CONSTRUCTION
E-ISSN: 2785-8731
VOLUME 5, ISSUE 1, 2025, 113 - 122
DOI: https://doi.org/10.15282/construction.v5i1.12110

RESEARCH ARTICLE

Urbanization and Land Surface Temperature in Kuantan: A Geographic Information Systems-Based Analysis of Urban Heat Island Dynamics

Z. Wenxin[1,2], S. Misbari[2]*, S. I. Doh[2]

[1]Baotou Railway Vocational & Technical College,014060 Inner Mongolia, China

[2]Faculty of Civil Engineering Technology, Universiti Malaysia Pahang Al-Sultan Abdullah, Lebuh Persiaran Tun Khalil Yaakob, 26300 Kuantan, Pahang, Malaysia

ABSTRACT - Rapid urbanization and industrial development in Kuantan, Malaysia, have significantly contributed to the intensification of the Urban Heat Island effect. In Kuantan, the urban heat island (UHI) effect has led to increased surface temperatures, especially in densely built areas, contributing to higher energy consumption for cooling. The loss of green spaces due to rapid urban expansion and industrial activities has further intensified heat retention, worsening thermal discomfort for residents. This study investigates the spatial and temporal dynamics of UHI in Kuantan using Landsat satellite images and Geographic Information System techniques. Land Surface Temperature (LST) data and the Normalized Difference Vegetation Index (NDVI) were analyzed to evaluate the relationship between urban expansion, vegetation cover, and surface temperature over a decade. The findings revealed a notable increase in UHI intensity, with urbanized areas experiencing higher LST compared to vegetated zones. Between 2005 and 2024, the Urban Heat Island Intensity (UHII) in Kuantan increased by approximately 5°C. Areas with reduced vegetation cover, such as industrial and commercial zones, demonstrated heightened heat accumulation, while green spaces effectively mitigated urban heat. These results underscore the critical importance of integrating green infrastructure into urban planning to address the challenges posed by UHI. The study provides actionable insights for sustainable urban development strategies in tropical cities like Kuantan.

ARTICLE HISTORY

Received	:	04th Mar. 2025
Revised	:	29th Apr. 2025
Accepted	:	24th May 2025
Published	:	10th June 2025

KEYWORDS

Urbanization
Heat island
Land surface
Geographic information system

1. INTRODUCTION

Kuantan City has undergone significant landscape and environmental transformations due to rapid industrialization and urban expansion [1]. As the largest city on the east coast of Peninsular Malaysia, Kuantan plays a pivotal role in the economic development of the region. Its strategic location, coupled with the proliferation of industrial projects, has brought about unprecedented economic growth. However, this rapid progress has also led to notable environmental changes, including the intensification of urban heat islands (UHI). This phenomenon, marked by elevated temperatures in urbanized areas compared to surrounding rural regions, has become a pressing concern, particularly in industrial zones where land-use changes are most pronounced [2]. Urban expansion leads to an increase in high-temperature areas, and the spatiotemporal variation of Land Surface Temperature (LST) is closely related to the distribution of built-up areas [3].

The urban heat island effect in Kuantan is primarily driven by the extensive replacement of natural vegetation with impervious surfaces such as concrete, asphalt, and industrial facilities [4]. The increase in impervious surfaces leads to a rise in land surface temperature [5]. Additionally, changes in vegetation can alter the spatial temperature balance [6]. These alterations not only increase the absorption and retention of heat but also disrupt local microclimates. The issue is further exacerbated by the region's tropical climate, which is characterized by high temperatures and humidity throughout the year. Industrial activities, such as those associated with bauxite mining and processing, contribute significantly to these changes. The removal of vegetation, exposure of soil, and construction of heat-absorbing structures intensify local temperature anomalies, leading to heightened heat stress for residents and ecosystems alike [7].

Most existing research focuses on large metropolitan areas, often overlooking smaller yet rapidly developing cities like Kuantan. This lack of attention is concerning, given the unique environmental and socio-economic contexts of such cities. Studies have shown that during heatwaves in the Sydney area, the nighttime urban heat island intensity increases by approximately 4˚C [8]. In particular, Kuantan’s rapid industrialization and urbanization create a distinctive landscape where the interplay between land-use changes and thermal characteristics demands detailed investigation. The implications of UHI extend beyond mere temperature increases. Elevated urban temperatures exacerbate energy consumption, particularly for cooling purposes, thereby increasing greenhouse gas emissions and intensifying global warming. Moreover, higher temperatures can negatively affect public health, increasing the risk of heat-related illnesses, especially among vulnerable populations. The environmental consequences are equally significant, with altered thermal conditions impacting biodiversity, water cycles, and overall ecosystem services. For Kuantan, where industrial zones are

***CORRESPONDING AUTHOR | S. Misbari** | ✉ syarifuddinm@umpsa.edu.my

expanding at a rapid pace, understanding and addressing the UHI phenomenon is not only critical for environmental sustainability but also for ensuring the well-being of its population.

This study seeks to address these challenges by leveraging advanced technologies and analytical methods. Satellite data, which provides comprehensive and high-resolution information on land surface temperatures and land-use patterns, offers a valuable tool for understanding UHI dynamics [9]. Combined with machine learning techniques, these data can be used to identify patterns, predict temperature variations, and model the impacts of different land-use scenarios [10]. Such an approach allows for a nuanced understanding of how industrialization influences local temperatures and provides a robust basis for developing targeted mitigation strategies. The study's objectives are twofold. Firstly, it aims to quantify the impact of industrialization on UHI formation in Kuantan by analyzing spatial and temporal variations in land surface temperatures. This involves examining the relationship between industrial activities, vegetation cover, and thermal characteristics to identify key drivers of heat anomalies. Subsequently, the research seeks to propose actionable mitigation strategies tailored to industrial zones. These strategies may include the incorporation of green infrastructure, such as urban forests and green roofs, as well as the adoption of reflective building materials and improved urban planning practices [11].

Rapid industrialization and urban expansion in Kuantan have brought about significant environmental challenges, with the intensification of urban heat islands being among the most pressing. This research seeks to fill the existing gaps in understanding and addressing UHI in the context of a rapidly industrializing city. By leveraging satellite data and machine learning techniques, the study not only advances the scientific understanding of UHI dynamics but also provides practical solutions for mitigating heat impacts [12]. Ultimately, the research aims to contribute to the sustainable development of Kuantan, ensuring that its economic growth is achieved without compromising environmental and social well-being.

2. MATERIALS AND METHOD

2.1 Study Area

Kuantan (Latitude: 3.8140° N, Longitude: 103.3260° E) is a prominent city located on the east coast of Peninsular Malaysia, within the state of Pahang, as illustrated in Figure 1. Positioned along the South China Sea, Kuantan experiences a tropical climate characterized by substantial rainfall year-round, with the monsoon season (November to February) bringing particularly intense downpours. The city sits at an average elevation of approximately 19 meters (62 feet) above sea level and is home to an estimated population of around 500,000, making it the largest urban center on Peninsular Malaysia's east coast. Kuantan is experiencing rapid industrialization, fueled by large-scale projects and urban expansion. Among these, the bauxite mining industry has notably transformed the local landscape. The conversion of natural vegetation into industrial facilities and concrete structures has exacerbated heat retention, contributing to the formation of UHI. These changes underscore the complex relationship between industrial growth and environmental challenges in the region.

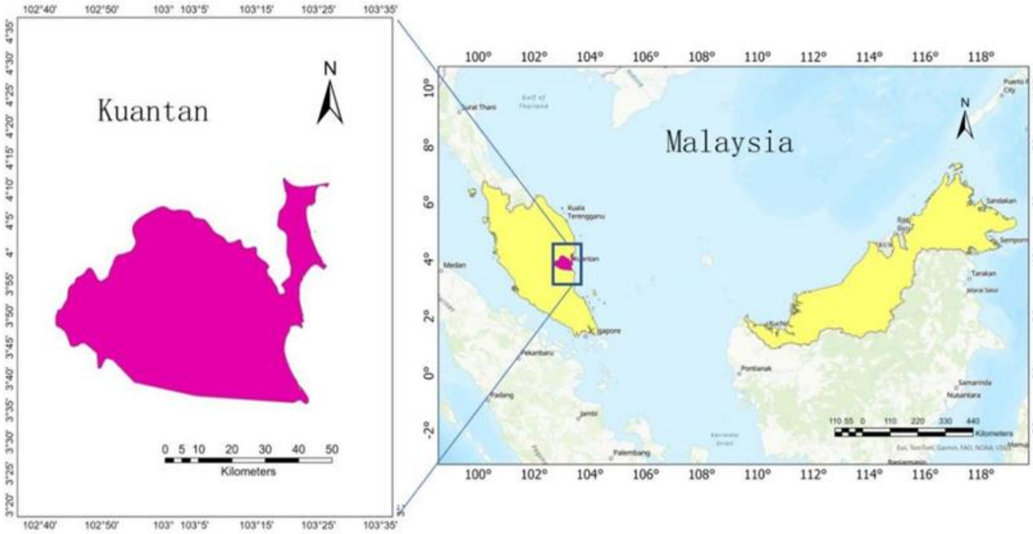

Figure 1. The map of Kuantan

2.2 Landsat Land Surface Temperature Products

Landsat imagery offers a significant advantage for UHI studies due to its suitable spatial resolution, providing 30-meter resolution for its multispectral bands and 100-meter resolution for thermal bands. The multispectral bands allow for detailed spectral analysis of urban features, while the thermal bands facilitate direct measurement of surface temperature variations across different land cover types [13]. In this study, Landsat images were acquired during the period 2005-2024 to ensure a comprehensive analysis of temporal changes. Preference was also given to images captured under sunny conditions to maintain consistency in surface heating patterns, thereby enhancing the reliability of the analysis. By focusing on the clearest and most representative imagery, this approach ensures that the data accurately reflect the thermal and spectral characteristics of Kuantan's urban landscape over time. The long temporal coverage of Landsat data enables the identification of trends and patterns in Land Use and Land Cover (LULC) and UHI development [14]. Table 1 shows three scene's ID of remote sensing data that have been used in this study. This is especially relevant for rapidly urbanizing cities like Kuantan, where industrial activities and urban expansion have significantly altered the landscape. By integrating high-resolution spatial data with robust analytical techniques, this study provides critical insights into the dynamics of urban heat islands and the associated environmental and socio-economic impacts, laying the groundwork for effective mitigation strategies.

Table 1. Specifications of remote sensing data

Scene ID (Landsat)	Path/ Row
LE07L1TP126057200503162020091402 T1	126/57
LE07L1TP126057201508192020090302T1	126/57
LC08 L1TP 26057202402092024021302T1	126/57

2.3 Landsat Land Surface Temperature Products

In this study, satellite images of the LANDSAT series of terrestrial satellites were used to retrieve surface temperature [15]. These satellites are well-suited for UHI research, given their capability to capture fine-scale spatial and temporal variations in surface temperatures [16]. To ensure the accuracy and reliability of the results, a comprehensive data preprocessing workflow was implemented, encompassing multiple critical steps. Radiometric correction is the first step in preprocessing, aiming to convert raw digital numbers (DNs) recorded by the satellite sensors into radiance or reflectance values. This process corrects for sensor-specific calibration errors and ensures the consistency of data across multiple scenes and time periods [17]. Following this, atmospheric correction is applied to remove the effects of atmospheric interference, such as water vapor, aerosols, and other gases, which can distort the radiometric measurements. This step is essential for accurately capturing the thermal and spectral characteristics of the Earth's surface [18]. Resampling techniques are employed to standardize the spatial resolution of the data, ensuring compatibility between the thermal and multispectral bands and facilitating subsequent analysis. These preprocessing steps collectively enhance the quality and usability of Landsat data, making them suitable for accurate LST retrieval [19]. By addressing sensor, atmospheric, and spatial inconsistencies, this workflow establishes a robust foundation for analyzing UHI dynamics in Kuantan, enabling the identification of key factors contributing to temperature variations and providing actionable insights for mitigation strategies. Employment of statistical methods to establish correlations between LULC transformations and LST changes [20], as shown in Figure 2.

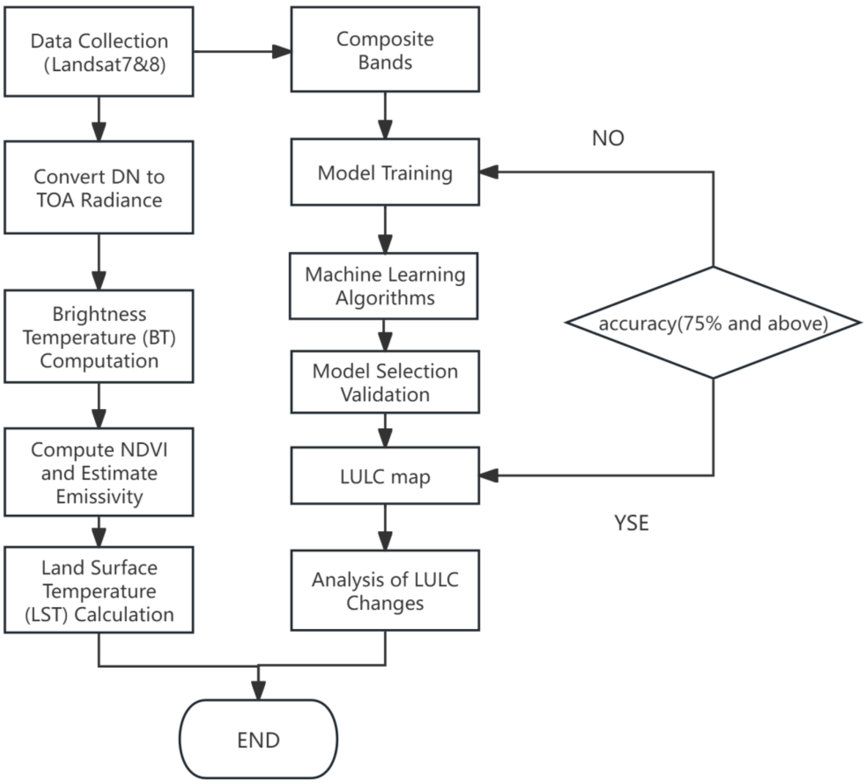

Figure 2. Flowchart of the study

The method of retrieving land surface temperature using NDVI is based on the relationship between vegetation cover and surface thermal radiation. The core concept involves extracting the Normalized Difference Vegetation Index (NDVI) from remote sensing data to estimate land surface emissivity, which is then combined with brightness temperature (BT) from the thermal infrared band for correction to obtain a more accurate LST. This method is widely applied in urban heat island research. The first step is to acquire remote sensing imagery, with commonly used data sources including the Landsat series [21]. These images typically contain multiple spectral bands, including visible, near-infrared, and thermal infrared bands. After acquiring the images, preprocessing steps such as radiometric calibration, atmospheric correction, and geometric correction are required to ensure data accuracy and eliminate atmospheric scattering and transmission effects, thereby improving the precision of subsequent calculations. Once image preprocessing is completed, NDVI can be calculated using the near-infrared and red bands. NDVI reflects the vegetation coverage of the land surface, with values typically ranging from -1 to 1. Positive values indicate high vegetation cover, while negative or near-zero values correspond to bare land, water bodies, or non-vegetated surfaces.

Since vegetation cover significantly affects surface thermal radiation properties, NDVI can be used to estimate land surface emissivity. Emissivity refers to the ability of a surface to emit radiation relative to an ideal black body, with values generally ranging from 0 to 1. Different land cover types have varying emissivity values; for example, vegetated areas typically have higher emissivity, while bare land and buildings have lower emissivity. By using NDVI and empirical models, a relationship between the Fractional Vegetation Cover (FVC) and land surface emissivity can be established to further estimate emissivity [22]. Based on the estimated emissivity, brightness temperature (BT) can be extracted from the thermal infrared band. After performing atmospheric correction, LST can be derived by combining emissivity and brightness temperature through the radiative transfer equation. The accuracy of this method mainly depends on the precision of emissivity estimation, the effectiveness of atmospheric correction, and the resolution and measurement accuracy of the sensor. Table 2 shows five different threshold ranges of accuracy standard based on results of processed satellite images.

Table 2. Accuracy standard

No.	Common thresholds	Vote
1	$0.81 \leq \kappa \leq 1.00$	Almost perfect agreement
2	$0.61 \leq \kappa \leq 0.800.61$	Substantial agreement
3	$0.41 \leq \kappa \leq 0.600.41$	Moderate agreement
4	$0.21 \leq \kappa \leq 0.400.21$	Fair agreement
5	$0.00 \leq \kappa \leq 0.200.00$	Slight agreement

3. RESULTS AND DISCUSSION

3.1 Normalized Difference Vegetation Index

The NDVI data from Kuantan, Malaysia, reveals notable vegetation changes between 2005 and 2015, as shown in Figure 3. The maximum NDVI declined from 0.696629 (moderate-to-dense vegetation) in 2005 to 0.507692 in 2015, indicating reduced green cover, likely due to deforestation, urban expansion, or land degradation. The minimum NDVI also dropped further into negative values (-0.477273 to -0.592105), suggesting increased non-vegetated areas like urban surfaces or bare soil. This shift implies weaker ecosystem health, with potential drivers including rapid urbanization, agricultural intensification, or climatic stressors. The shrinking vegetation range may lead to higher urban heat effects and reduced biodiversity. To mitigate further decline, sustainable land-use policies and green infrastructure development should be prioritized.

3.2 Land Surface Temperature Map

Kuantan, a coastal city in Malaysia, experiences a tropical climate with temperatures typically ranging from 12°C to 33°C. Using Landsat satellite data, LST changes were analysed for 2005, 2015, 2024. The results (Figure 4) show no significant change in the city’s overall temperature range, indicating stable regional climatic conditions over the years. However, localized changes in high-temperature areas were observed, particularly in the eastern part of the city. The extent of these high-temperature zones has noticeably increased, pointing to rapid urbanization, including the expansion of impervious surfaces like buildings and roads, which retain heat and elevate surface temperatures.

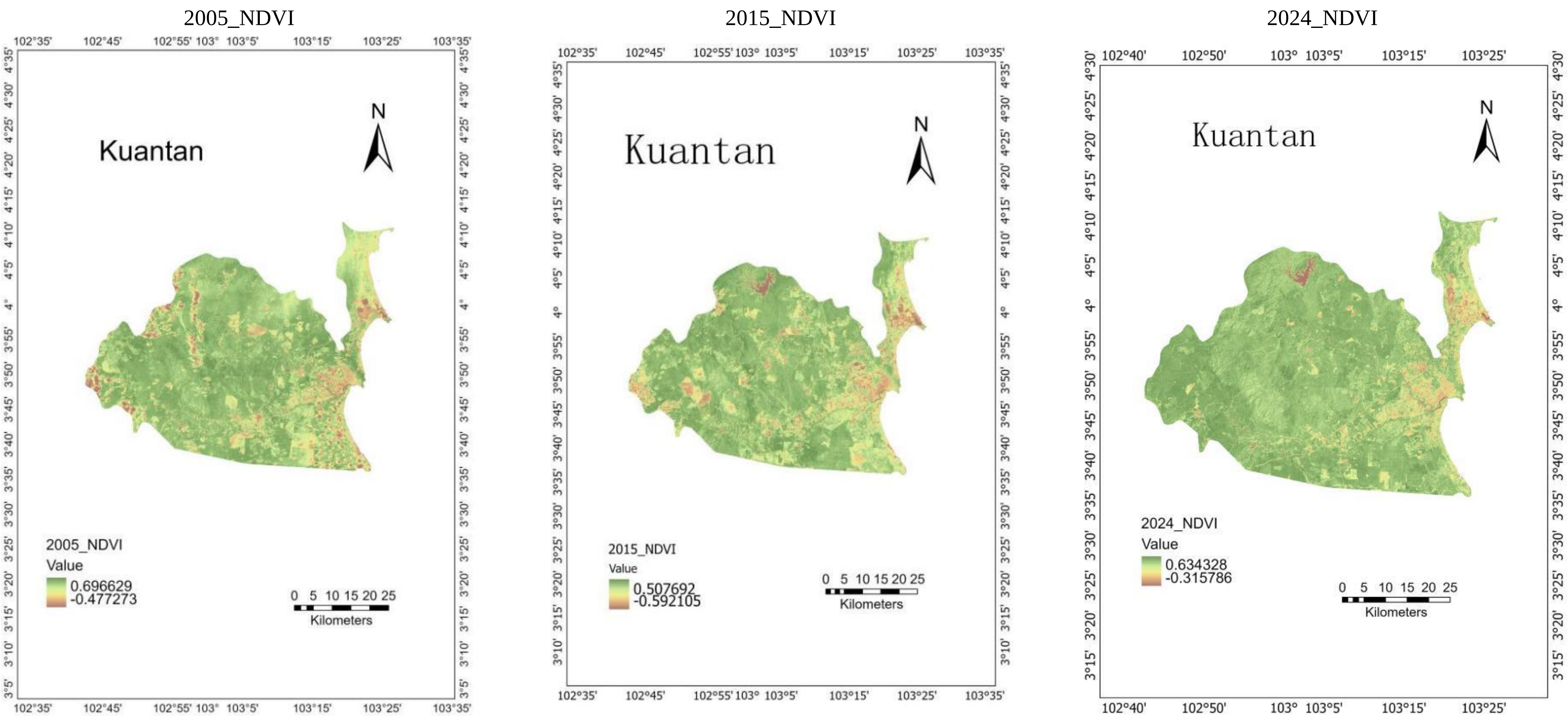

Figure 3. NDVI (2005/2015/2024)

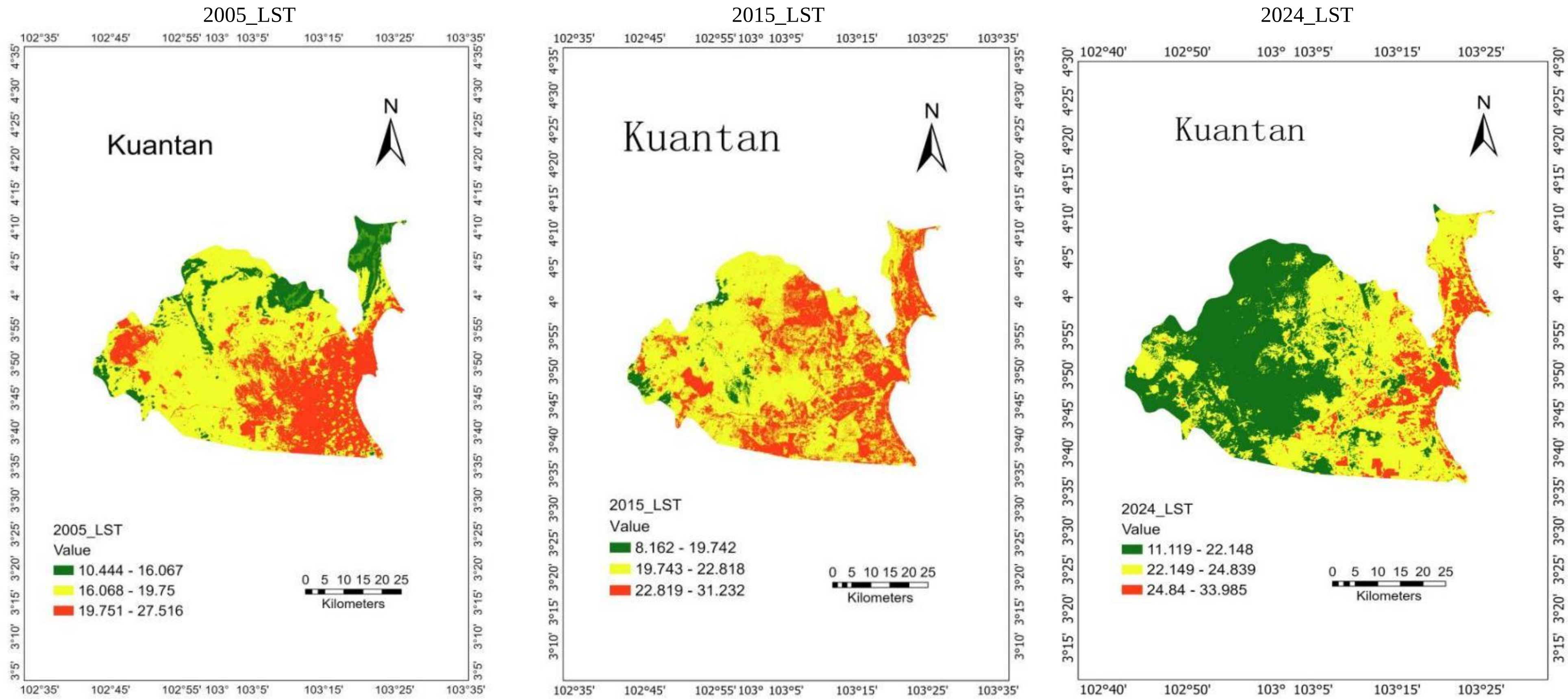

Figure 4. LST in Kuantan (2005/2015/2024)

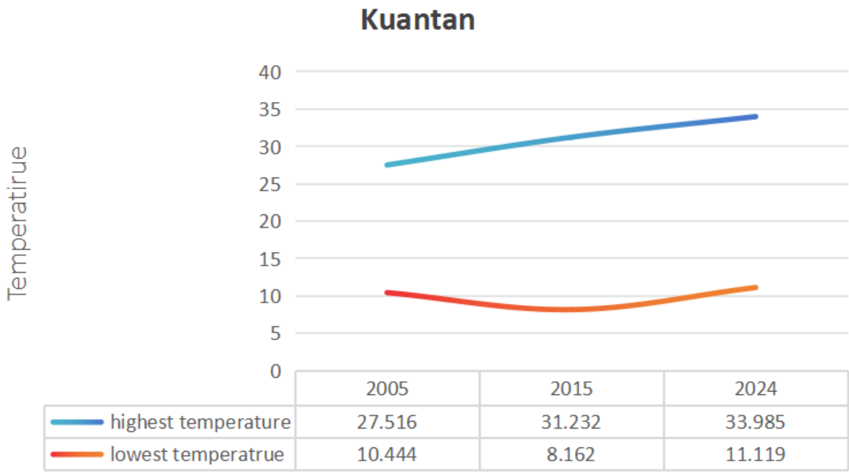

Figure 5. LST change in Kuantan (2005-2024)

The highest temperature in Kuantan increased from 27.516℃ in 2005 to 31.232℃ in 2015 and further rose to 33.985℃ in 2024, showing a continuous upward trend, as shown in Figure 5. Meanwhile, the lowest temperature decreased in 2015 (8.162℃) but rebounded to 11.119℃ in 2024. This change may be related to urbanization, land use changes (such as reduced vegetation and increased buildings), and global climate change. The intensification of the UHI effect is also a key factor, as the expansion of infrastructure in densely populated areas may contribute to the rise in night-time temperatures.

3.3 LULC map

The supervised classification method based on Support Vector Machine (SVM) was applied to land use classification in Kuantan, Malaysia, dividing the area into four categories: buildings, water bodies, vegetation, and barren land [23]. First, training samples were used to extract spectral features of each category, and the SVM algorithm identified the optimal classification hyperplane in the feature space to generate the classification results. Subsequently, the Kappa coefficient was employed for accuracy assessment [24]. By comparing the classification results with ground truth (validation samples), overall accuracy, user accuracy, and producer accuracy were calculated from the confusion matrix. The Kappa coefficient quantified the overall consistency of the classification results, evaluating the reliability of the classification model. In Kuantan, the area is divided into four categories: buildings, water bodies, vegetation, and barren land. Figure 6 indicates that the land use changes in Kuantan from 2005 to 2024 are primarily concentrated in the eastern coastal region, where the built-up areas have significantly increased. This suggests that Kuantan is undergoing a steady and orderly process of urbanization. Accuracy assessment of LULC has indicated by the overall accuracy, user accuracy, producer accuracy, and kappa statistics [25]. Table 3 shows more than 80% accuracy, which is acceptable for further investigation.

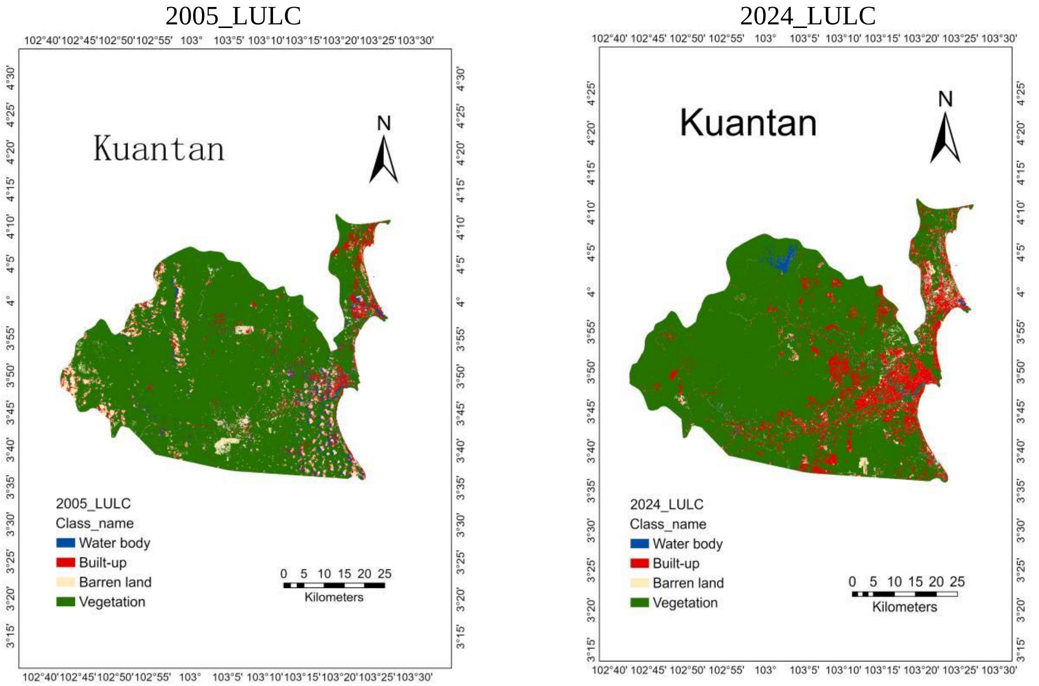

Figure 6. LULC of Kuantan in 2005 and LULC of Kuantan in 2024

Table 3. Accuracy assessment in the LULC

Class	User Accuracy (UA)	Accuracy (PA)
Water body	0.8000	1
Built-up	0.7270	1
Berran land	0.8000	0.8
vegetation	0.9880	0.934
Overall Accuracy	0.9320	-
Kappa Coefficient	0.8327	-

The comparison of land use between 2005 and 2024 in the Kuantan region (Figure 6) reveals notable differences, particularly in specific areas. In the western parts of Kuantan, the vegetation cover has remained relatively stable over the years, indicating minimal changes in land use or development activities. This stability may be attributed to the presence of natural reserves and limited urbanization in that region. Figure 7 indicates that the vegetation area in the Kuantan region has not significantly decreased over the past 20 years. Moreover, urbanization has not expanded extensively in the western part; instead, it is mainly concentrated in the eastern coastal areas. significant changes are observed in the eastern coastal areas and the central living hubs. These areas have experienced a notable increase in the number of buildings and urban infrastructure. The growth in built-up areas reflects the ongoing urban expansion, likely driven by population growth, economic activities, and the region's strategic importance as a coastal city.

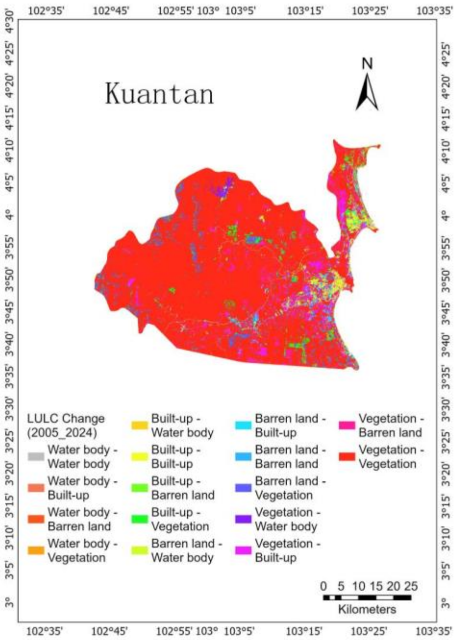

Figure 7. LULC change from 2005-2024

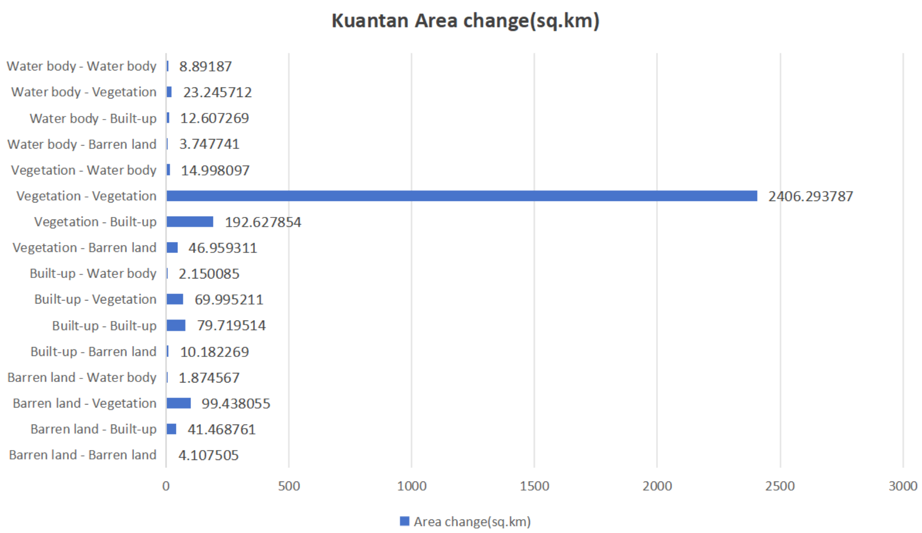

Figure 8. Change-detection analysis in Kuantan (2005-2024)

Figure 8 indicates that the vegetation in the Kuantan area remained relatively stable from 2005 to 2024. Additionally, the expansion of buildings was also quite significant, with the vegetation cover changing by 192 square kilometres for the construction of buildings. The central living areas of Kuantan have expanded to accommodate the growing demand for housing, services, and infrastructure. This shift could include the development of new residential neighbourhoods, commercial zones, and public amenities, reflecting the city's response to changing demographic and economic conditions. However, the increase in built-up areas raises questions about sustainability and the balance between development and environmental conservation.

4. CONCLUSIONS

The study of land use changes and their relationship with land surface temperature in Kuantan is of vital importance due to the region's rapid urbanization and its strategic location along Malaysia's east coast. As the capital of Pahang, Kuantan has experienced significant socio-economic growth, leading to substantial transformations in its land use patterns. These changes are particularly pronounced in the eastern coastal and urban areas, where vegetation and natural landscapes are increasingly being replaced by built-up environments. Understanding the implications of these changes is crucial for sustainable urban planning and environmental management in the region. The relationship between land use and LST is a key focus for addressing urbanization challenges. As natural vegetation is replaced by impervious surfaces, such as buildings, roads, and industrial facilities, the thermal properties of the surface change, often resulting in higher LST. Studying these changes in Kuantan allows for the identification of hotspots where urbanization is contributing most significantly to temperature increases. In summary, the land use dynamics of Kuantan from 2005 to 2024 highlight a dichotomy between stability in the west and rapid urbanization in the east and central regions. The findings underscore the need for balanced development strategies that promote economic growth while preserving the region's environmental integrity.

ACKNOWLEDGEMENTS

The authors would like to thank the Faculty of Civil Engineering Technology, Universiti Malaysia Pahang Al-Sultan Abdullah for providing the facilities for the research. This study was not supported by any grants from funding bodies in the public, private, or not-for-profit sectors.

CONFLICT OF INTEREST

The authors declare no conflicts of interest

AUTHORS CONTRIBUTION

W.X. Zhai: Data curation, Writing- Original Draft Preparation

M. Syarifuddin: Research Methodology, Conceptualization

S.I. Doh: Conceptualization

AVAILABILITY OF DATA AND MATERIALS

The data supporting this study's findings are available on request from the corresponding author

ETHICS STATEMENT

Not applicable.

REFERENCES

[1] N. A. Latip and M. U. Umar, "A sustainable carbon footprint analysis for the City of Kuantan, Pahang Malaysia," *Planning Malaysia*, vol. 20, no. 4, pp. 1-7, 2022.

[2] M. Boujelbene, I. Boukholda, T. Guesmi, M. B. Amara, and N. Khalilpoor, "Solar reflection and effect of roof surfaces material characteristics in heat island mitigation: Toward green building and urban sustainability in Ha'il, Saudi Arabia," *International Journal of Low-Carbon Technologies*, vol. 18, pp. 1039-1047, 2023.

[3] S. Saha, T. Verma, and D. A. B. Oliveira, "Evolution of urban areas and land surface temperature," In *2024 IEEE International Conference on Computer Vision and Machine Intelligence (CVMI)*, pp. 1-6, 2024.

[4] Y. Zhang, Y. Wang, N. Ding, and X. Yang, "Spatial pattern impact of impervious surface density on urban heat island effect: A case study in Xuzhou, China," *Land*, vol. 11, no. 12, p. 2135, 2022.

[5] J. Magidi and F. Ahmed, "Spatio-temporal variations of land surface temperature using Landsat and MODIS: Case study of the City of Tshwane, South Africa," *South African Journal of Geomatics*, vol. 9, no. 2, pp. 379-396, 2020.

[6] Y. Li, Z. L. Li, H. Wu, C. Zhou, X. Liu, P. Leng, et al. “Biophysical impacts of earth greening can substantially mitigate regional land surface temperature warming,” *Nature Communications*, vol. 14, no. 1, p. 121, 2023.

[7] B. Gherri, “The role of urban vegetation in counteracting overheating in different urban textures,” *Land*, vol. 12, no. 12, p. 2100, 2023.

[8] J. Kong, Y. Zhao, D. Strebel, K. Gao, J. Carmeliet, and C. Lei, “Understanding the impact of heatwave on urban heat island in Greater Sydney: Temporal surface energy budget change with land types,” *Science of the Total Environment*, vol. 903, p. 166374, 2023.

[9] Almeida CRd, Teodoro AC, Gonçalves A. “Study of the Urban Heat Island (UHI) using remote sensing data/techniques: A systematic review,” *Environments*, vol. 8, no. 10, p. 105, 2021.

[10] G. Mutani, A. Scalise, X. Sufa, and S. Grasso, “Synergising machine learning and remote sensing for urban heat island dynamics: A comprehensive modelling approach,” *Atmosphere*, vol. 15, no. 12, p. 1435, 2024.

[11] F. Balany, A. W. M. Ng, N. Muttil, S. Muthukumaran, and M. S. Wong, “Green infrastructure as an urban heat island mitigation strategy—A review,” *Water*, vol. 12, no. 12, p. 3577, 2020.

[12] A. Addas, “Machine learning techniques to map the impact of urban heat island: Investigating the City of Jeddah,” *Land*, vol. 12, no. 6, p. 1159, 2023.

[13] M. P. Acosta, M. Dikkers, F. Vahdatikhaki, J. Santos, and A. G. Dorée, “A comprehensive generalizability assessment of data-driven Urban Heat Island (UHI) models,” *Sustainable Cities and Society*, vol. 96, p. 104701, 2023.

[14] D. P. Roy, M. A. Wulder, T. R. Loveland, C. E. Woodcock, R. G. Allen, M. C. Anderson, et al., “Landsat-8: Science and product vision for terrestrial global change research,” *Remote sensing of Environment*, vol. 145, pp. 154-172, 2014.

[15] B. Güneralp, A. S. Perlstein, and K. C. Seto, “Balancing urban growth and ecological conservation: A challenge for planning and governance in China,” *Ambio*, vol. 44, pp. 532-543, 2015.

[16] D. Zhou, J. Xiao, S. Bonafoni, C. Berger, K. Deilami, Y. Zhou, et al., “Satellite remote sensing of surface urban heat islands: Progress, challenges, and perspectives,” *Remote Sensing*, vol. 11, no. 1, p. 48, 2018.

[17] G. Chander, B. L. Markham, and D. L. Helder, “Summary of current radiometric calibration coefficients for Landsat MSS, TM, ETM+, and EO-1 ALI sensors,” *Remote Sensing of Environment*, vol. 113, no. 5, pp. 893-8903, 2009.

[18] J. G. Masek, E. F. Vermote, N. E. Saleous, R. Wolfe, F. G. Hall, K. F. Huemmrich, et al., “A Landsat surface reflectance dataset for North America, 1990-2000,” *IEEE Geoscience and Remote sensing letters*, vol. 3, no. 1, pp. 68-72, 2006.

[19] N. E. Young, R. S. Anderson, S. M. Chignell, A. G. Vorster, R. Lawrence, and P. H. Evangelista, “A survival guide to Landsat preprocessing,” *Ecology*, vol. 98, no. 4, pp. 920-932, 2017.

[20] X. Duan, M. Haseeb, Z. Tahir, S. A. Mahmood, A. Tariq, A. Jamil, et al., “A geospatial and statistical analysis of land surface temperature in response to land use land cover changes and urban heat island dynamics,” *Scientific Reports*, vol. 15, no. 1, p. 4943, 2025.

[21] N. Aslan and D. Koc-San, “The use of land cover indices for rapid surface urban heat island detection from multi-temporal landsat imageries,” *ISPRS International Journal of Geo-Information*, vol. 10, no. 6, p. 416, 2021.

[22] S. Guha and H. Govil, “Land surface temperature and normalized difference vegetation index relationship: A seasonal study on a tropical city,” *SN Applied Sciences*, vol. 2, no. 10, p. 1661, 2020.

[23] A. Taati, F. Sarmadian, A. Mousavi, C. T. H. Pour, and A. Shahir, “Land use classification using support vector machine and maximum likelihood algorithms by Landsat 5 TM images,” *Walailak Journal of Science and Technology*, vol. 12, no. 8, pp. 681-687, 2015.

[24] M. F. Baig, M. R. U. Mustafa, H. Takaijudin, and M. T. Zeshan, “Comparative analysis of support vector machine and maximum likelihood classifications using satellite images of Selangor, Malaysia,” In *2021 Third International Sustainability and Resilience Conference: Climate Change*, pp. 405-409, 2021.

[25] P. Dash, S. L. Sanders, P. Parajuli, and Y. Ouyang, “Improving the accuracy of land use and land cover classification of landsat data in an agricultural watershed,” *Remote Sensing*, vol. 15, no. 16, p. 4020, 2023.