Investigating the Impact of NDVI on Urban Island Heat Effect Across four Islands in Trang Province, Thailand

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Abstract

This research investigates the interplay between the Normalized Difference Vegetation Index (NDVI) and Land Surface Temperature (LST) across various surface types of 4 Islands in Trang Province, Thailand. To assess the urban heat island (UHI) effect, ground-based temperature measurements alongside satellite-derived NDVI data used in this study elucidate how variations in vegetation cover influence thermal conditions in urban and peri-urban environments. Field measurements were conducted across multiple surface types, including asphalt, concrete, dry ground, water, sand, rocks, and vegetated areas, using infrared thermometers following the GLOBE Protocol. Simultaneously, NDVI values were extracted for the study area using high-resolution satellite data from MODIS NASA APPEARS and Copernicus Sentinel platforms to analyze vegetation density relative to surface temperatures comprehensively. Preliminary results indicate a pronounced thermal disparity between urbanized and green spaces, with maximum recorded LSTs reaching 48.2°C in densely built environments compared to 30.7°C in tree-covered areas. The findings suggest a significant inverse correlation between NDVI and LST, where higher vegetation indices correlate with reduced surface temperatures, highlighting the cooling effects of green infrastructure. This study underscores the critical role of vegetation in mitigating UHI effects, providing essential insights for urban planners and policymakers in Trang Province. The findings are expected to contribute to effective heat mitigation strategies and sustainable urban development in the context of climate change.

Keywords: Urban Heat Island, Land Surface Temperature, GLOBE Protocol, NDVI, Remote Sensing, Urban Planning

1. Introduction

1.1 Background

The Normalized Difference Vegetation Index (NDVI) is a widely used metric for assessing vegetation health and density [1]. NDVI values range from -1 to 1 and are calculated from the reflectance of near-infrared (NIR) and red light, providing a quantitative measure of vegetation cover. Negative values indicate water and clouds, positive values near zero indicate bare soil and higher positive values indicate denser vegetation. Land Surface Temperature (LST) is a critical parameter in understanding the thermal characteristics of the Earth's surface, influenced by factors such as land cover, albedo, and vegetation [2]. The Urban Heat Island (UHI) effect is where urban areas experience higher temperatures than their rural surroundings due to changes in human activities and land use [3]. This effect has significant implications for urban planning, public health, and climate resilience, making it crucial to understand the factors that influence it.

$$NDVI = \frac{NIR - RED}{NIR + RED}$$

Where

- NIR: Near Infrared Reflectance
- RED: Red reflectance.

1.2 Research Context

Previous studies in Thailand have primarily focused on highly urbanized cities, particularly in Bangkok [14]. Our research extends this work by examining multiple small islands with varying levels of urbanization and incorporating ground-based and satellite measurements, providing a more comprehensive understanding of UHI patterns in small-scale urban contexts in Thailand.

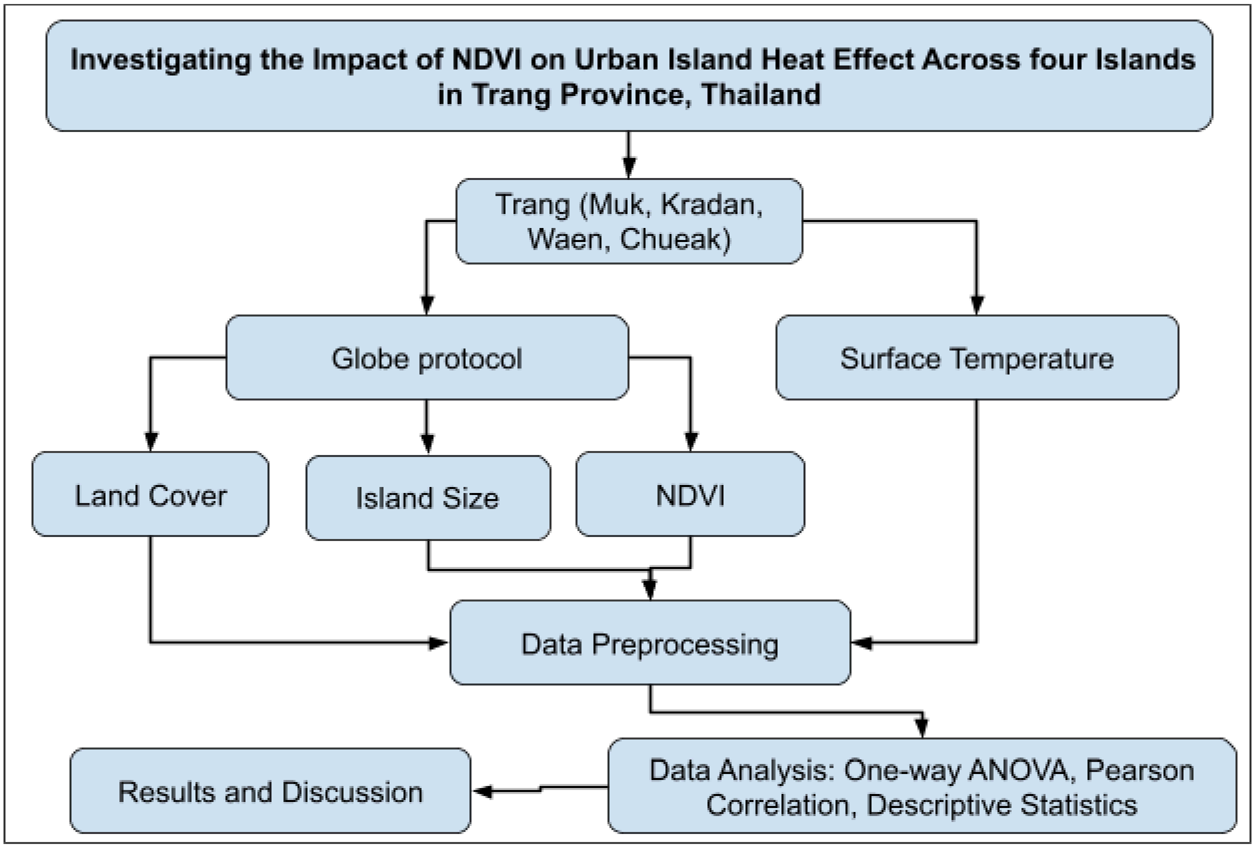


Figure 1: Experimental Design

1.3 Research Objectives

The primary objective of this study is to analyze the relationship between NDVI values of different islands and the LST of various surfaces (asphalt, concrete, dry ground, water, sand, rocks, and vegetated areas) to assess how vegetation affects the urban heat island effect [4]. This research aims to provide valuable insights for urban planners and policymakers in Trang Province, Thailand, to develop effective heat mitigation strategies and promote sustainable urban development.

1.4 Research Questions

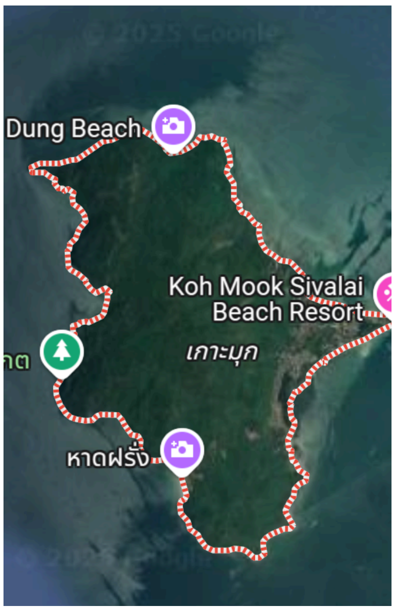
- How do NDVI values vary across different islands?
- What are the average LST readings for various surfaces?
- Is there a correlation between NDVI and LST readings?

- Do the satellite LST measurements obtained from MODIS correspond to ground-based measurements?

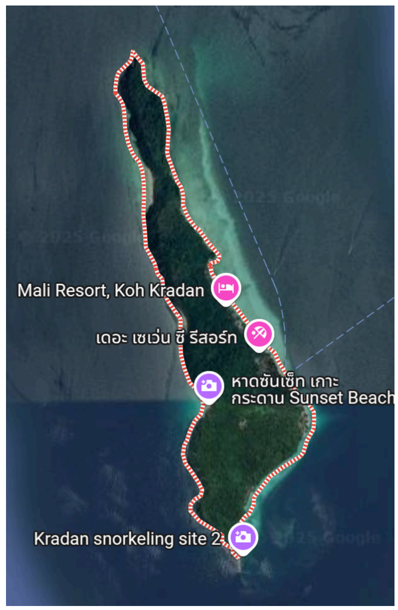
2. Materials and Methods

2.1 Study Areas

This research involved



Mook Island

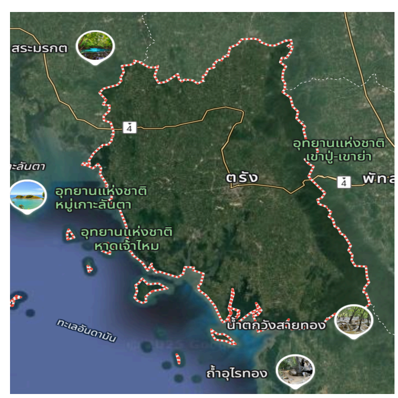


Kradan Island

Thailand

Waen Island

Chueak Island



Trang Province

Figure 2: Study location maps

2.2 Description of Islands

The study focuses on four islands in Trang Province, Thailand, each characterized by distinct geographical locations, sizes, and urban characteristics. These islands, namely Muk, Kradan, Waen, and Chueak, were selected based on their varying degrees of urbanization and vegetation cover. Island A is predominantly urban with limited green spaces, while Island B has a mix of urban and peri-urban areas. Island C is characterized by extensive vegetation, and Island D combines urban and natural landscapes [5].

Table 1: Study location coordinates

Island	Size	Coordinates	Site Characteristics
Muk	8.12 Km^2	7.373176°N, 99.294978°E	Predominantly urban with limited green spaces and developed infrastructure.
Kradan	1.89 Km^2	7.313395°N, 99.253160°E	A mix of urban and agricultural areas showcasing development and greenery.
Waen	0.21 Km^2	7.379333°N, 99.248283°E	A commercial district with significant vegetation provides a setting to study urban heat effects.
Chueak	0.21 Km^2	7.406056°N, 99.231100°E	A combination of resort and forest areas offers natural landscapes alongside urban elements.

3 Data Collection Methods

3.1 NDVI Measurement

NDVI data were collected using high-resolution satellite imagery from MODIS NASA APPEARS (Muk and Kradan Islands) and Copernicus Sentinel (Muk, Kradan, Waen, and Chueak Islands) platforms [6]. Data from both satellites were compared to ensure and validate consistency. The satellite images were acquired during the dry season to minimize the influence of seasonal variations on vegetation health. The NDVI values were extracted for each island, ensuring the data collection period was consistent across all locations. The following table summarizes the NDVI values for each island:

Table 2: Avg. NDVI Values for Each Island

Island Name	Year Range	Avg. NDVI Value
Muk	2020-2025	0.63
Kradan	2020-2025	0.55
Waen	2020-2025	0.52
Chueak	2020-2025	0.36

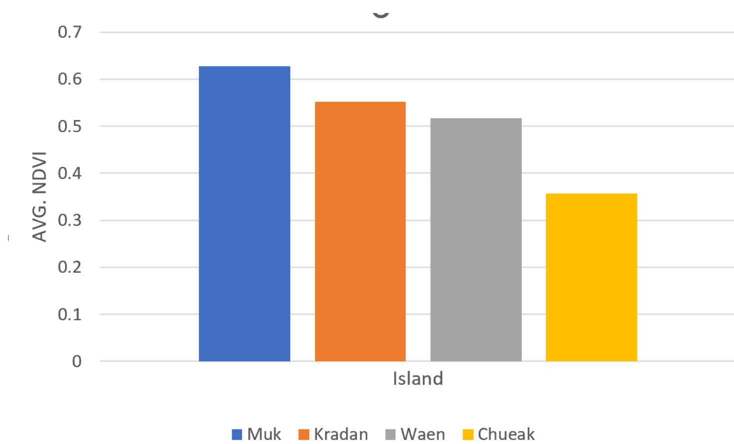


Figure 3: Avg. NDVI Values for Each Island

3.2 LST Measurement

Surface temperatures were measured using infrared thermometers following the GLOBE Protocol [7]. The measurements were conducted across multiple surface types, including asphalt, concrete, dry ground, water, sand, rocks, and vegetated areas. The data was collected during the daytime to capture peak temperature readings.

3.2.1 Ground-Based Measurements

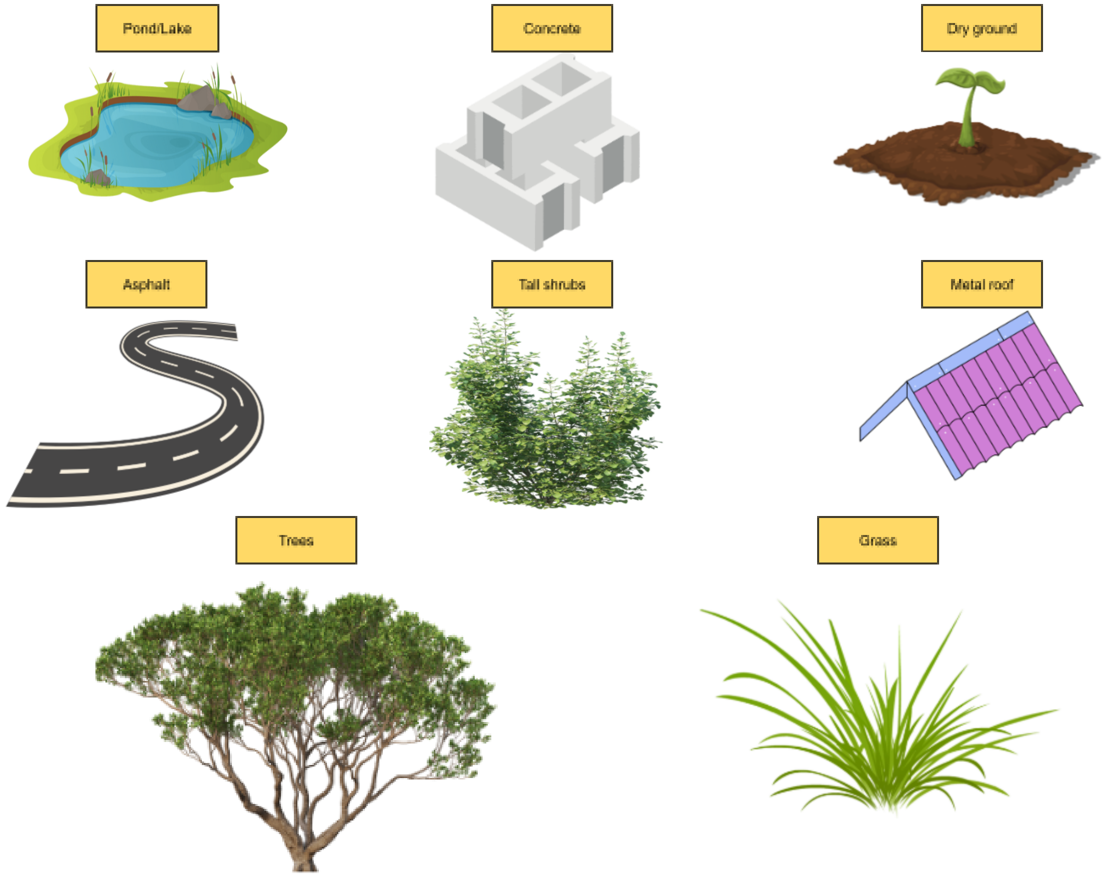
Temperature measurements were conducted using:

- Infrared thermometer gun (Model MESTEK IR03A, Range -50~400°C/600°C)
- GLOBE Protocol land cover observation tools
- Standard meteorological equipment for ambient conditions

3.2.2 Sampling Protocol:

- Ground shooting measurements taken at standardized heights (50 cm above ground)
- Three readings per point to ensure accuracy
- Data collected during both day (10:00-12:00) and night (18:00-20:00)

3.2.3. Surface types monitored:



Dry ground, Grass, Concrete, Metal roof, Pond/Lake, Asphalt road, Tall shrubs, Trees

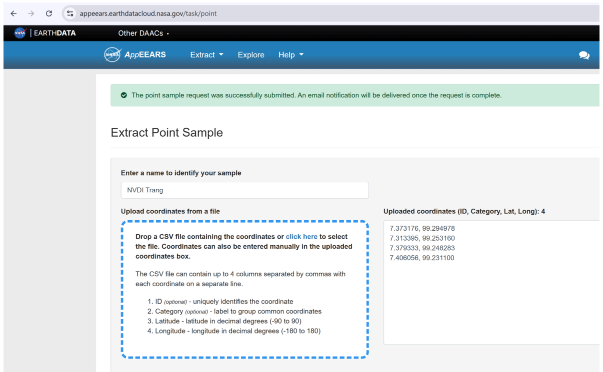
Image acquired with drone.

Figure 4: Ground shooting surfaces

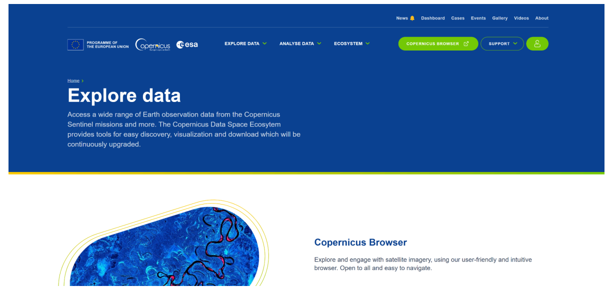
3.2.4 Satellite Data

MODIS NASA APPEARS and Copernicus Sentinel platforms data collection:

- Land Surface Temperature (LST) products
- Temporal resolution: Daily observations
- Spatial resolution: 1km
- Period: 2020-2025



(a) MODIS APPEARS



(b) SENTINEL Copernicus

Figure 5: Satellite data sources

3.3 Data Analysis Methods

3.3.1 Statistical Analysis

The statistical analysis involved calculating the correlation coefficient between NDVI and LST values for each island. The Pearson correlation coefficient was used to quantify the strength and direction of the relationship between the two variables [8]. The results were interpreted in the context of the research questions, focusing on the impact of vegetation cover on surface temperatures. Other analyses were performed, including:

- Descriptive statistics for each surface type for both day and night.
- Urban Heat Island Intensity Analysis
- One-way ANOVA to compare temperatures across surface types.
- Descriptive statistics and direct comparison time series analysis for temporal patterns.

3.4 Quality Control Measures

3.4.1 Instrument Calibration:

- Daily calibration of infrared thermometers
- Cross-validation with standard thermometers

3.4.2 Data Validation:

- Removal of outliers (>3 standard deviations)
- Satellite data quality filtering

3.4.5 Software and Tools

- Google Earth and Google Maps for spatial analysis and mapping
- Google Sheets with XLMiner for statistical analysis
- GLOBE Observer mobile application
- NASA APPEARS platform interface
- Copernicus
- Microsoft Excel

4. Results

4.1NDVI and LST Measurements

The NDVI values ranged from 0.36 in the smaller Chueak to 0.63 in the larger Muk Island [9]. The LST readings showed a significant variation across different surface types, with the highest temperatures recorded in asphalt-covered areas and the lowest in tree-covered regions.

4.2 Statistical Analysis Results

Table 3: Case study: ANOVA Results for Surface Type Comparison for Kradan Island

DAY TIME						
Groups	Count	Sum	Average (°C)	Variance		
LST Dry Ground	4	144.7	36.175	8.7225		
LST Sand	4	135.6	33.9	2.25		
LST Grass	4	126	31.5	2.89		
LST Rocks	4	143.5	35.8	8.72		
LST Trees	4	122.3	30.58	1.22		
LST Concrete	4	146.7	36.675	25.6025		
LST Metal roof	4	132	33.00	4.98		
LST Waterr	4	122.3	30.58	1.22		
LST Asphalt Road	4	0.00	0.00	0.00		
ANOVA						
Source of Variation	SS	df	MS	F	P-value	F crit

Between Groups	4179.9	8	522.49	74.27	0	2.31
Within Groups	189.94	27	7.03			
Total	4369.87	35				

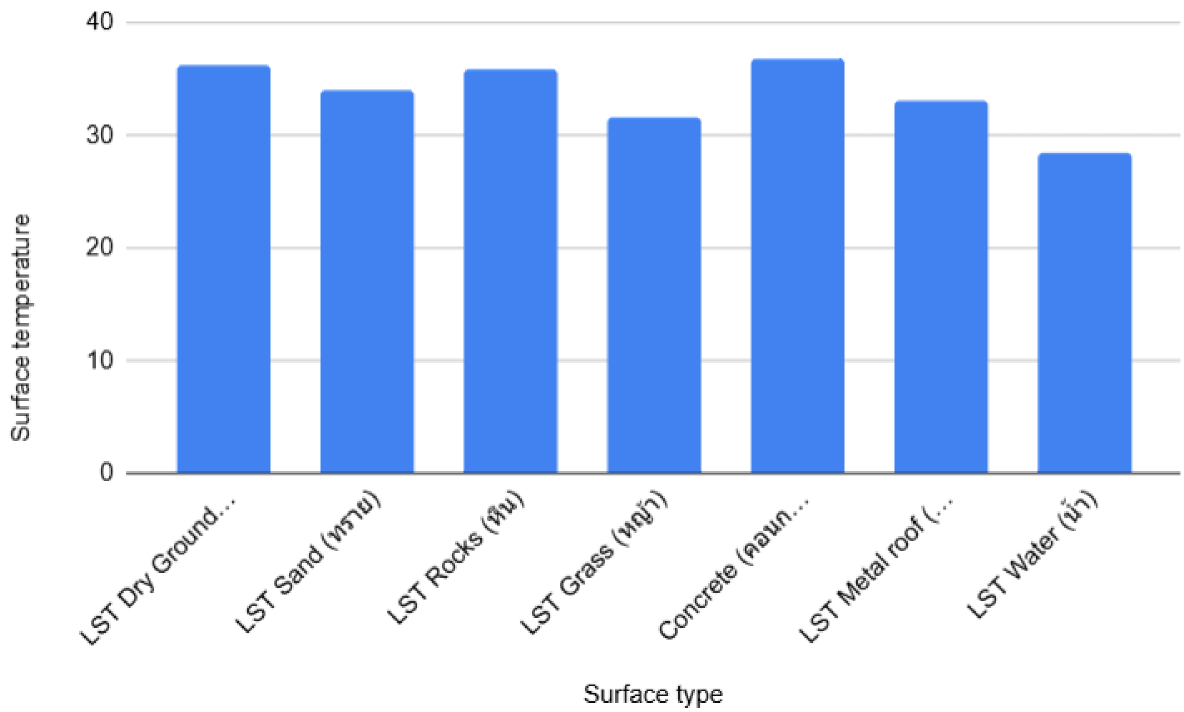


Figure 6: Surface Temperature for different surface type in Kradan island

Table 3 above indicates significant differences in Land Surface Temperature (LST) among various surface types on Kradan Island, Trang Province, Thailand ($F(8, 27) = 74.27$, $p < 0.001$). The highest average LST was observed on Concrete (36.68°C), followed by Dry Ground (36.18°C) and Rocks (35.88°C). In contrast, Water had the lowest average LST (28.35°C), with Trees (30.58°C) and Grass (31.50°C) also showing relatively cooler temperatures. Notably, Asphalt Road recorded no LST (0°C), which may indicate missing or erroneous data. The significant p-value ($p = 0$) suggests that surface type strongly influences LST, highlighting the variability in thermal properties across different materials and natural features on the island. This information is crucial for understanding microclimates and planning sustainable development on Kradan Island. Below is a brief comparative analysis of the results.

1. Overall Temperature Range:

- Daytime: 28.35°C - 36.68°C (8.33°C range)

2. Surface-by-Surface Comparison:
   - Concrete: 36.68°C (hottest surface)
   - Dry Ground: 36.18°C
   - Rocks: 35.88°C
   - Sand: 33.90°C
   - Metal roof: 33.00°C
   - Grass: 31.50°C
   - Trees: 30.58°C
   - Water: 28.35°C (coolest surface)
   - Asphalt Road: Not recorded

3. **Key Insights:**

1. Largest Temperature Variations:

Concrete and Dry Ground exhibit the highest daytime temperatures (36.68°C and 36.18°C, respectively), suggesting significant heat absorption and retention.

Water and Trees remain the coolest (28.35°C and 30.58°C, respectively), highlighting their thermoregulation properties.

2. Most Stable Surfaces:

Water (28.35°C) and Trees (30.58°C) show the lowest temperatures and likely the least variation, acting as natural coolants.

Grass (31.50°C) also demonstrates moderate stability, though warmer than water and trees.

3. Urban Heat Island (UHI) Implications:

Built surfaces like Concrete and Dry Ground absorb and retain significant heat, contributing to higher daytime temperatures. Natural surfaces like Water, Trees, and Grass play a critical role in mitigating UHI effects by maintaining cooler and more stable temperatures. Although asphalt road data was not recorded due to the absence of asphalt on the Island, asphalt is known to retain heat, similar to concrete.

4. **Implications:**

The data underscores the thermal regulation benefits of natural surfaces (water, trees, grass) compared to built surfaces (concrete, dry ground, metal roofs). This highlights the importance of preserving natural landscapes and incorporating green infrastructure to mitigate UHI effects and maintain a cooler microclimate on Kradan Island.

4.3 Satellite Data Analysis

4.3.1 Correlation Analysis

The correlation analysis revealed a strong inverse relationship between NDVI and LST. Higher NDVI values, indicating denser vegetation, were associated with lower surface temperatures [10]. The correlation coefficients for each island are summarized in the following table:

Table 4: Correlation analysis of NDVI vs LST

Island Name	NDVI	LST	Correlation Coefficient	Size
Muk	0.63	32.34	-0.42	8.12 Km^2
Kraden	0.56	34.58	-0.08	1.89 Km^2
Waen	0.52	29.13	–0.03	0.21 Km^2
Chueak	0.36	29.15	0.01	0.21 Km^2

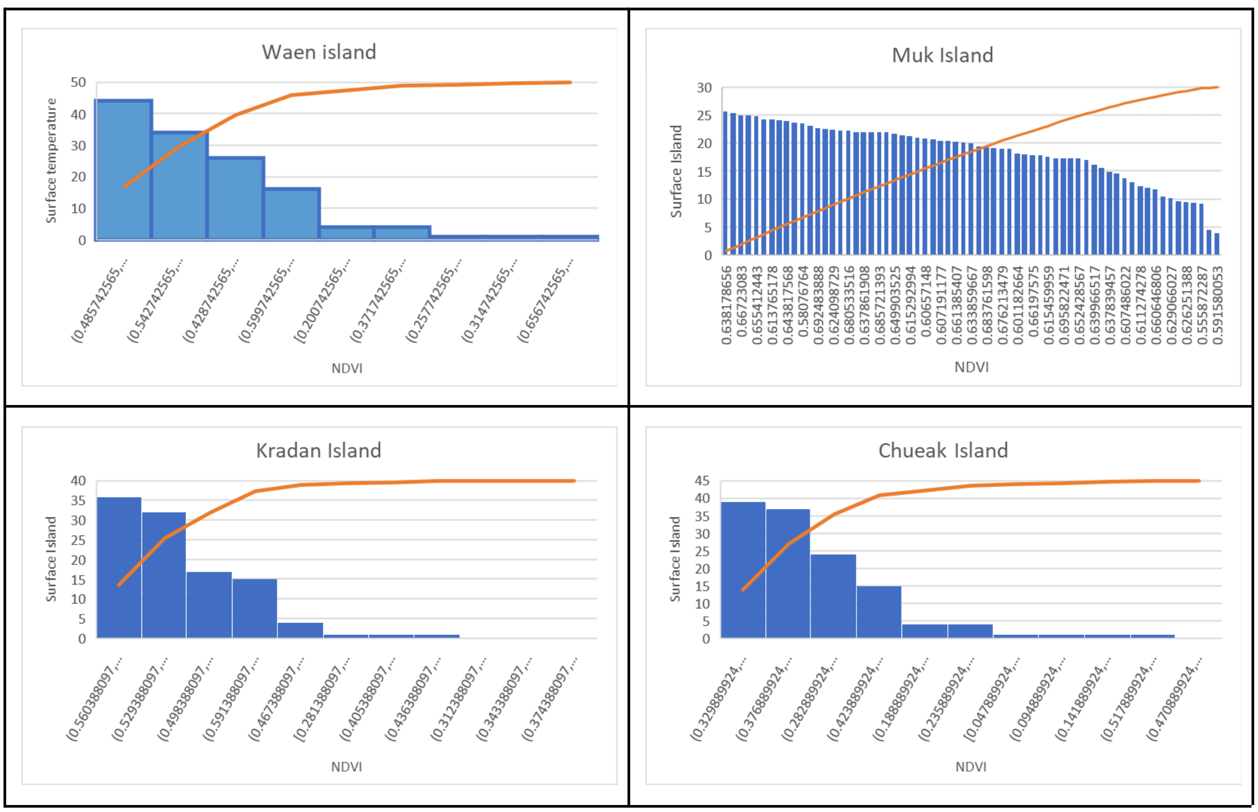


Figure 7: Correlation Coefficient vs. LST of island

4.3.2 Graphical Representation

A graph was plotted to visualize the relationship between Correlation Coefficient and Size, highlighting the inverse correlation between vegetation density, surface temperature, and the surface area of the Islands.

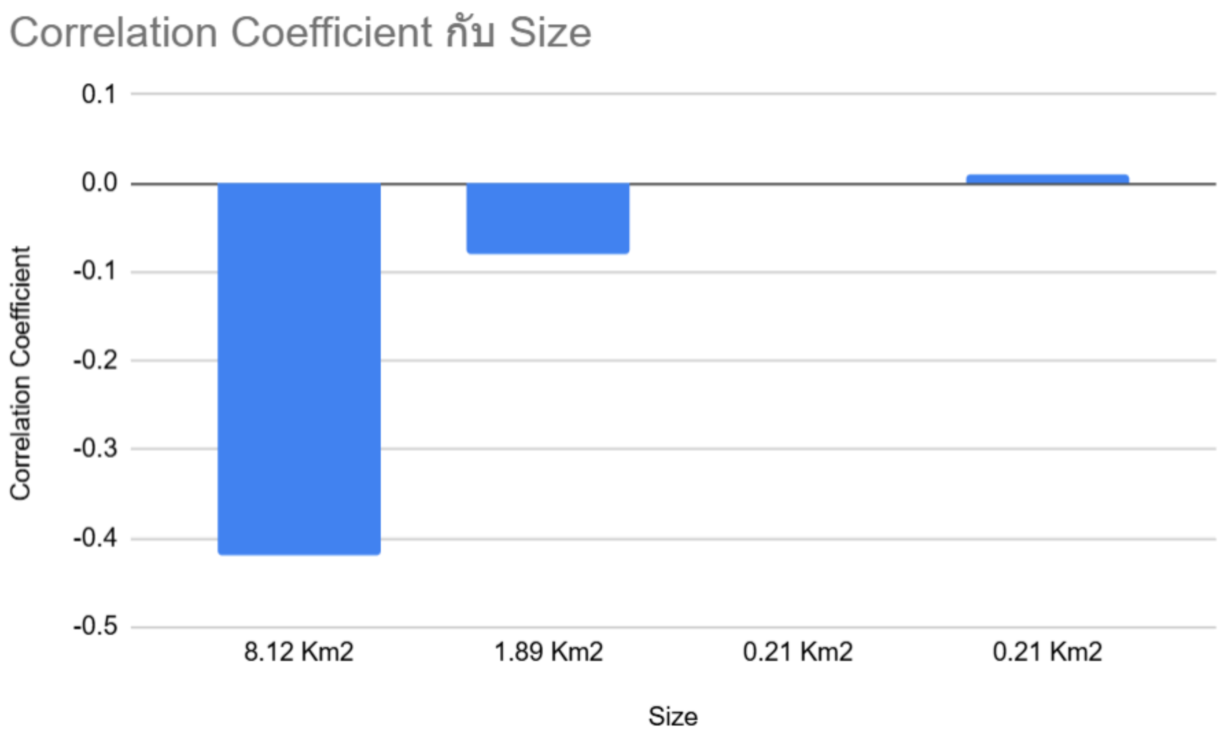


Figure 8: Correlation Coefficient vs. Size of island

5. Discussion

5.1 Interpretation of Results

The results indicate a significant inverse correlation between NDVI and LST, suggesting that higher vegetation cover leads to lower surface temperatures [11]. This finding aligns with previous studies demonstrating the cooling effects of green infrastructure in urban environments. The pronounced thermal disparity between urbanized and green spaces underscores the critical role of vegetation in mitigating the UHI effect.

5.2 Factors Influencing Results

Several factors may influence the observed results, including urban density, vegetation type, and climate conditions [12]. Higher urban density, characterized by increased impervious surfaces, contributes to higher LST readings. The vegetation type also plays a crucial role, with dense tree cover providing more significant cooling effects than sparse vegetation. Additionally, local climate conditions, such as humidity and wind patterns, can affect the thermal characteristics of the study area.

5.3 Limitations

The study encountered several limitations, including data availability and measurement challenges [13]. The reliance on satellite data download for NDVI and LST data may introduce inaccuracies due to cloud cover and atmospheric conditions. Additionally, the use of ground-based measurements for LST may be subject to spatial and temporal variability, potentially affecting the accuracy of the results.

6. Conclusion

6.1 Key Findings and Significance

The study concludes that vegetation is critical in mitigating the UHI effect, with higher NDVI values correlating with reduced surface temperatures [14]. These findings highlight the importance of green infrastructure in urban planning and sustainable development, particularly in climate change. The results provide valuable insights for urban planners and policymakers in Trang Province, emphasizing the need for strategies that promote vegetation cover and reduce urban heat.

6.2 Future Research

Potential areas for further research include exploring the impact of different vegetation types on UHI mitigation, investigating the influence of microclimatic conditions on surface temperatures, and developing predictive models to assess the long-term effects of urbanization on thermal environments [15].

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I would like to claim IVSS badges

1. **I have an impact**

   The report clearly describes how a local issue led to the research question or connects local and global impacts. Students must clearly explain or demonstrate how the research has benefited their community by making recommendations or taking action based on the study's findings. This study, Mapping and Identifying Urban Heat Island Hotspots in Thailand: A Multi-Provincial Study Using Ground-Based and Satellite Measurements

2. **I am a STEM professional.**

   The report clearly describes a collaboration with a STEM professional that improved the research methodology, contributed to greater rigor, and supported more sophisticated analysis and interpretation of the results. Data was used to analyze the results, creating graphs to show relationships between the data.

3. **I am a data scientist.**

   The report carefully examines the students' proprietary data and additional sources. Students will critically evaluate the limitations of these data, draw inferences about past, present, or future events, and use the data to answer questions or solve problems within the presented system. This may include gathering data from other academic institutions or using data from external databases. We developed a Mapping and Identifying Urban Heat Island Hotspots in Thailand: A Multi-Provincial Study Using Ground-Based and Satellite Measurements.

Appendix A: Data sources

1. NASA APPEARS MODIS
2. COPERNICUS SENTINEL 2 AND 3