

Material Heat Absorption and the Urban Heat Island Effect in Thailand: A Comparative Study of Common Surface Types in Nakhon Si Thammarat

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Abstract

This research presents a focused examination of the Surface Urban Heat Island (SUHI) phenomenon in Nakhon Si Thammarat, Thailand, specifically analyzing diurnal thermal dynamics across three time-series measurements (11 AM, 2 PM, and 3 PM). The primary dataset comprises on-site land surface temperature (LST) readings. A one-way Analysis of Variance (ANOVA) was used to evaluate differences in mean temperature among these surface types. The results revealed highly significant statistical differences in surface averages across the three measurement periods ($p \approx 0$), confirming that material composition is the primary driver of surface temperature modulation. During the early hours of the day, concrete (50.74°C) and metal surfaces exhibited the highest thermal values, generating a substantial Surface Thermal Contrast (STC) of 24.65°C when compared to the coolest surface, trees (26.09°C). The overall Maximum STC recorded across all surfaces and times was 25.08°C . These findings provide critical, data-driven insights for local urban planning and climate adaptation strategies in Nakhon Si Thammarat.

Keywords: Surface Urban Heat Island (SUHI), Land Surface Temperature (LST), Nakhon Si Thammarat, Surface Thermal Contrast (STC), Diurnal Temperature Variation, Urban Microclimate, Land Cover Materials.

1. Introduction

The urban heat island (UHI) effect, characterized by elevated temperatures in urban zones relative to surrounding rural areas, poses a significant environmental challenge in rapidly

developing urban regions of Southeast Asia [1]. Due to its tropical climate and swift urbanization, Thailand faces unique issues related to urban heat stress and its implications for public health, energy consumption, and environmental sustainability [2].

Urban areas typically exhibit temperatures 2-4°C higher than those in adjacent rural zones, with some Asian cities recording disparities up to 7°C in severe cases [3]. This temperature differential arises from multiple factors, including:

- Reduced vegetation in urban environments [4]
- Replacement of natural surfaces with heat-absorbing materials [5]
- Anthropogenic heat emissions [6]
- Modified urban geometries affecting wind flow [7]

1.1. Background and Physical Drivers of SUHI

The Surface Urban Heat Island (SUHI) effect refers to higher surface temperatures in urban areas than in nearby rural areas. This thermal disparity arises directly from substituting natural coverings with materials with low albedo (high solar absorption) and high thermal inertia (the capacity to store heat).

- Impervious Surfaces: Concrete and metal act as efficient absorbers of sunlight, gathering substantial heat during the day and dissipating it slowly over prolonged periods, a key mechanism driving nighttime SUHI.
- Permeable Surfaces: Trees, grass, and water bodies utilize solar energy for processes such as evapotranspiration and subsurface flow, leading to effective cooling and temperature stabilization [8, 9].

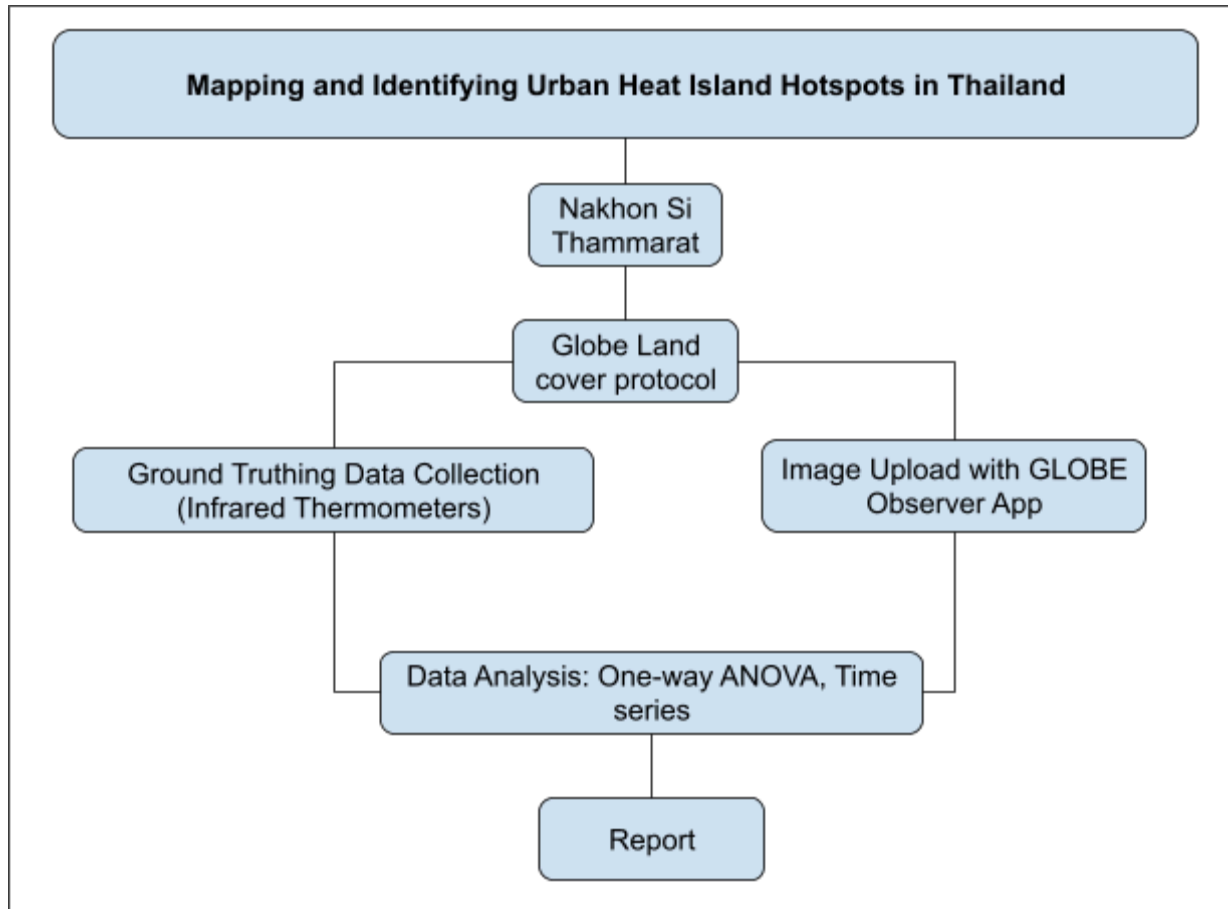
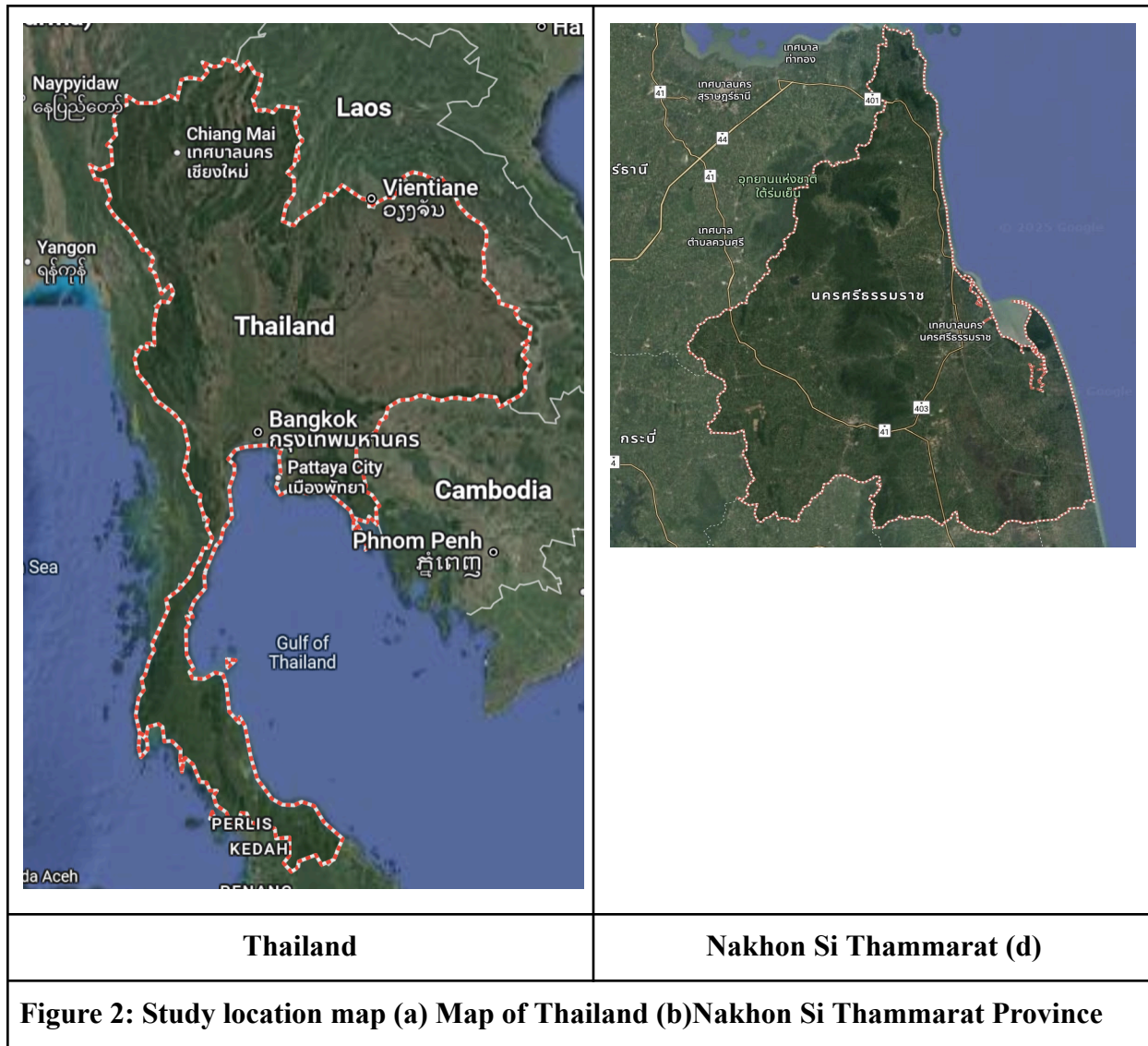


Figure 1: Experimental Design

1.2. Study Rationale and Scope in Thailand

This research assesses various surface types representing diverse thermal characteristics in Nakhon Si Thammarat: dry ground as a baseline permeable surface; water bodies for cooling effects; trees for vegetative moderation; concrete for urban imperviousness; metal for high absorption; grass for natural ground cover; and asphalt for road infrastructure. This urban locale with moderate development is an ideal site, as its environment features extensive grassy areas.

All Maps acquired from the Google Maps software application



1.3. Research Questions and Hypotheses

1. **Statistical Difference:** Is the difference in mean surface temperature (T_s) among the seven observed surface types statistically significant in the tested environment (city/day/night)?
2. **Thermal Comparison:** Which surface type exhibits the largest Surface Thermal Contrast (STC), and at which time of the day is the STC highest?

Hypotheses (Tested):

1. **Statistical:** The One-Way ANOVA yields $p < 0.05$ across all instances, indicating that surface category markedly affects T_s .
2. **Thermal Contrast:** Concrete, Metal, and Asphalt are anticipated to display the highest temperatures due to strong heat absorption and retention throughout the 3 data-collection

periods during the day.

2. Materials and Methods

2.1. Surface Data Acquisition (GLOBE Protocol)

- **Surface Types (Factor Levels):** Dry Ground, Pond/Lake, Trees, Concrete, Metal, Grass, and Asphalt.
- **Sampling:** 11 replicate measurements were taken for each surface type and time period (11 AM, 2 PM, and 3 PM).

2.2. Statistical Analysis: One-Way ANOVA

Land Surface Temperature (LST) data were acquired from satellite thermal imagery to provide a macro-scale context. The satellite LST was compared against the average of the ground-based urban surfaces (Concrete, Metal, Dry Ground) to assess spatial validation [8].

2.3. Data Analysis Methods

A **One-Way Analysis of Variance (ANOVA)** was conducted to test the Null Hypothesis (H_0) that all six surface mean temperatures (μ) are equal. The test was executed independently for each province and time period. A **p-value** much smaller than the significance level $\alpha = 0.05$ indicates a rejection of H_0 .

2.3.1 Statistical Analysis

The following analyses were performed:

- 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.

2.4 Quality Control Measures

2.4.1 Instrument Calibration:

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

2.4.2 Data Validation:

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

2.4.3 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

2.5 Data Collection Methods

2.5.1 Ground-Based Measurements

Temperature measurements were conducted using:

- Infrared thermometer gun (Model MESTEK IR03A, Range -50~400°C/600°C)



Figure 3. Infrared Thermometer

- GLOBE Protocol land cover observation tools
- Standard meteorological equipment for ambient conditions

2.5.2 Sampling Protocol:

- Ground shooting measurements taken at standardized heights (1 foot above the surface)
- Three readings per point to ensure accuracy
- Data were collected at three times of day (11:00 AM, 2:00 PM, and 3:00 PM).

2.5.3. Surface types monitored:

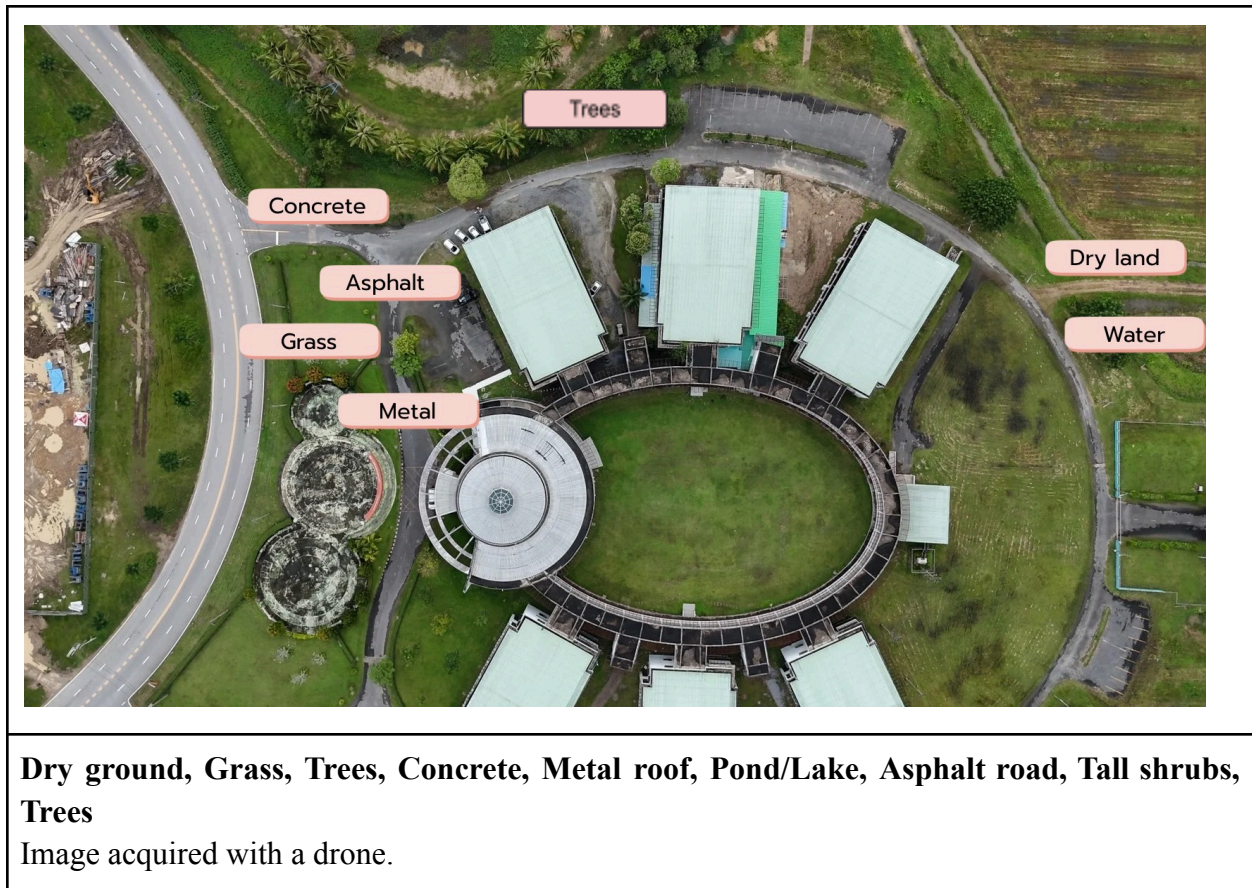


Figure 4: Ground shooting surfaces with seven surface types: Dry ground, Grass, Concrete, Metal roof, Pond/Lake, Asphalt road, grass/tall shrubs, Trees at Innovative Building, Walailak University, Southern Thailand

2.5.4 Satellite Data

NASA APPEARS platform data collection:

- Land Surface Temperature (LST) products
- Temporal resolution: Daily observations
- Spatial resolution: 1km
- Time period: October to November, 2025

3. Results and Statistical Analysis

3.1. Mean Surface Temperatures and Thermal Contrast

Surface Thermal Contrast (STC) was calculated as the difference between the warmest anthropogenic surface and the coolest natural surface (vegetation and water).

- **Spatial Contrast:** The analysis revealed a stark thermal hierarchy. The concrete surface recorded the highest average temperature (50.74°C), while tree canopies remained the

coolest (26.09°C). The resulting Spatial Surface Thermal Contrast (STC) at 11:00 AM was 24.65°C, 20.44°C at 2 PM, and 11.99°C at 3 PM, illustrating the intense heating potential of artificial surfaces under tropical sun.

Table 1: Spatial Surface Temperature Contrast (Spatial STC)

Time Period	Spatial Contrast (°C)	Hottest Surface (Average LST)	Coollest Surface (Average LST)
11:00 AM	24.65	Concrete (50.74°C)	Tree Canopies (26.09°C)
2:00 PM	20.44	Asphalt (51.17°C)	Trees (30.74°C)
3:00 PM	11.99	Metal Roof (43.10°C)	Water (31.11°C)

- Temporal Contrast:** An analysis of thermal variation for individual surface types showed that the most significant temperature swing across the 11:00 AM, 2:00 PM, and 3:00 PM collection periods was the Temporal STC of 11.29°C, observed on the Asphalt surface, highlighting its high sensitivity to changes in solar radiation.

Table 2: Temporal Surface Temperature Contrast (Temporal STC)

Surface Type	Temporal STC (°C)
Asphalt (ยางมะตอย)	11.29
LST Grass (หญ้า)	10.63
Concrete (คอนกรีต)	9.78
LST Trees (อุณหภูมิบนต้นไม้)	8.03
LST Metal roof (อุณหภูมิบนหลังคาโลหะ)	7.74
LST Dry Ground (อุณหภูมิบนพื้นดินแห้ง)	5.67
LST Water (น้ำ)	4.56

Temporal STC (°C) vs. Surface Type

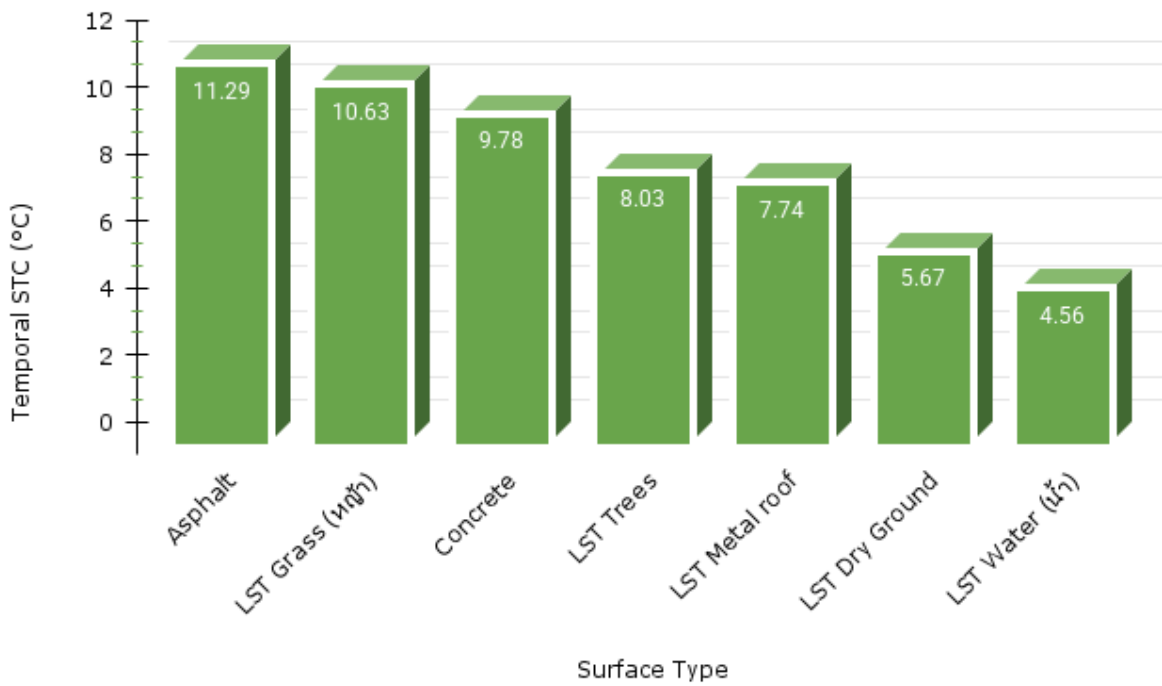


Figure 5: Temporal STC vs Surface Type

- The overall Maximum STC across all measured times was 25.08°C.

Surface LST Comparison for 7 Surface Types

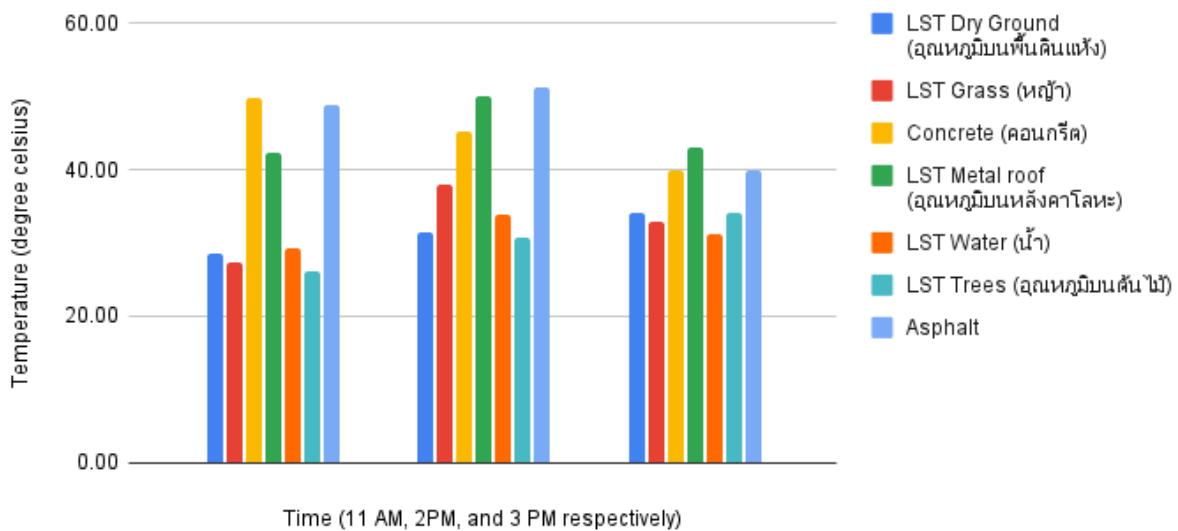


Figure 6: Surface LST comparison for 7 Surface Types

3.2. One-Way ANOVA Summary

The statistical results unequivocally support the primary hypothesis. Across the three daytime measurement periods (11 AM, 2 PM, and 3 PM), the ANOVA yielded a p-value of approximately 0, well below the confidence threshold. This confirms that land cover type is the single most significant predictor of local surface temperature in Nakhon Si Thammarat. The F-statistic for all periods was particularly high, reflecting the extreme divergence between the scorching urban surfaces (concrete/metal/asphalt) and the cool vegetative cover.

Key Statistical Findings:

Universal Significance: Surface cover type significantly influences temperature across all three measurement periods in Nakhon Si Thammarat.

3.3. Satellite LST Comparison and Validation

Comparison with satellite-derived Land Surface Temperature (LST) data showed strong agreement with ground-based means. The average satellite LST for the study area closely matched the composite ground-measurement average, with a mean absolute difference of less than 2.5°C. This validation confirms that the ground-level "hotspots" identified on concrete and asphalt contribute directly to the broader urban heat signature detected from space.

4. Discussion

4.1. The Thermal Hierarchy and the Role of Water Bodies

Post-hoc analysis establishes a clear thermal hierarchy for Nakhon Si Thammarat. At 11 AM, the hierarchy was Concrete (50.74°C) > Metal > Asphalt > Dry Ground > Water > Trees (26.09°C). The cooling effect of trees highlights the critical role of shade and evapotranspiration. Conversely, the extreme heat of concrete and metal underscores the need for high-albedo materials to mitigate SUHI.

4.2. Comparative SUHI Intensity: Diurnal Variation (11 AM, 2 PM, 3 PM)

The analysis distinguishes the temporal evolution of the SUHI effect across the three daytime periods. Immediate Solar Absorption is the key mechanism driving the extreme temperatures.

- **Peak Heating:** Surfaces like Concrete and Metal show rapid heating and high temperatures, particularly at 11 AM, with Concrete recording the maximum average LST of 50.74°C. This indicates these high-thermal-mass materials are highly efficient at instantaneous solar absorption during the early to mid-day period.

- **Temporal Fluctuation:** The significant Temporal STC of 11.29°C observed on the Asphalt surface (Section 3.1) highlights its high sensitivity to changes in solar radiation throughout the afternoon, reflecting a complex interplay between solar input and convection across the three time points.

4.3. Multi-Scale Validation and the GLOBE Advantage

Highly significant ANOVA results confirm the GLOBE protocol reliably captures thermal differences. Extensive day-and-night measurements in Nakhon Si Thammarat provide robust local data, with good satellite alignment (difference of 1.55°C). Ground measurements excel at resolving micro-scale features that satellites average out, strengthening conclusions on surface material impacts [11, 12, 14].

5. Conclusion

This study successfully quantified the thermal impact of seven distinct surface types in Nakhon Si Thammarat. Statistical analysis confirmed that surface material is the primary driver of microclimate variations ($p < 0.05$). The findings reveal a key diurnal heat challenge characterized by extreme thermal contrast across the surfaces measured at 11 AM, and significant temporal temperature fluctuations in high-absorption materials like asphalt across the 11 AM, 2 PM, and 3 PM measurement periods. Urban planning strategies for Nakhon Si Thammarat must therefore prioritize a two-pronged approach: increasing vegetative cover to combat daytime peaks and reducing the surface area of high-thermal-mass materials to mitigate heat retention.

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Appendices

Appendix A: LST Data (11 AM)

Full Name	Nick name (ชื่อเล่น)	Time (เวลา)	LST Dry Ground (อุณหภูมิบน พื้นดินแห้ง)	LST Grass (หญ้า)	Concrete (คอนกรีต)	LST Metal roof (อุณหภูมิบน หลังคา โลหะ)	LST Water (น้ำ)	LST Trees (อุณหภูมิบน ต้นไม้)	Asphalt
Teehapat Petcharat	Naiinn	11 AM	22.57	23.00	62.47	43.36	29.39	18.00	53.52
Kanpapat Limpitigran ont	JayJay	11 AM	22.89	22.87	62.47	43.56	29.39	18.42	53.52
Adithep Songnoo	Nine	11 AM	22.67	23.00	62.51	43.46	29.39	18.00	53.58
Theethut punchakunat horn	Kendo	11 AM	35.80	18.30	63.60	43.70	29.39	22.90	56.10
Walanorn Saenliao	Eua	11 AM	29.00	30.00	42.64	36.90	35.00	29.60	49.34
Surapong Jitmas	Tonkla	11 AM	30.11	29.60	31.65	30.10	32.40	34.70	48.20

Naphat pherbangkhem	Newton	11 AM	28.60	32.60	42.64	57.10	24.00	26.70	39.20
Manatchai Sangtong	Ozone	11 AM	28.00	30.60	42.64	57.10	24.30	30.50	41.10
Punpitcha Rassameepoing	Tara	11 AM	28.70	30.00	42.64	36.90	35.00	29.60	49.43
Punyaporn Sriwimas	Lothmay	11 AM	32.70	30.00	46.90	36.90	27.50	29.00	47.00
Onchisa Phungam	Earn	11 AM	32.70	30.00	47.00	36.90	27.50	29.60	46.90

Appendix B LST Data (2 PM)

Full Name (ชื่อ-นามสกุล)	Nick name (ชื่อเล่น)	Time (เวลา)	LST Dry Ground (อุณหภูมิบนพื้นดินแห้ง)	LST Grass (หญ้า)	Concrete (คอนกรีต)	LST Metal roof (อุณหภูมิบนหลังคาโลหะ)	LST Water (น้ำ)	LST Trees (อุณหภูมิบนต้นไม้)	Asphalt
Teephapat petcharat	Naiinn	2 PM	30.00	38.30	45.5	54.70	35.70	30.50	52.00
Surapong Jitmas	Tonkla	2 PM	26.50	38.00	43	44.00	32.00	32.00	53.90
Naphat pherbangkhem	Newton	2 PM	31.50	36.80	44.3	45.30	31.40	31.60	51.40
Kanpapat Limpitigrant	JayJay	2 PM	30.00	38.30	45.5	54.70	35.70	30.50	52.00
Theethut punchakunathorn	Kendo	2 PM	30.00	38.30	45.5	54.70	35.70	30.50	52.00
Adithep	Nine	2 PM	30.00	38.30	45.5	54.70	35.70	30.50	52.00

Songnoo									
Walanorn Saenliao	Eua	2 PM	30.00	38.30	54.2	54.70	35.70	30.50	51.00
Punpitcha Rassameepong	Tara	2 PM	31.00	38.30	45.1	54.70	35.80	30.50	53.00
Punyaporn Sriwimas	Lothmay	2 PM	36.40	37.00	46.6	44.00	30.00	29.10	46.60
Onchisa Phungam	Earn	2 PM	36.40	38.40	46.6	44.00	30.00	32.00	46.60
Manatchai Sangtong	Ozone	2 PM	34.6	36.90	36.7	45.60	35.70	30.40	52.40

Appendix C

Day LST Data (3 PM)

Full Name (ชื่อ-นามสกุล)	Nick name (ชื่อเล่น)	Time (เวลา)	LST Dry Ground (อุณหภูมิบน พื้นดินแห้ง)	LST Grass (หญ้า)	Concrete (คอนกรีต)	LST Metal roof (อุณหภูมิบน หลังคา โลหะ)	LST Water (น้ำ)	LST Trees (อุณหภูมิบน ต้นไม้)	Asphalt
Teephapat patcharat	Naiinn	3 PM	38.49	30.50	34	34.30	30.50	41.00	41.20
Surapong Jitmas	Tonkla	3 PM	37.40	30.50	34	34.30	30.50	31.00	41.20
Naphat pherbangkhem	Newton	3 PM	37.20	30.20	33.8	33.00	30.20	31.40	41.00
Kanpapat Limpitigranont	JayJay	3 PM	34.00	35.50	47.2	52.20	32.50	33.00	41.40
Theethut punchakunathorn	Kendo	3 PM	34.00	35.50	47.2	52.20	32.50	33.00	41.40
Adithep Songnoo	Nine	3 PM	34.00	35.50	47.2	52.20	32.50	33.00	41.40

Walanorn Saenliao	Eua	3 PM	34.00	35.50	47.2	51.00	32.50	33.00	41.40
Punpitcha Rassameeping	Tara	3 PM	34.00	35.50	47.2	53.00	32.45	33.00	42.00
Punyaporn Sriwimas	Lothmay	3 PM	29.40	30.50	33.8	30.90	24.00	36.00	33.80
Onchisa Phungam	Earn	3 PM	29.40	30.50	33.8	30.90	32.20	36.00	33.80
Manatchai Sangtong	Ozone	3 PM	34.20	32.70	34.2	50.10	32.40	34.90	40.10

Appendix B: ANOVA Nakhon Si Thammarat 11 AM

Anova: Single Factor

SUMMARY

<i>Groups</i>	<i>Count</i>	<i>Sum</i>	<i>Average</i>	<i>Variance</i>
LST Dry Ground (อุณหภูมิมบนพื้นดินแห้ง)	11	313.74	28.52181818	19.23327636
LST Grass (หญ้า)	11	299.97	27.27	21.1025
Concrete (คอนกรีต)	11	558.15	50.74090909	93.58814909
LST Metal roof (อุณหภูมิมบนหลังคาโลหะ)	11	465.98	42.36181818	70.95347636
LST Water (น้ำ)	11	323.26	29.38727273	13.41086182

LST Trees (อุณหภูมิมบน ต้นไม้)	11	287.02	26.09272727	33.92818182
Asphalt	11	537.89	48.89909091	27.99356909

ANOVA

<i>Source of Variation</i>	<i>SS</i>	<i>df</i>	<i>MS</i>	<i>F</i>	<i>P-value</i>	<i>F crit</i>
Between Groups	7677.342862	6	1279.557144	31.96495322	0	2.23119242
Within Groups	2802.100145	70	40.03000208			
Total	10479.44301	76				

2 PM

Anova: Single
Factor

SUMMARY

<i>Groups</i>	<i>Count</i>	<i>Sum</i>	<i>Average</i>	<i>Variance</i>
LST Dry Ground (อุณหภูมิมบนพื้นดิน แห้ง)	10	311.8	31.18	9.277333333
LST Grass (หญ้า)	10	380	38	0.3488888889
Concrete (คอนกรีต)	10	461.8	46.18	9.037333333
LST Metal roof (อุณหภูมิมบนหลังคา โลหะ)	10	505.5	50.55	28.845
LST Water (น้ำ)	10	337.7	33.77	6.657888889

LST Trees (อุณหภูมิตนไม้)	10	307.7	30.77	0.7712222222
Asphalt	10	510.5	51.05	6.140555556

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	4770.741714	6	795.123619	91.12683917	0	2.246407983
Within Groups	549.704	63	8.725460317			
Total	5320.445714	69				

3 PM

Anova: Single Factor

SUMMARY

Groups	Count	Sum	Average	Variance
LST Dry Ground (อุณหภูมิตนพื้นดินแห้ง)	11	376.09	34.19	8.3923
LST Grass (หญ้า)	11	362.4	32.94545455	6.414727273
Concrete (คอนกรีต)	11	439.6	39.96363636	48.01454545
LST Metal roof (อุณหภูมิตนหลังคาโลหะ)	11	474.1	43.1	101.242
LST Water (น้ำ)	11	342.25	31.11363636	6.450045455

LST Trees (อุณหภูมิบนต้นไม้)	11	375.3	34.11818182	7.841636364
Asphalt	11	438.7	39.88181818	9.245636364

ANOVA

<i>Source of Variation</i>	<i>SS</i>	<i>df</i>	<i>MS</i>	<i>F</i>	<i>P-value</i>	<i>F crit</i>
Between Groups	1316.098579	6	219.3497632	8.184653788	0.00000102030231	2
Within Groups	1876.008909	70	26.80012727			2.23119242
Total	3192.107488	76				

I would like to claim IVSS badges

1. I have an impact

The report clearly describes how a local issue gave rise 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 comparative study of Trang, Saraburi, and Suphanburi ground measurements against satellite data

2. I am a STEM professional.

The report clearly describes a collaboration with a STEM professional that improved the research methodology, increased rigor, and enabled more sophisticated analysis and interpretation of the results. Data were analyzed, and graphs were created to illustrate relationships.

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 collecting data from other academic institutions or from external databases. We developed a Mapping and identification of urban heat island hotspots in Thailand: a comparative study of ground measurements in Trang, Saraburi, and Suphanburi against satellite data.