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Research Article

Spatiotemporal Analysis Of Urban Land Surface Temperature (Ulst) In Davao City

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ABSTRACT

Urban expansion has significantly altered the spatial configuration of green spaces, intensifying the urban heat island (UHI) effect in rapidly growing cities like Davao City. This study investigated the spatiotemporal dynamics of urban land surface temperature (ULST) from 2015 to 2024 across the city's three congressional districts. Using Landsat 9 satellite imagery and geospatial processing in QGIS, annual land surface temperature (LST) trends were derived and analyzed. Results revealed a consistent increase in both minimum and maximum LST values across all districts, with 2024 recording peak temperatures nearing or exceeding 38°C. The most pronounced warming occurred in District I, particularly in highly urbanized barangays such as 1-A, 7-A, and 11-B. Spatial analysis confirmed that densely built-up, vegetation-deficient zones exhibited the highest thermal intensities, while greener, less developed areas maintained cooler surface temperatures. These findings demonstrate the strong inverse relationship between vegetation cover and surface temperature and underscore the ecological implications of urban land use change. Aligned with the Sustainable Development Goals (SDGs), this study calls for the urgent integration of green infrastructure, climate-adaptive planning, and ecological restoration into the city's development agenda. This research contributes critical empirical data to support sustainable urban strategies and enhance climate resilience in Davao City.

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INTRODUCTION

As urbanization continues to accelerate, it is projected that around 68% of the global population will be living in urban areas (United Nations, 2018). This shift contributes to the decline and loss of urban green spaces, posing a significant challenge, particularly in developing countries (Baker et al., 2018). The fragmentation and deterioration of these spaces result in various socioeconomic and environmental issues, including habitat loss, disruption of urban ecosystems, and reduced biodiversity (Betts et al., 2019). Furthermore, it intensifies the urban heat island effect and disrupts the microclimate within urban environments (Rahaman et al., 2021). On a global scale, the rapid urban expansion observed in developing nations over recent decades has often been accompanied by substantial land use and land cover (LULC) changes (Guo et al., 2022), which can impact local and regional climates by altering surface energy dynamics and water balances (Han et al., 2020; Gou et al., 2019).

Rising temperatures have become an increasing concern for urban ecosystems, especially in heavily populated and industrialized areas (Mekonnen et al., 2020). The process of urbanization significantly contributes to higher land surface temperatures, which in turn affects residents' health, productivity, and the overall urban ecological balance (Degefu et al., 2021; Deilami et al., 2018). Vulnerable populations particularly the elderly and economically disadvantaged are most at risk from these temperature increases (Wang et al., 2021). In 2023, Davao City experienced a heat index between 36°C and 56°C (Daugdaug, 2023), levels that exceed the normal range and fall under the "extreme caution" category (Edge Davao, 2023).

This study aligned with the United Nations Sustainable Development Goals (SDGs), specifically Goal 3 (Good Health and Well-Being), Goal 11 (Sustainable Cities and Communities), Goal 13 (Climate Action), and Goal 15 (Life on Land). It offers important insights into the environmental consequences of urbanization and emphasizes the critical role of preserving and enhancing green spaces to mitigate the negative impacts of urban heat. The results can serve as a valuable reference for policymakers, urban planners, and environmental advocates in formulating strategies for sustainable urban development in Davao City.

Due to ongoing industrialization and urbanization in Davao City, the extent of green spaces continues to diminish (Palma, 2019). Despite this trend, there is a lack of comparative research examining the dynamics of land surface temperature across the city's three congressional districts. This gap underscores the need for the present study. The primary objective is to analyze the spatial and temporal changes of land surface temperature in Davao City from 2015 to 2024. Specifically, the study aims to: (i) examine the trends and patterns of urban land surface temperature (ULST) in the urban barangays within the three (3) congressional districts from 2015 to 2024; and (ii) compare

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the changes of land surface temperature among the urban barangays in the same years. The study was anchored in the theory of Uneven Development by Marxist scholars (Smith & Harvey, 1990).

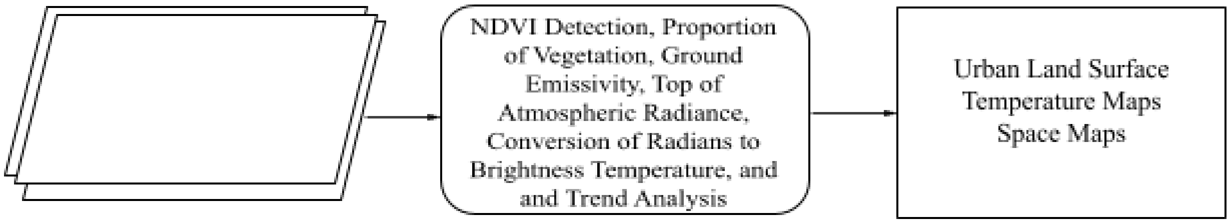

Figure 1. Conceptual Framework of the Study

MATERIALS AND METHODS

This study employed a descriptive, quantitative, non-experimental research design. The research was conducted in Davao City, located at 7.207573°N latitude and 125.395874°E longitude (7° 12' 27.2628'' North, 125° 23' 45.1464'' East). Davao City, situated on the island of Mindanao, is classified as a first-class highly urbanized city. The city is composed of three congressional districts, which are further subdivided into 11 administrative districts, encompassing a total of 182 barangays. This study concentrated on the urban barangays across the three districts. The 92 urban barangays, District 1 comprises 52, District 2 has 25, and District 3 includes 15. For data collection, the researchers used satellite imagery from Landsat 9 and processed it through Quantum Geographic Information System (QGIS) software to generate visual maps. A series of calculations were performed in the analysis of land surface temperature, including the computation of Top-of-Atmosphere Spectral Radiance, Brightness Temperature, Normalized Difference Vegetation Index (NDVI), Proportion of Vegetation, and Emissivity. These calculations and analyses were conducted using QGIS software.

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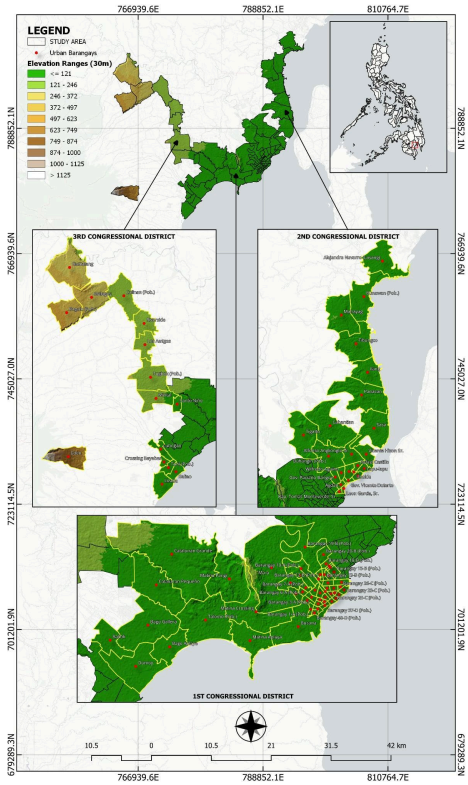

Figure 2. Map Showing the Location of the Study

RESULTS AND DISCUSSION

Dynamics of Urban Land Surface Temperature (ULST) in the Urban Barangays of Davao City from 2015-2024

Land Surface Temperature (LST) is a critical parameter representing the temperature of the Earth's land surfaces as observed from satellite sensors or in situ ground measurements. Studying LST is essential due to its pivotal role in numerous environmental, climatic, and urban planning applications. In urban environments, LST is used to analyze the Urban Heat Island (UHI) effect, where cities often record significantly higher temperatures than their rural surroundings, affecting energy consumption, public health, and urban sustainability (Saha et al., 2024).

Table 1 displays the annual minimum and maximum land surface temperatures (LST) across Davao City's urban barangays from 2015 to 2024, revealing notable fluctuations influenced by urbanization, land use change, and climate variability. Minimum LST ranged from 9.891°C in 2018 to 19.548°C in 2024,

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while maximum LST varied between 28.949°C and 38.406°C in the same years. The low temperatures in 2018 likely stemmed from increased rainfall or reduced solar radiation (Smith et al., 2020), while the extreme highs in 2024 suggest intensified urban heat island (UHI) effects and global warming (Jones & Wang, 2022). From 2019 to 2024, minimum LST steadily increased, indicating reduced nighttime cooling due to expanding built-up areas and vegetation loss (Zhao et al., 2014). Maximum LST peaked in 2024, pointing to intensified daytime heating linked to rapid development and green space decline (Gómez-Baggethun & Barton, 2013). A temperature dip in 2022 may reflect short-term climatic influences like La Niña (NOAA, 2022). These patterns underscore growing thermal stress in the city.

Table 1

Minimum and Maximum Annual Land Surface Temperature of Urban Barangays in Davao City from 2015-2024

Year	Land Surface Temperature (℃)	
	Minimum	Maximum
2015	11.189	35.386
2016	14.528	30.384
2017	14.154	32.429
2018	9.891	28.949
2019	17.399	33.037
2020	16.988	35.011
2021	17.605	33.344
2022	10.083	33.142
2023	15.928	33.426
2024	19.548	38.406

Figure 3 shows a clear rise in Land Surface Temperature (LST) in Davao City from 2015 to 2024. Minimum LST increased from about 11.19°C to 19.55°C, while maximum LST rose sharply from 35.39°C to nearly 38.41°C. A dip in 2018, likely due to La Niña's cooler, wetter conditions, was followed by a steady increase linked to urban expansion and loss of green spaces. Urbanization intensifies the Urban Heat Island effect as built environments retain more heat than natural areas (Li et al., 2022). Construction, vegetation loss, and higher energy use in Davao reflect regional trends in Southeast Asia (Rizwan et al., 2008). Climate change further amplifies these impacts by increasing heatwaves and altering rainfall patterns (IPCC, 2023). The 2024 temperature peak may also result from reduced tree cover, which helps cool surfaces through evapotranspiration (Gill et al., 2022). These findings highlight the urgent need for urban planning that boosts green spaces, uses reflective materials, and promotes climate-resilient infrastructure to reduce thermal stress.

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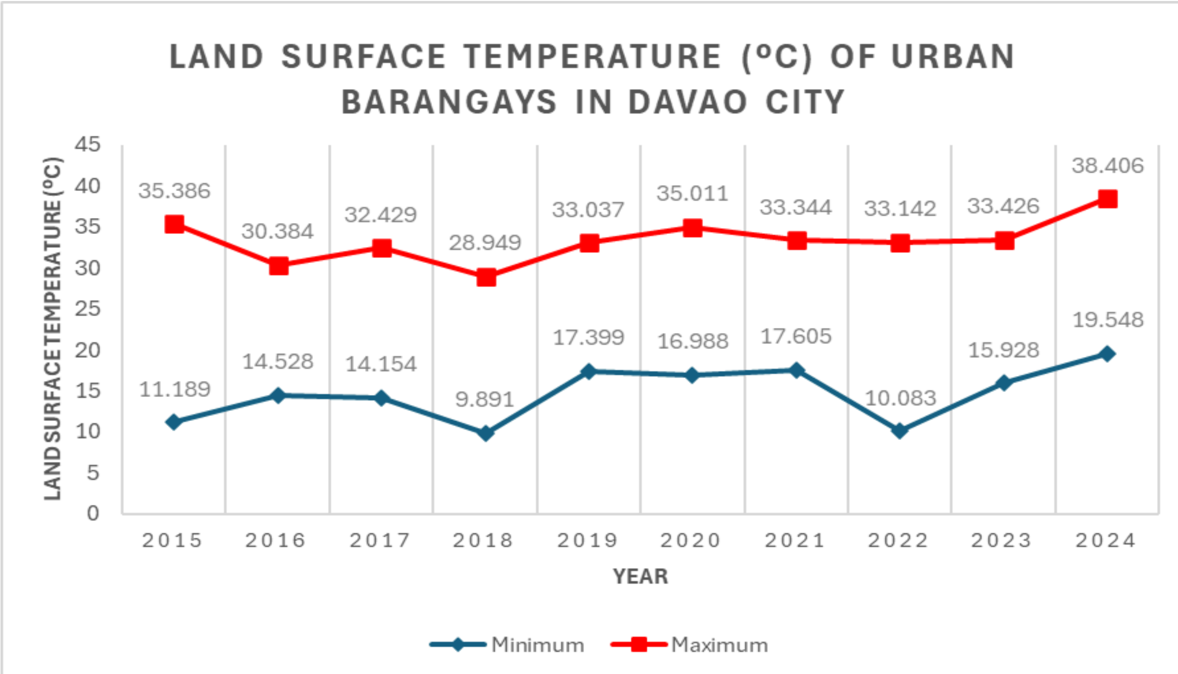

Figure 3. Trend Graph showing the Minimum and Maximum Annual Land Surface Temperature of Urban Barangays in Davao City

Spatiotemporal analysis of Land Surface Temperature (LST) in Davao City from 2015 to 2024 shows a clear warming trend, especially in central and lowland areas. High-temperature zones above 30°C expanded, peaking in 2024 due to urbanization and loss of vegetation, intensifying the Urban Heat Island (UHI) effect. A brief cooling during the 2020–2021 lockdowns reversed with resumed activity. This trend aligns with studies linking land cover change to urban warming. Rising temperatures pose risks to health and infrastructure. Mitigation requires urgent policies promoting urban greening, reflective materials, and climate-resilient planning (Li et al., 2023; Kumar et al., 2024).

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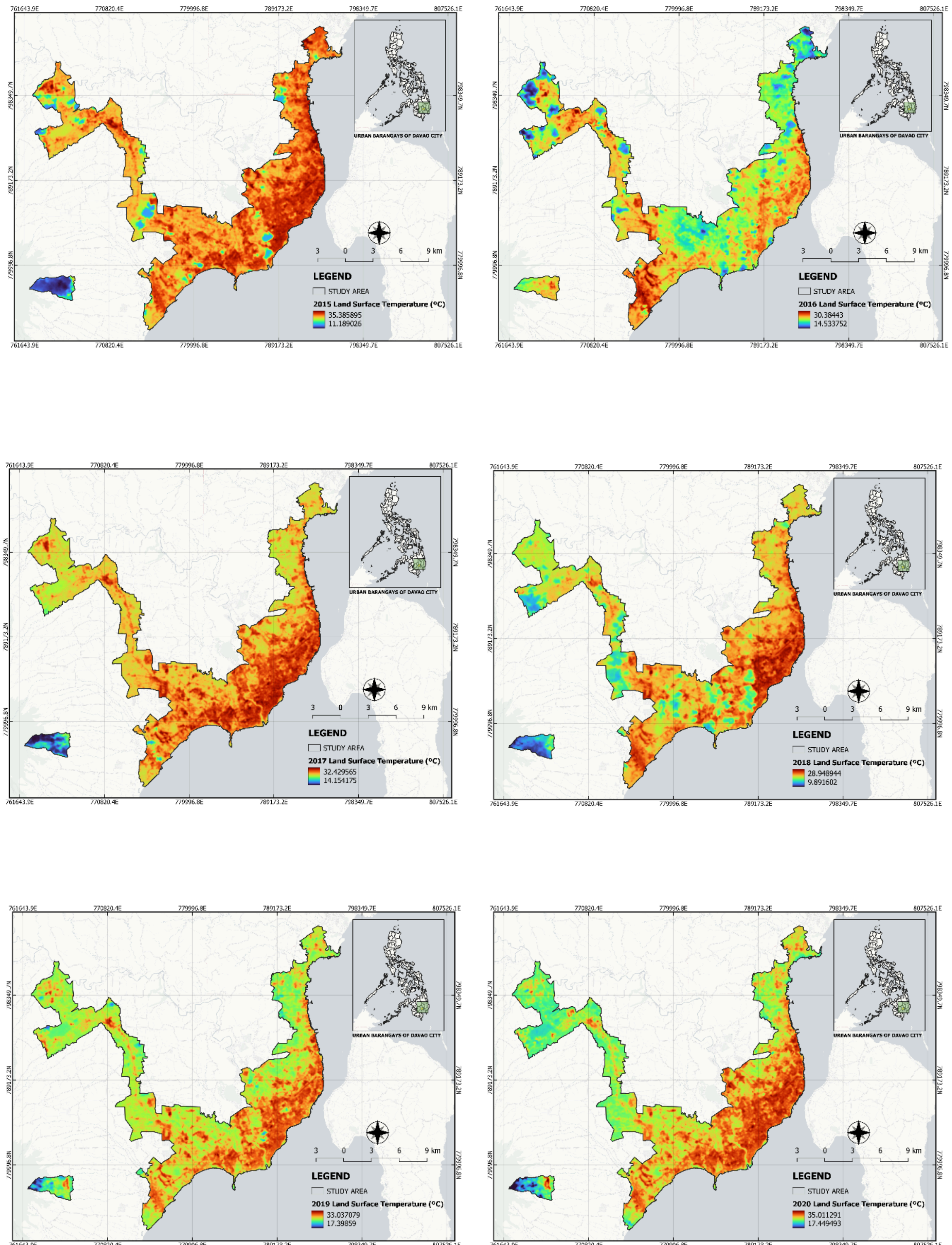

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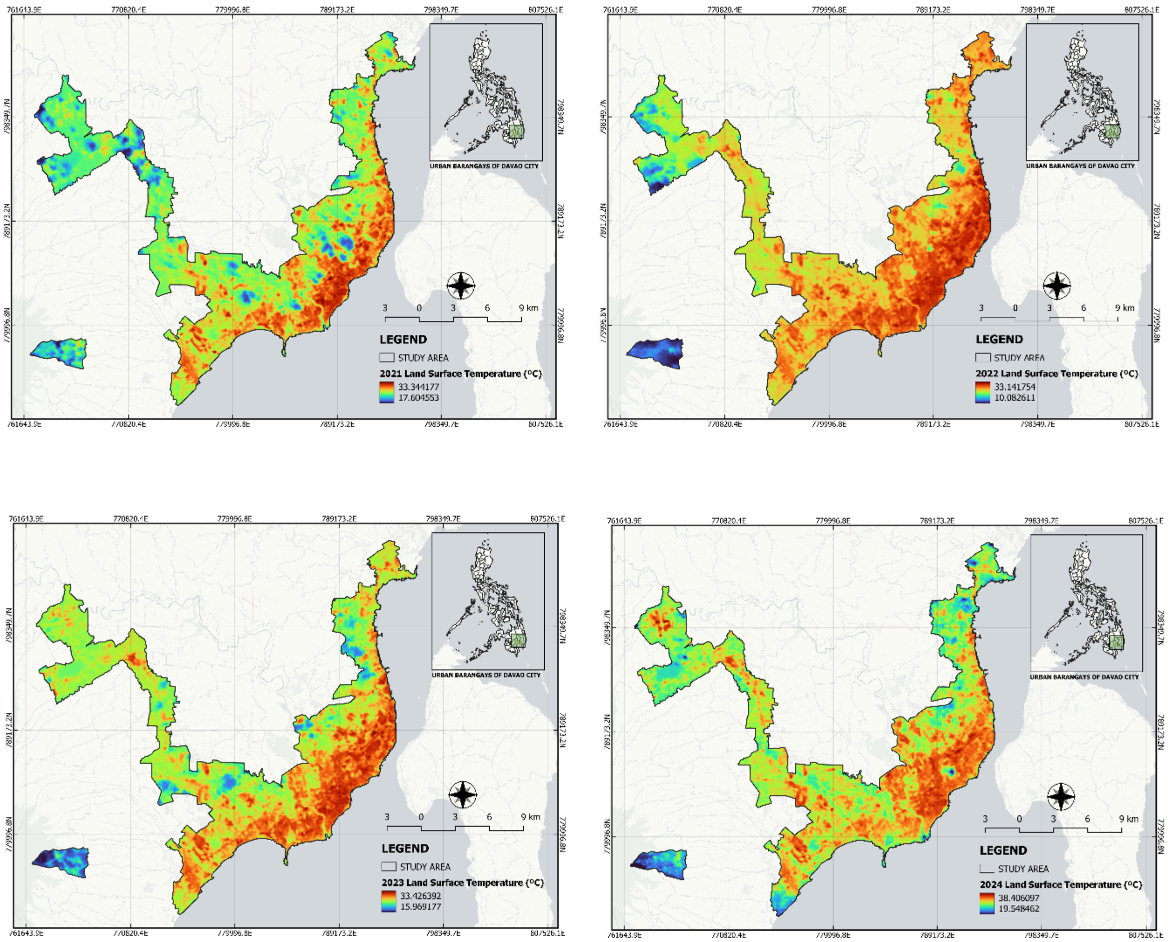

Figure 4. Urban Land Surface Temperature (ULST) Maps in Urban Barangays in Davao City from 2015-2024

By analyzing the areas with constant increase in land surface temperature, the data revealed that all of the top 10 urban barangays with the highest land surface temperature (LST) from 2015 to 2024 are located within the 1st Congressional District of Davao City. Barangay 1-A ranks highest, followed by Barangays 7-A, 11-B, and 2-A. The concentration of high-LST barangays within a single district suggests a notable spatial pattern of urban heat distribution, which may be attributed to higher levels of built-up areas, reduced vegetation cover, dense population, and intensive commercial and industrial activities commonly found in central urban zones.

This trend reflects the urban heat island (UHI) effect, where the modification of natural land surfaces and the presence of

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impervious materials such as concrete and asphalt lead to increased surface temperatures. The dominance of 1st District barangays in the top 10 ranking underscores the urgency to implement green infrastructure, enhance urban green spaces, and adopt climate-adaptive urban planning in the city's core districts. Mitigation efforts in these areas are crucial not only for environmental sustainability but also for protecting public health, particularly among vulnerable populations exposed to prolonged heat stress.

Table 2

Top 10 Urban Barangays in Davao City with highest Land Surface Temperature (LST) from 2015 to 2024

Rank	Barangay	Congressional District
1	Barangay 1-A	1st
2	Barangay 7-A	1st
3	Barangay 11-B	1st
4	Barangay 2-A	1st
5	Barangay 3-A	1st
6	Barangay 6-A	1st
7	Barangay 10-A	1st
8	Barangay 4-A	1st
9	Barangay 9-A	1st
10	Barangay 12-B	1st

Comparison on the Changes in Urban Land Surface Temperature (ULST) among the Urban Barangays Across the Three (3) Congressional Districts in Davao City

Congressional District I from 2015 to 2024

As shown in Table 3 and Figure 5 below, the analysis of land surface temperature (LST) data from 2015 to 2024 in Congressional District I revealed a notable warming trend, particularly in the minimum temperatures. The lowest minimum temperature was recorded in 2018 at 13.94°C, while the highest occurred in 2020 at 23.72°C, indicating a significant rise that may reflect localized climate shifts or intensified urban heat island effects. The average minimum temperature across the decade suggests a gradual warming trend, with the most recent year, 2024, recording 21.65°C—substantially higher than early-decade values such as 16.06°C in 2015.

Maximum LSTs also demonstrate variability, peaking at 38.03°C in 2024, the highest value of the ten-year period. This progression aligns with broader global climate patterns,

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where increasing urbanization and land cover changes contribute to elevated surface temperatures (Zhou et al., 2016). The concurrent rise in both minimum and maximum temperatures may have implications for public health, agriculture, and infrastructure planning in the region. These findings emphasize the importance of sustained LST monitoring to inform adaptive climate resilience strategies (Li et al., 2020).

Table 3

Minimum and Maximum Annual Land Surface Temperature Congressional District I from 2015 to 2024

Year	Land Surface Temperature (℃)	
	Minimum	Maximum
2015	16.06	36.17
2016	15.20	30.95
2017	20.71	33.45
2018	13.94	29.45
2019	20.41	33.48
2020	23.72	36.11
2021	18.77	35.35
2022	19.26	32.83
2023	18.35	33.20
2024	21.65	38.03

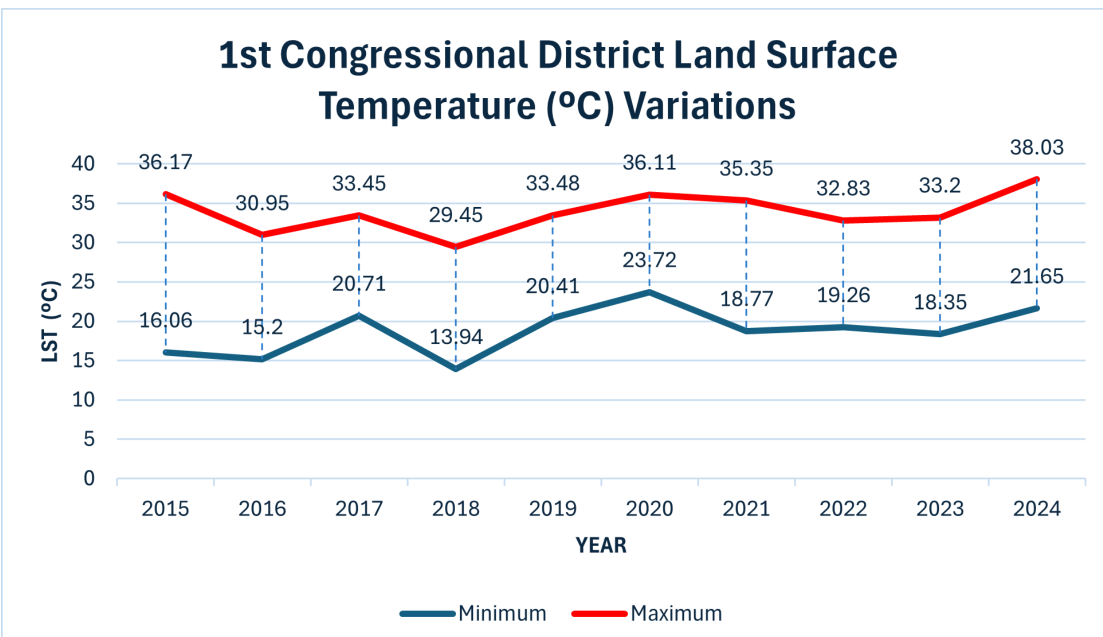

Figure 5. Trend Graph showing the Minimum and Maximum Annual Land Surface Temperature of Congressional District I in Davao City

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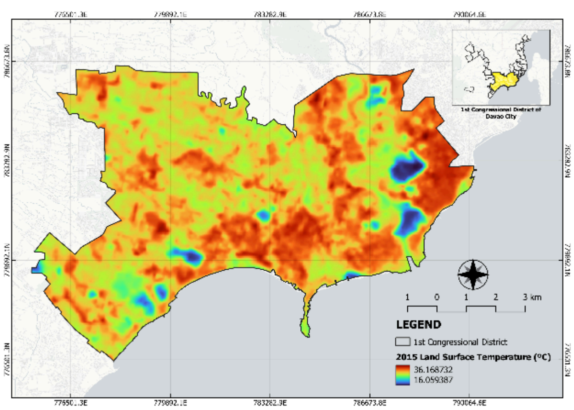
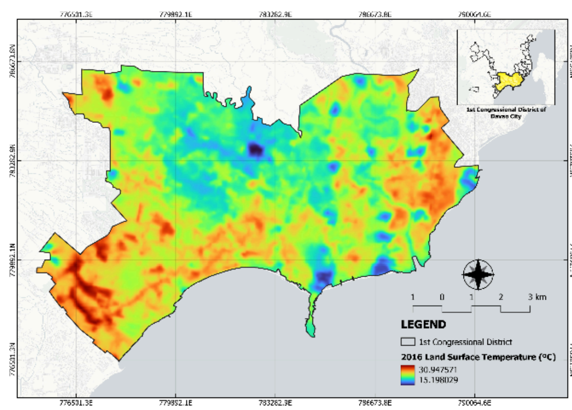
By analyzing the spatiotemporal patterns of Urban Land Surface Temperature (ULST) in the 1st Congressional District, the maps below revealed that areas with higher LST values represented by red hue are primarily concentrated in built-up zones. This spatial clustering highlights the presence of the Urban Heat Island (UHI) effect, which is largely driven by impervious surfaces such as concrete and asphalt, high infrastructure density, and limited vegetation cover. These features reduce the natural cooling capacity of the urban landscape. Recent research supports this observation, noting that urban expansion in tropical and coastal cities intensifies the UHI phenomenon by increasing impervious land cover and decreasing green space (Pal & Ziaul, 2021). In contrast, cooler areas indicated by green and blue hues are typically found in regions with dense vegetation and bodies of water.





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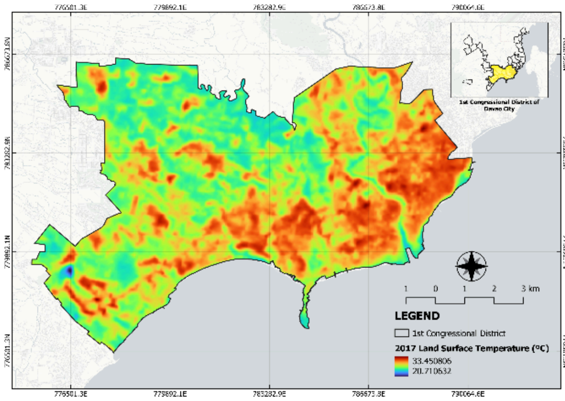

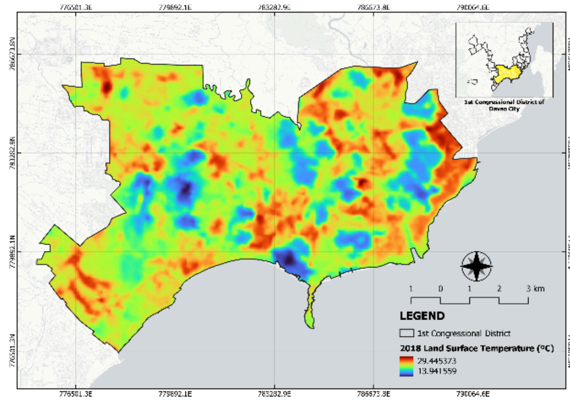

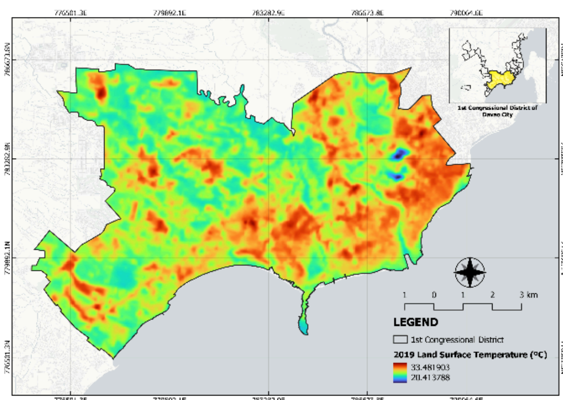

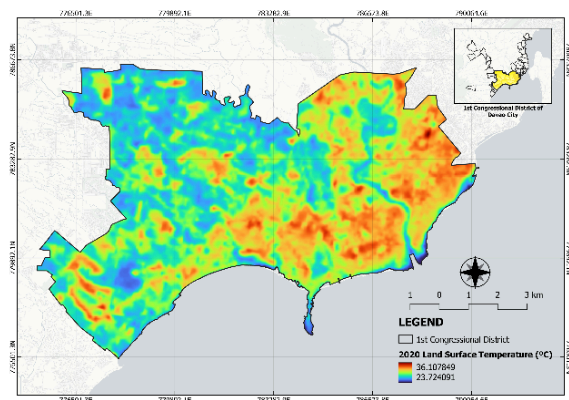

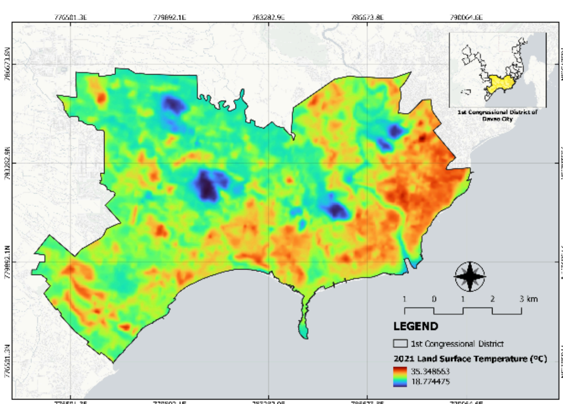

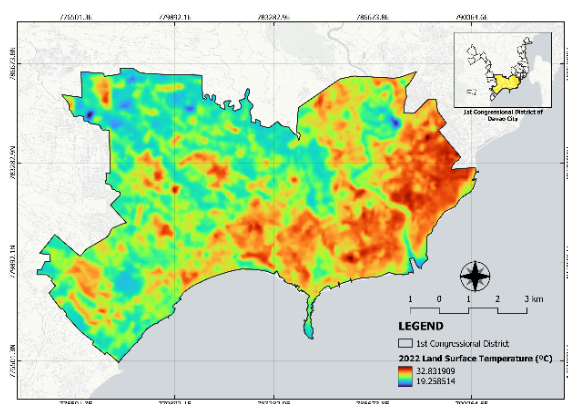

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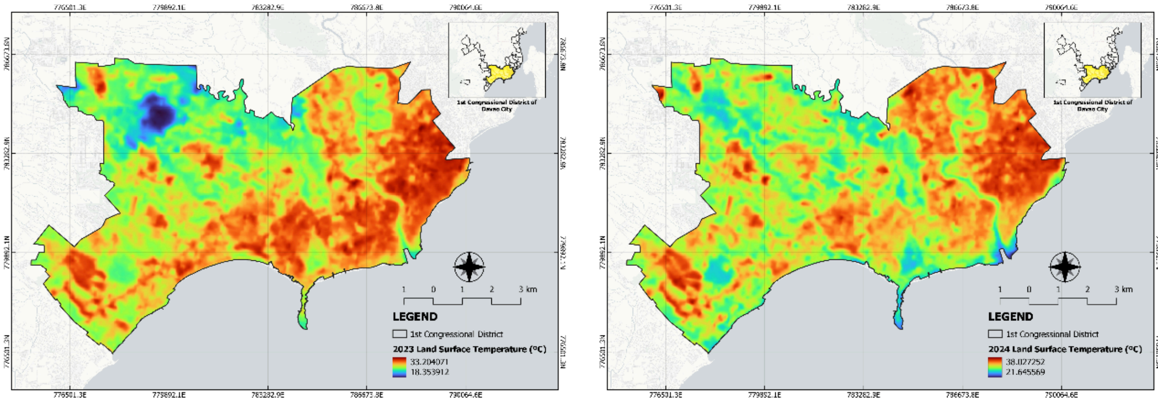

Figure 6. Urban Land Surface Temperature (ULST) Maps of Congressional District I from 2015 to 2024

Congressional District II from 2015 to 2024

The land surface temperature (LST) in Congressional District II from 2015 to 2024 showed notable fluctuations in minimum temperatures, ranging from 14.76°C in 2016 to a peak of 23.57°C in 2017, as shown in Table 4 and Figure 7. These irregularities may result from changes in land cover, urban expansion, or hydrological shifts affecting surface heat dynamics (Zhou et al., 2019). In contrast, maximum LSTs remained consistently high, peaking in 2015 (38.69°C) and again in 2024 (38.16°C), indicating persistent thermal stress likely driven by anthropogenic land use and climate variability. These patterns are consistent with studies linking urbanization and reduced vegetation to increased surface warming due to altered albedo and energy balance (Peng et al., 2021). The resurgence of high maximum temperatures by 2024 highlights rising heat exposure risks in urban and peri-urban areas. These trends stress the importance of climate-resilient urban planning and continuous environmental monitoring.

Table 4

Minimum and Maximum Annual Land Surface Temperature in Congressional District II from 2015 to 2024

Year	Land Surface Temperature (℃)	
	Minimum	Maximum
2015	16.09	38.69
2016	14.76	30.53
2017	23.57	32.83

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2018	17.03	29.30
2019	21.49	32.44
2020	21.44	35.47
2021	18.77	33.05
2022	16.97	33.22
2023	18.24	33.44
2024	18.49	38.16

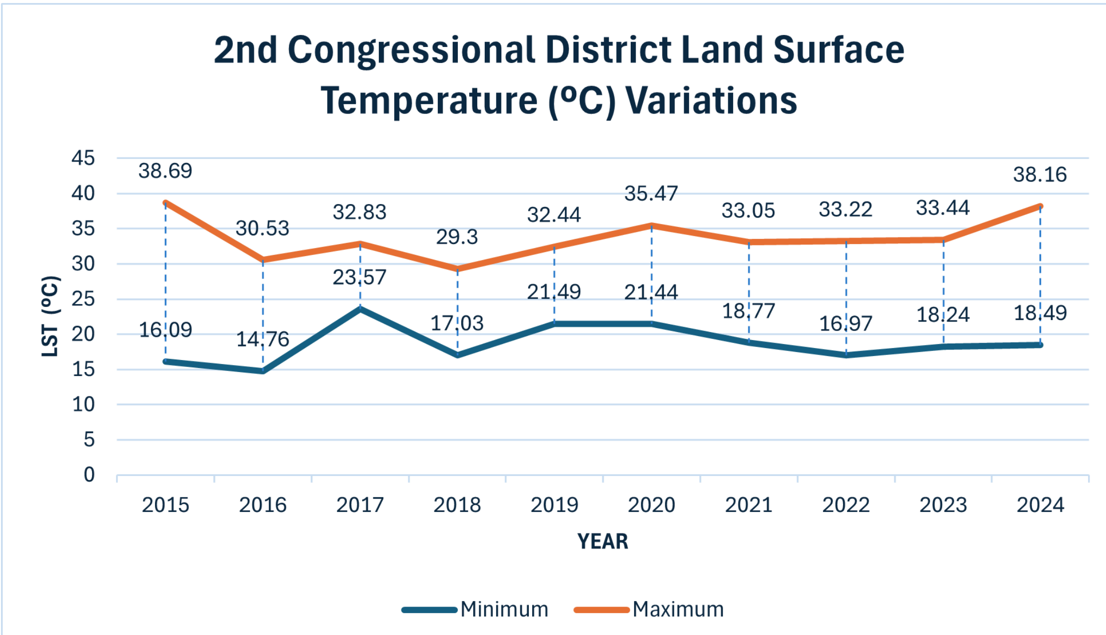

Figure 7. Trend Graph showing the Minimum and Maximum Annual Land Surface Temperature of Congressional District II in Davao City

Similar findings emerged from the spatiotemporal analysis of Urban Land Surface Temperature (ULST) in Congressional District II of Davao City. The LST maps reveal a consistent trend of rising temperatures, particularly in the southern and central portions of the district, which are primarily characterized by urban and agricultural land uses. These areas demonstrate a pronounced Urban Heat Island (UHI) effect, driven by the proliferation of impervious surfaces and the decline of vegetation cover (Pal & Ziaul, 2021). In contrast, cooler temperatures remain in less developed, vegetated zones. Notably, the years 2023 and 2024 exhibit intensified heat patterns, indicating the cumulative impacts of rapid urbanization and ongoing climate change (Huang et al., 2021; Sun et al., 2022). These observed patterns emphasize the urgent need to implement climate-resilient urban planning strategies and to integrate green infrastructure in order to mitigate the adverse thermal impacts and

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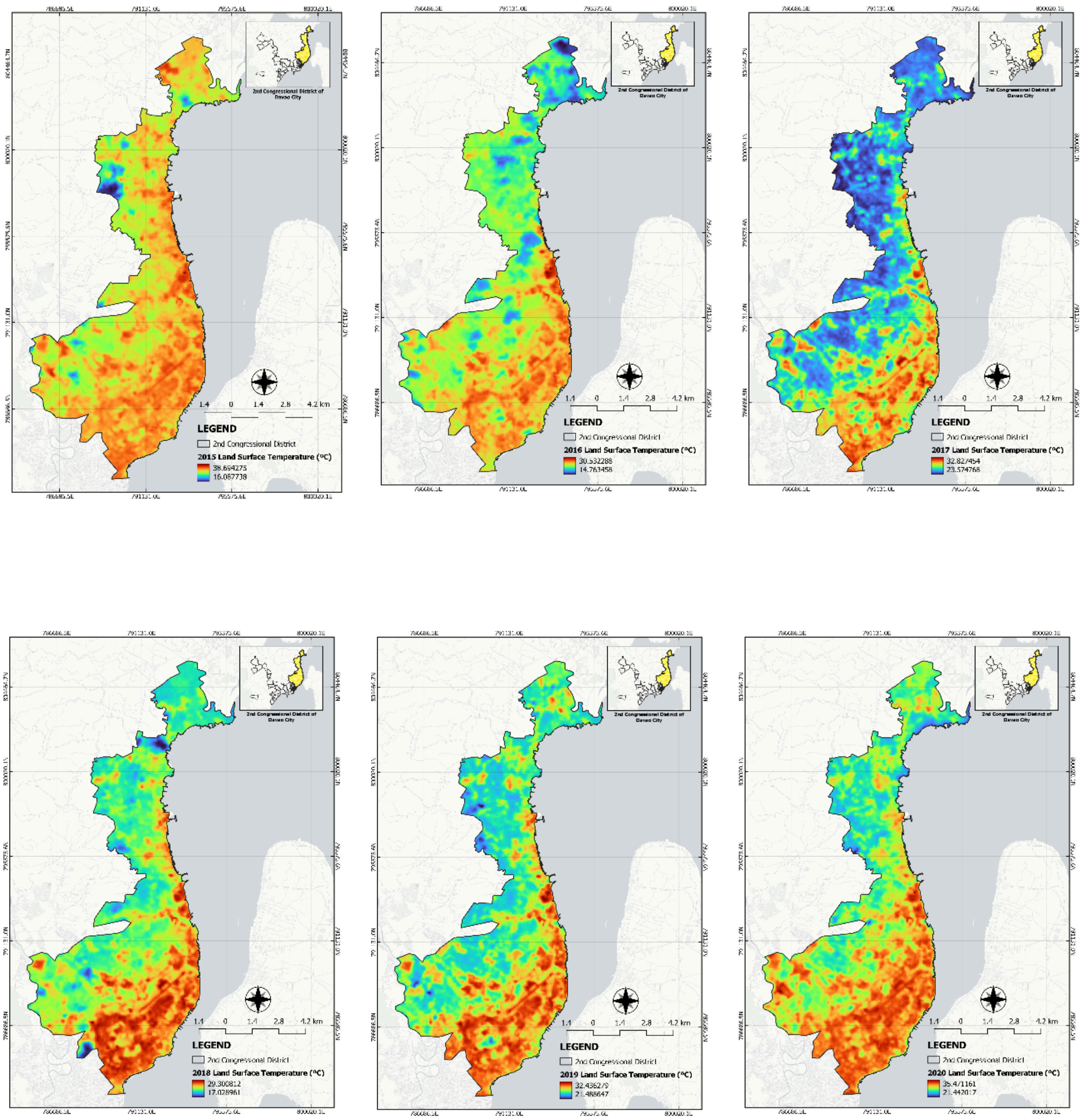
promote environmental sustainability within the district.



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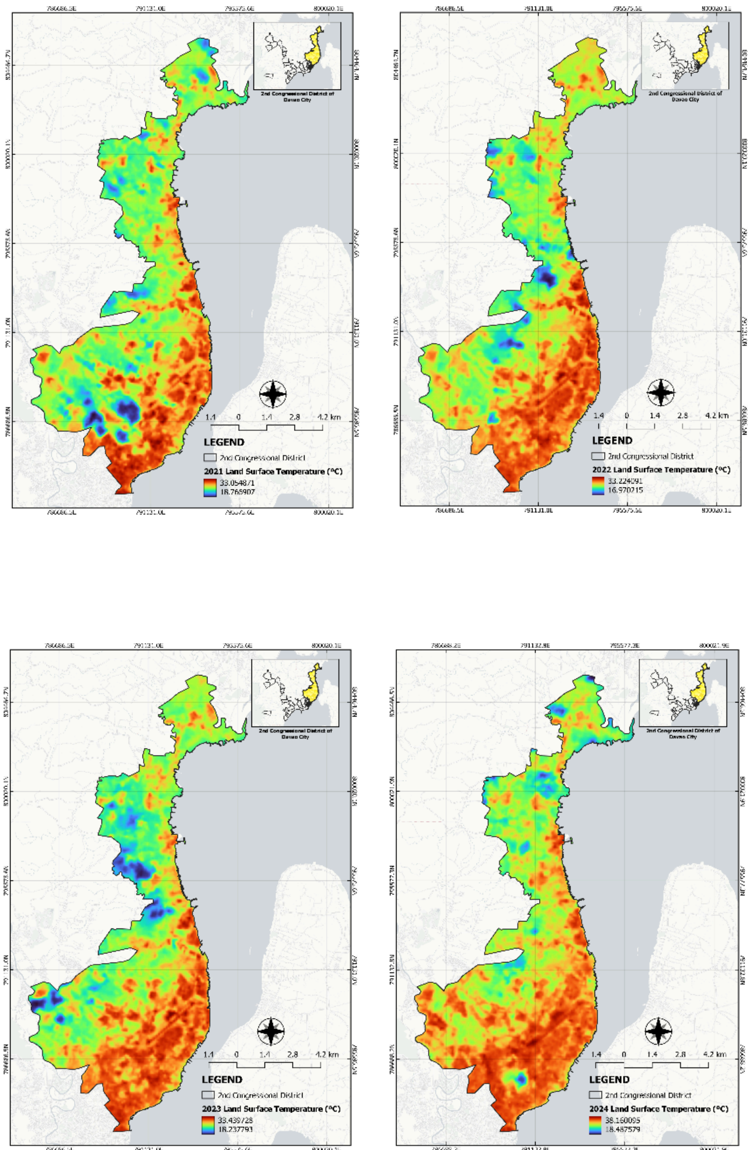

Figure 8. Urban Land Surface Temperature (ULST) Maps of Congressional District II from 2015 to 2024

Congressional District III from 2015 to 2024

Table 5 and Figure 9 present the minimum and maximum annual land surface temperatures (LST) recorded in District III from 2015 to 2024. Over the recent five-year period (2020–2024), both minimum and maximum LST values exhibit a noticeable upward trend, signaling intensified surface warming. The minimum LST rose from 14.64 °C in 2020 to 18.54 °C in 2024, suggesting decreased nighttime cooling and increased heat retention in built-up areas (Li et al., 2020). Simultaneously, the maximum LST increased from 32.75 °C to 38.41 °C,

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reflecting a growing urban heat island (UHI) effect, consistent with trends in developing cities (Zhou et al., 2021). The spike in 2024, which recorded the highest maximum LST of the decade, highlights the combined impact of urban expansion, land cover change, and greenhouse gas emissions (Sun et al., 2022). These patterns align with satellite-based projections for Southeast Asia and underscore the urgency for climate-resilient urban planning and sustained LST monitoring.

Table 5
Minimum and Maximum Annual Land Surface Temperature in District III from 2015 to 2024

Year	Land Surface Temperature (℃)	
	Minimum	Maximum
2015	11.54	35.39
2016	14.35	29.66
2017	15.70	31.97
2018	10.77	27.52
2019	17.44	31.23
2020	14.64	32.75
2021	17.42	30.63
2022	11.11	28.88
2023	16.40	30.95
2024	18.54	38.41

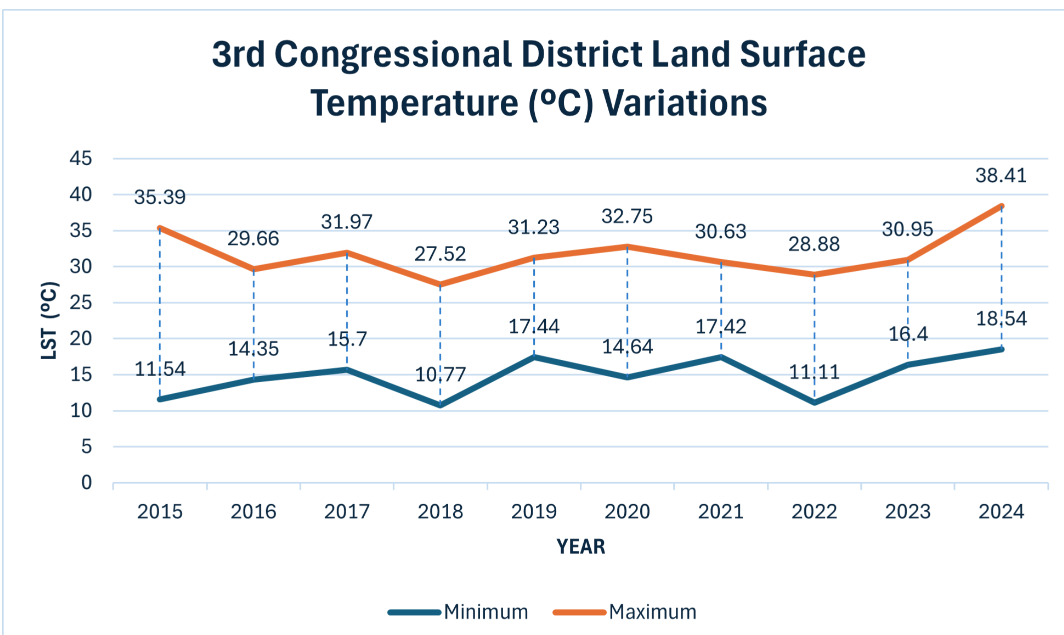

Figure 9. Trend Graph showing the Minimum and Maximum Annual Land Surface Temperature of Congressional District III in Davao City

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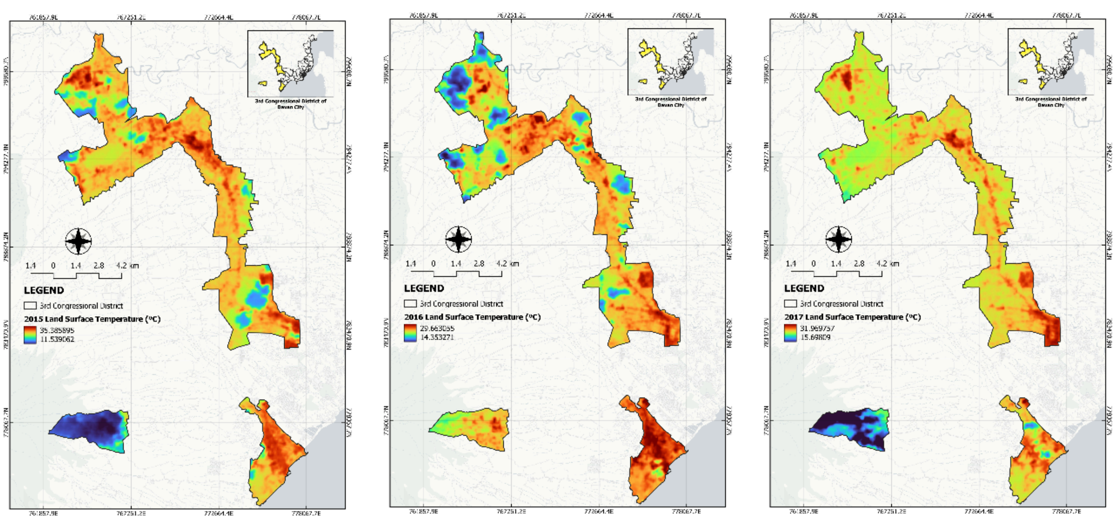
The Land Surface Temperature (LST) maps for Congressional District III from 2015 to 2024 reveal distinct spatial and temporal patterns that reflect the intensifying effects of urban heat. Warmer surface temperatures, indicated by orange to red hues, are predominantly concentrated in the southern and southeastern parts of the district. These areas are characterized by dense urban development, limited vegetation cover, and a high proportion of impervious surfaces such as concrete and asphalt. In contrast, cooler zones which depicted by green to blue hues, are mainly found in the less developed or more vegetated central and northern portions of the district. These spatial patterns align with existing research that links rapid urban expansion and loss of green cover to elevated LST in tropical and coastal cities (Pal & Ziaul, 2021; Zhou et al., 2021).

Temporally, there is a clear warming trend, particularly evident in the years 2023 and 2024, marked by an expansion and intensification of heat-affected areas. This escalation can be attributed to ongoing land conversion, reduced evapotranspiration from vegetation loss, and broader climate variability. The findings are consistent with regional climate projections forecasting increased urban heat under continued environmental stress. These trends underscore the urgent need for climate-responsive urban planning, including the integration of green infrastructure and sustainable land management strategies (Huang et al., 2021; Sun et al., 2022).



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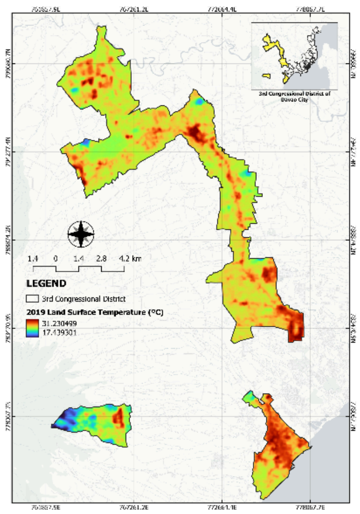

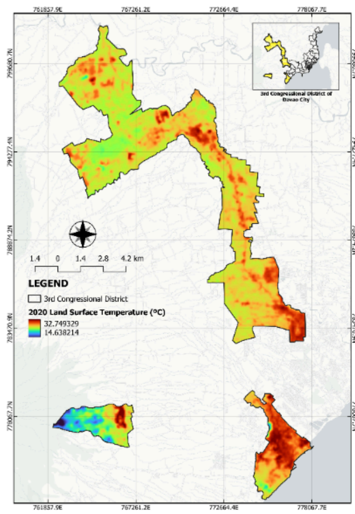

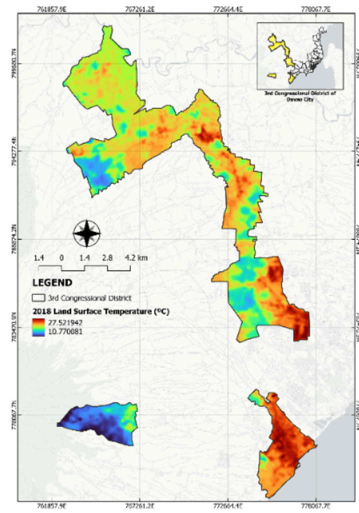

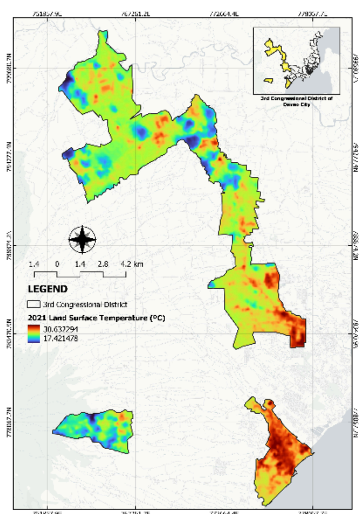

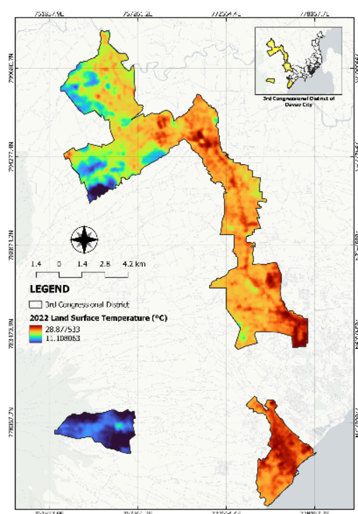

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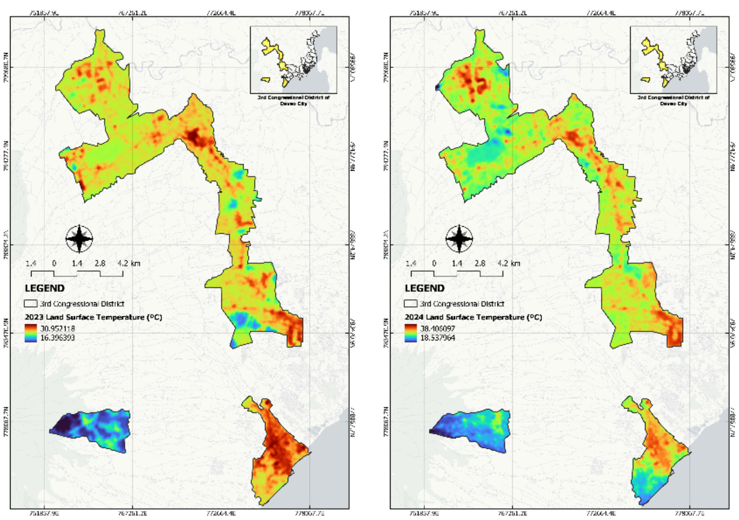

Figure 10. Urban Land Surface Temperature (ULST) Maps of Congressional District III from 2015 to 2024

In comparison, the analysis of Land Surface Temperature (LST) data from 2015 to 2024 across the 1st, 2nd, and 3rd Districts revealed a clear warming trend in all regions. The 1st District exhibited a steady increase in both minimum and maximum temperatures, with the maximum reaching 38.03°C in 2024 and the minimum rising to 21.65°C. The 2nd District consistently recorded the highest maximum temperatures for most of the years, peaking at 38.16°C in 2024, and showed significant fluctuations in minimum temperatures, with a notable spike to 23.57°C in 2017. The 3rd District, initially the coolest of the three with a minimum of 10.77°C in 2018 and a maximum of 27.52°C the same year, experienced a sharp rise in both measures, culminating in the highest maximum temperature of 38.41°C in 2024. By 2024, all three districts demonstrated minimum temperatures above 18°C and maximums near or above 38°C, indicating a strong and consistent warming trend over the decade. These findings suggest increasing urban heat effects or broader climate shifts across all districts, necessitating attention for environmental planning and adaptation strategies.

CONCLUSION AND RECOMMENDATION

Thereupon, the decade-long analysis of Land Surface Temperature (LST) data from 2015 to 2024 across the 1st, 2nd, and 3rd Districts highlights a pronounced and consistent warming trend. All three districts recorded substantial increases in both minimum and maximum temperatures, with 2024 marking peak values nearing or exceeding 38°C. This trend poses serious implications for urban

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livability, public health, energy demand, and climate resilience. Spatial analysis further reveals that coastal and lowland barangays are most vulnerable to heat intensification, particularly the District I.

Based on the findings, several strategic recommendations are put forward. Firstly, integrating green infrastructure into urban planning is essential. This involves setting mandatory green space requirements for new developments, encouraging the use of vertical gardens, green roofs, and tree-lined streets, and incorporating LST evaluations into land use planning and project approvals. Secondly, reforestation and ecological restoration efforts should be prioritized, particularly in Districts I and II. Community-led greening initiatives must be supported, and efforts should be made to reconnect fragmented green corridors to strengthen biodiversity and ecological networks. Thirdly, land use policies need to be revised and rigorously implemented. The Comprehensive Land Use Plan (CLUP) should adopt climate-adaptive guidelines, limiting development in environmentally sensitive areas such as coastal zones. Penalties for illegal land clearing should be balanced with incentives for environmentally responsible, green-certified developments. Finally, it is critical to invest in heat-resilient infrastructure. This includes utilizing reflective building materials, expanding shaded public areas, and developing urban parks to function as cooling spaces. Collectively, these measures aim to reduce the urban heat island effect, protect vital ecosystem services, and support the long-term sustainability and livability of Davao City.

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