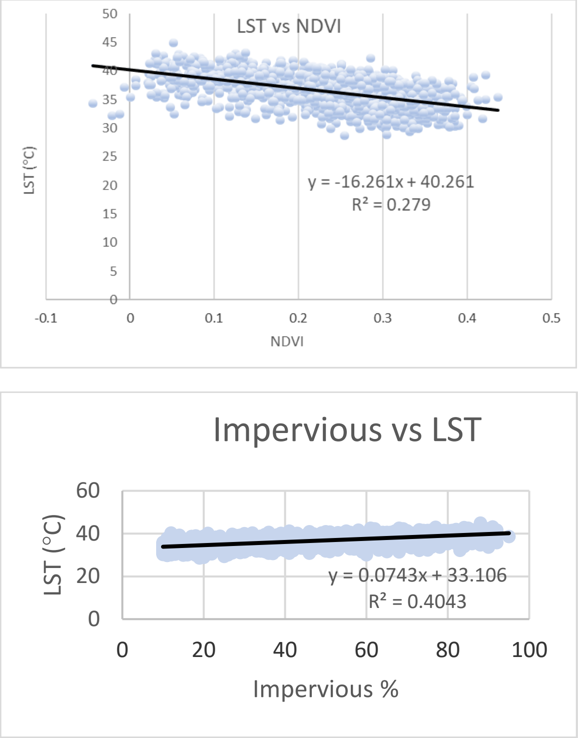

Fig 3. Relationship between LST, Imperviousness and NDVI

The LST–NDVI relationship indicates a clear cooling effect of vegetation: LST decreases by approximately 1.6°C for each 0.10 increase in NDVI (slope ≈ -1.6 °C per 0.10 NDVI), with an $R^2 \approx 0.279$. Conversely, imperviousness exhibits a warming effect: LST increases by approximately 0.74°C for each 10% increase in impervious cover, with $R^2 \approx 0.404$. Together, these results confirm a consistent and spatially coherent coupling between land cover condition and surface heating (across East Baton Rouge Parish, where hotter surfaces are most strongly associated with increased impervious fraction and reduced vegetation greenness.

4.2.1 Joint effects of imperviousness and vegetation on LST

Variables	Coefficients	Standard Error	Lower 95%	Upper 95%	P-value
Intercept (LST)	34.213	0.378	33.471	34.956	0.000
NDVI	-3.022	0.979	-4.944	-1.101	0.002
Impervious	0.065	0.004	0.058	0.073	<0.0001
R Square= 0.409; Significant level p<0.05					

Table 2: Regression of LST, NDVI and Impervious surface

Results indicate that both drivers are statistically significant and operate in the expected directions (Table 2). Imperviousness shows a positive association with LST: +0.66°C per +10% impervious cover (p<0.0001). Vegetation greenness shows a negative association with LST: −0.30°C per +0.10 NDVI (p=0.002). The model explains a substantial portion of LST variability, with $R^2 \approx 0.409$ and adjusted $R^2 \approx 0.41$ based on n=1,422 observations (Table 2).

4.3 Heat & Degradation Index (HDI)

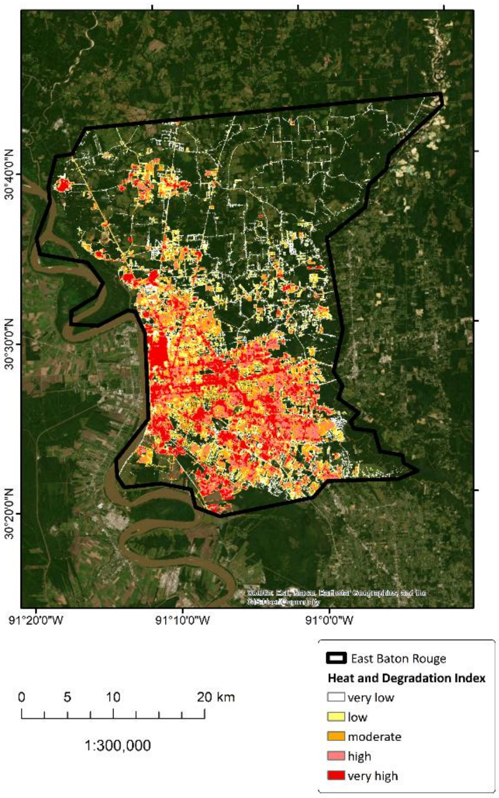

Fig 4. Heat and Degradation Index

The Heat & Degradation Index (HDI) was mapped across East Baton Rouge Parish as a composite indicator, with higher values indicating hotter (higher ΔLST), more impervious, and less vegetated locations. The resulting priority surface shows a strong concentration of high HDI scores within the developed core and along major corridors, consistent with areas characterized by dense impervious cover and limited canopy.

HDI values were classified into five categories (very low, low, moderate, high, very high). Approximately 35.56% of the parish fell within the combined high + very high priority classes, corresponding to about 150.3 km² of land area (Figure 4). The moderate class accounted for 26.59%, while the low + very low areas accounted for 37.85%. Spatially, high-priority pixels form clustered zones through the urbanized center and extend outward along development corridors and nodes, indicating where surface sealing and vegetation scarcity co-occur with elevated thermal deviation.

4.4 Discussion

Results from East Baton Rouge Parish (EBRP) show a pronounced surface urban heat island signal under warm, clear-sky conditions, with an urban–rural contrast of 8.01◦C. This magnitude and the mapped clustering of "hot" thermal deviations are consistent with the established physical basis of urban heating: built and impervious materials increase heat storage and sensible heat flux, while vegetation cools surfaces through shading and evapotranspiration (Oke, 1982; Voogt & Oke, 2003; Weng, 2009).

The statistical relationships reinforce the map-based interpretation. Bivariate fits indicate that LST increases with imperviousness and decreases with greenness, and the multivariate regression confirms that impervious fraction and NDVI remain independently significant predictors of LST. This aligns with broader evidence from U.S.-scale remote-sensing studies showing impervious surface area as a dominant driver of spatial LST variability and with recent multi-city analyses documenting robust cooling efficiencies of vegetation (especially trees) and warming efficiencies of impervious surfaces, often interacting with neighborhood context (Imhoff et al., 2010; Lin et al., 2023).

The Heat & Degradation Index (HDI) operationalizes these coupled drivers into a planning-oriented priority surface by highlighting locations where high thermal deviation, high imperviousness, and low vegetation co-occur. The finding that 35.56% (~150.3 km²) of EBRP falls within the high/very-high HDI classes suggests that sprawl-linked surface sealing and vegetation scarcity represent a widespread, spatially structured priority rather than isolated hotspots. Because the workflow relies on routinely updated Landsat surface temperature products and nationally consistent impervious datasets, it is well suited for repeatable monitoring and for supporting targeted mitigation, such as corridor greening, shaded parking retrofits, cool materials, and permeable redesign, at decision scales (USGS, 2024; MRLC, n.d.; U.S. EPA, n.d.).

Limitations include the use of satellite-derived surface temperature (not air temperature), threshold sensitivity in defining rural/urban masks and deviation classes, and mixed pixels at 30 m resolution in heterogeneous suburban areas. However, thermal remote sensing is widely used for diagnosing SUHI patterns and their links to land cover and urban form, and the consistency of the observed spatial clusters with the regression results indicates that the dominant signals are robust (Voogt & Oke, 2003; Stewart & Oke, 2012).

5. Conclusion

This study quantified the impacts of urban sprawl on surface urban heat intensity in East Baton Rouge Parish (EBRP) using remotely sensed land surface temperature (LST) integrated with vegetation greenness and impervious surface indicators. Results show a strong parish-wide surface urban heat island signal during warm, clear-sky conditions, with a mean urban LST of 36.27°C compared to 28.26°C in the rural reference mask, yielding ΔLST=8.01°C. Thermal deviation mapping further demonstrated that heat exposure is spatially clustered, with persistent hot zones concentrated across the urban core and extending along major corridors and development nodes—patterns consistent with large paved surfaces, dense roof cover, and limited street-tree canopy.

Statistical analyses confirmed the land-cover controls on surface heating. LST decreased with vegetation greenness and increased with impervious cover, and the multivariate regression showed that both drivers remain independently significant predictors of LST (adj. R2≈0.41), indicating that surface sealing and vegetation condition jointly shape neighborhood-scale thermal penalties. Building on these relationships, the Heat & Degradation Index (HDI) translated the thermal signal into a planning-oriented priority surface; 35.56% (~150.3 km²) of EBRP was classified as high or very high priority, identifying locations where high thermal deviation, high imperviousness, and low vegetation co-occur.

The workflow provides a transparent and reproducible method for monitoring sprawl-related heat burdens and prioritizing interventions at decision scales. The findings support targeted cooling and restoration actions, including corridor and street-tree expansion, shaded parking retrofits, cool roofs and pavements, and permeable redesign, especially in high-HDI zones where multiple degradation signals overlap. Because the approach relies on routinely updated, open geospatial products, it can be repeated over time to evaluate whether policies and investments reduce thermal penalties as the parish continues to grow.

6.Acknowledgement

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