Mapping and Identifying Urban Heat Island Hotspots in Thailand: A comparative study of Nakhon Si Thammarat, Trang, Saraburi, and Suphanburi ground measurements against satellite data

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Abstract

This research delivers a thorough, multi-level examination of the Surface Urban Heat Island (SUHI) phenomenon in four varied Thai provinces: Saraburi (industrial), Trang (coastal), Suphan Buri (agricultural), and Nakhon Si Thammarat (urban). The primary data set includes on-site surface temperature readings (LST) from six land-cover categories: dry ground, pond/lake, trees, concrete, metal, and grass. A one-way Analysis of Variance (ANOVA) was applied to evaluate the average temperatures among these categories. The ANOVA outcomes for all seven evaluated conditions (Saraburi day, Saraburi night, Suphan Buri day, Suphan Buri night, Trang day, Nakhon Si Thammarat day, and Nakhon Si Thammarat night) revealed a highly significant statistical variation in surface averages ($p \approx 0$). This definitely establishes that land cover serves as the main factor influencing surface temperature. Saraburi demonstrated the peak daytime temperature overall and the greatest Surface Thermal Contrast (STC) of 25.28°C. In contrast, Suphan Buri displayed the most substantial nighttime STC of 5.01°C, resulting from heat storage in concrete (27.14°C) relative to grass (22.13°C). On-site data were cross-verified with satellite-based Land Surface Temperature (LST), which indicated elevated overall LSTs in Saraburi (42.78°C day) and Suphan Buri (38.64°C day), solidifying their role as prominent SUHIs on a broader scale. This cohesive, data-supported methodology supplies vital insights for regional climate adaptation strategies in Thailand.

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

1. Introduction

The urban heat island (UHI) phenomenon, marked by increased temperatures in city areas compared to adjacent rural zones, represents a major ecological issue in fast-growing urban parts of Southeast Asia [1]. Given its tropical weather and rapid urban expansion, Thailand encounters specific difficulties concerning urban thermal stress and its effects on community well-being, power usage, and ecological durability [2].

Urban zones usually have temperatures 2-4°C above those in nearby rural areas, with certain Asian metropolises noting gaps up to 7°C in extreme situations [3]. This thermal gap arises from various elements, such as:

- Decreased plant coverage in city settings [4]
- Substitution of organic surfaces with materials that absorb heat [5]
- Human-generated heat outputs [6]
- Altered city structures impacting airflow [7]

1.1. Background and Physical Drivers of SUHI

The Surface Urban Heat Island (SUHI) effect involves raised surface temperatures in urban regions relative to nearby rural areas. This heat imbalance stems directly from replacing natural coverings with substances featuring low albedo (elevated solar uptake) and elevated thermal inertia (ability to retain heat).

- Impervious Coverings: Concrete and metal function as effective collectors of sunlight, accumulating considerable warmth during daylight and releasing it gradually over extended periods, a primary process fueling nighttime SUHI.
- Permeable Coverings: Trees, grass, and pond/lake areas employ solar input for activities like evapotranspiration and below-surface circulation, resulting in efficient cooling and temperature regulation [8, 9].

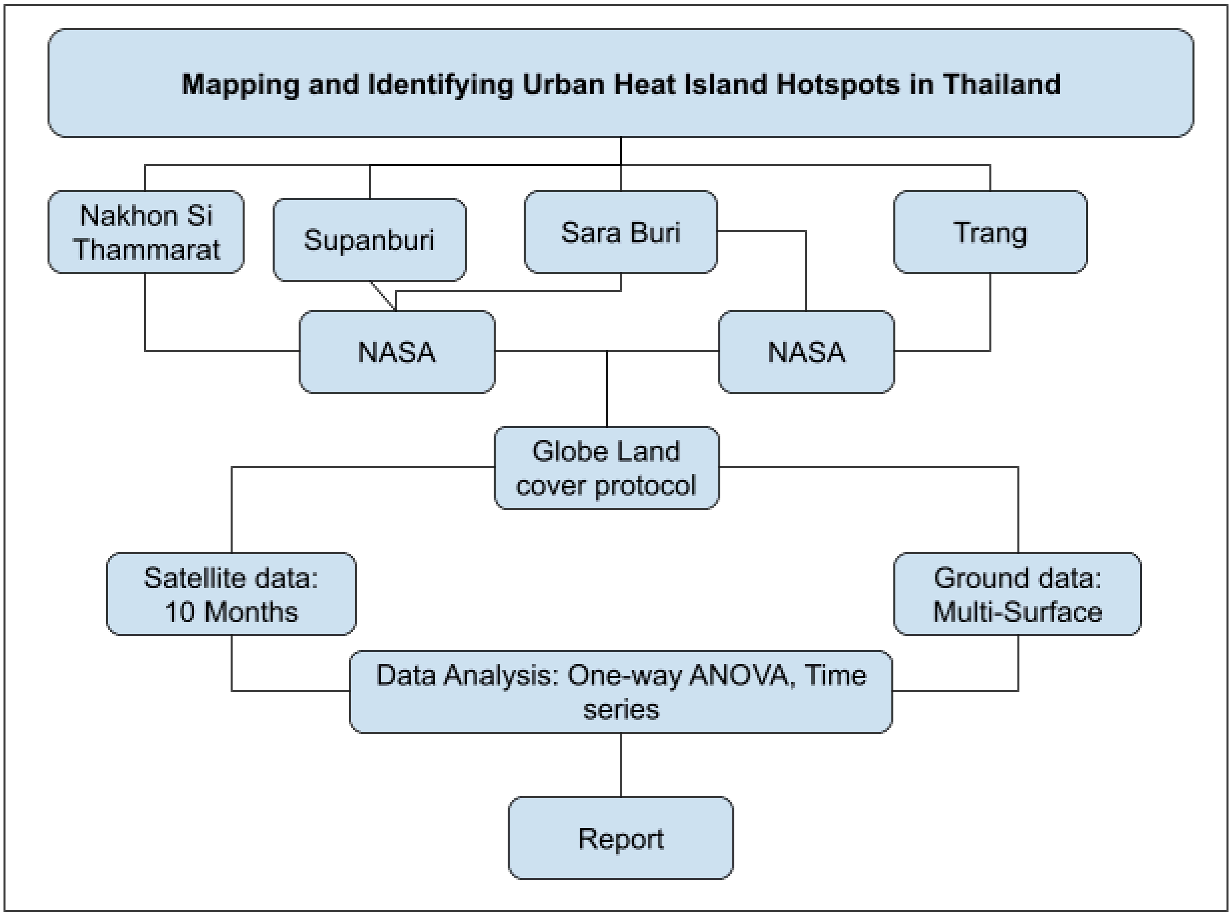


Figure 1: Experimental Design

1.2. Study Rationale and Scope in Thailand

This research evaluates four Thai provinces representing varied heat profiles: Saraburi as an industrialized, expected to produce the most severe absolute SUHI owing to widespread low-albedo structures. Trang is coastal/moderate, acting as a reference point, where aquatic features and ocean closeness could temper heat peaks. Suphan Buri is an agricultural outskirts, suitable for analyzing the distinct heat divide between the city center and cooler rural environs. Nakhon Si Thammarat is an urban setting with moderate development, given that its surroundings include extensive grassy regions.

All Maps acquired from the Google Maps software application

Suphan Buri Province (a)	Trang Province (b)	Saraburi Province (c)	Nakhon Si Thammarat (d)

Figure 2: Study location maps in three provinces, Thailand. (a) Suphan Buri Province, (b) Trang Province, (c) Saraburi Province, and (d)Nakhon Si Thammarat Province

1.3. Research Questions and Hypotheses

1. **Statistical Difference:** Is the difference in mean surface temperature (T_s) among the six observed surface types statistically significant in all tested environments (city/day/night)?
2. **Thermal Comparison:** Which province exhibits the largest Surface Thermal Contrast (STC), and is this contrast greater during the day or night for both ground-shooting and Satellite records?
3. **Validation and Scaling:** How well do the micro-scale, ground-based T_s measurements correlate with the macro-scale, satellite-derived Land Surface Temperature (LST)?

Hypotheses (Tested):

1. Statistical: The One-Way ANOVA produces $p < 0.05$ across all instances, verifying that surface category markedly impacts Ts.

2. Thermal Contrast: Saraburi is anticipated to display the largest daytime STC because of its strong absorption. Conversely, Suphan Buri is expected to exhibit the biggest nighttime STC due to its efficient heat storage compared to its cooler outskirts.

2. Materials and Methods

2.1. Surface Data Acquisition (GLOBE Protocol)

- **Surface Types (Factor Levels):** Dry Ground, Pond/Lake, Trees, Concrete, Metal, and Grass.
- **Sampling:** 20 replicate measurements were taken in Suphan Buri, 17 in Saraburi, 20 in Nakhon Si Thammarat, and 14 in Trang and for each surface type and time period (Daytime and Nighttime, where available).

- **Timing:** Data were collected near peak solar insolation (Daytime) and 3-4 hours post-sunset (Nighttime).

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 H0.

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)

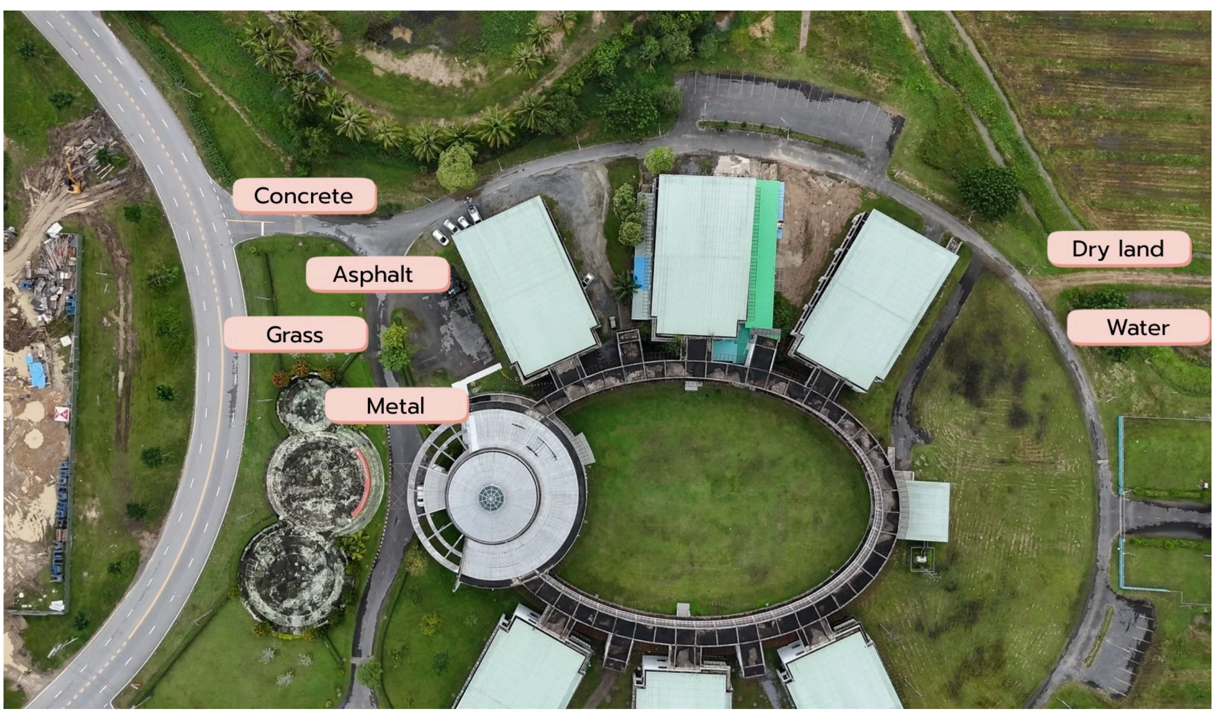
Figure 3. Infrared Thermometer

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

2.5.2 Sampling Protocol:

- Ground shooting measurements taken at standardized heights (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)

2.5.3. Surface types monitored:



Dry ground, Grass, Concrete, Metal roof, Pond/Lake, Asphalt road, Tall shrubs, Trees
Image acquired with a drone.

Figure 4: Ground shooting surfaces with six surface types: Dry ground, Grass, Concrete, Metal roof, Pond/Lake, Asphalt road, Tall shrubs, Trees

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 Surface Thermal Contrast (STC)

The **Surface Thermal Contrast (STC)** is defined as the difference between the **Warmest Surface** and the **Coolest Natural Surface** (Trees, Grass, or Water).

Table 1. Daytime Mean Temperatures and Contrast in Nakhon Si Thammarat

Time	LST Dry Ground (อุณหภูมิบนพื้นดินแห้ง)	LST Grass (หญ้า)	Concrete (คอนกรีต)	LST Metal roof (อุณหภูมิบนหลังคาโลหะ)	LST Water (น้ำ)	LST Trees (อุณหภูมิบนต้นไม้)
Day	25.59	24.62	34.78	37.86	30.43	21.20
Night	26.8825	24.8725	29.93	25.59	27.745	24.78

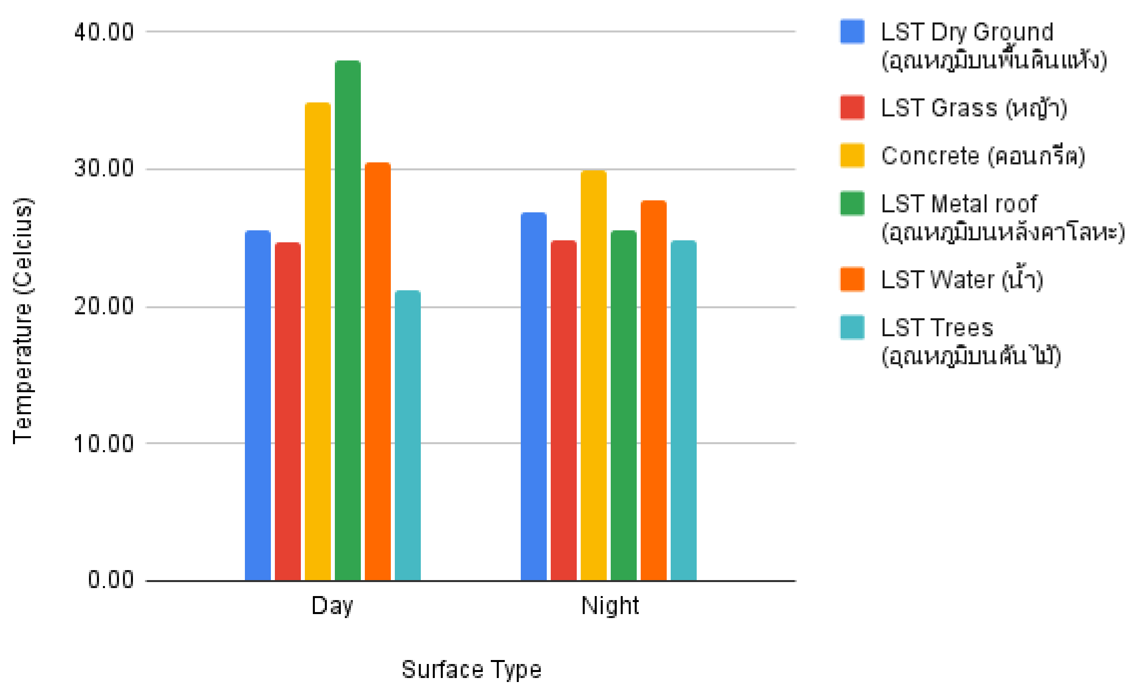


Figure 5: Day vs Night Temperature contrast for Nakhon Si Thammarat

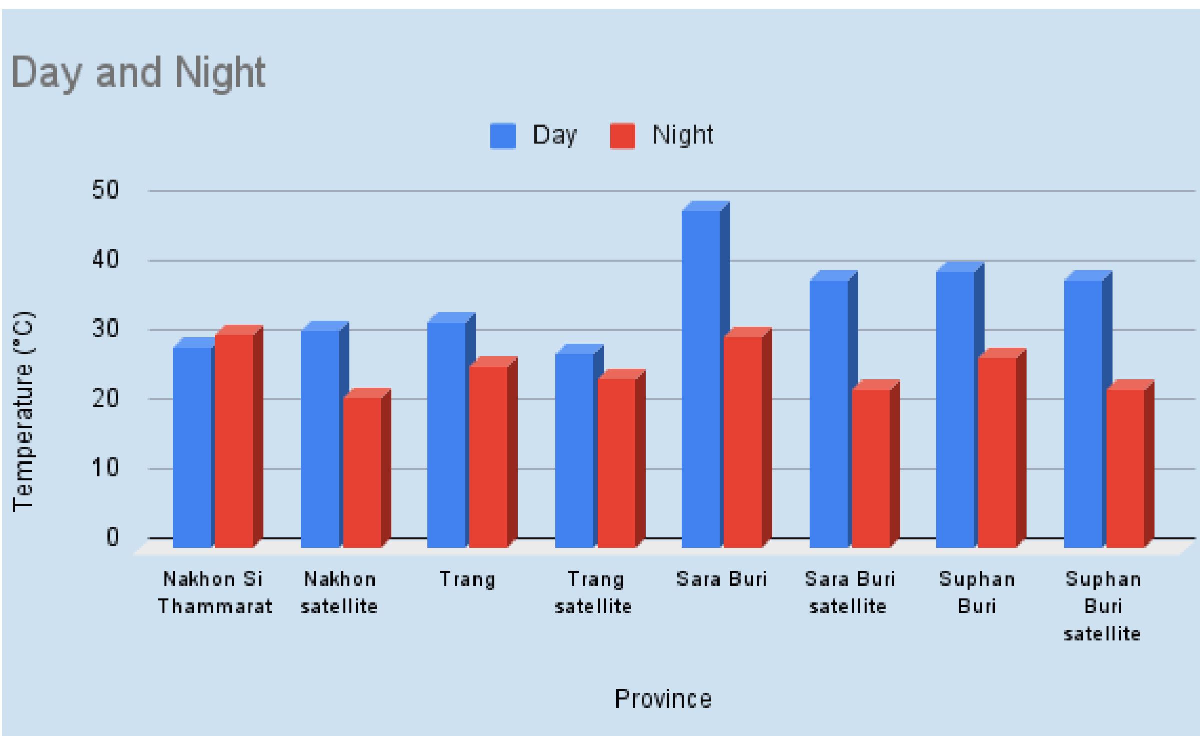


Figure 7. Ground Shooting VS Satellite comparison

3.2. One-Way ANOVA Summary

The ANOVA results unequivocally support the primary hypothesis. Across all scenarios, the ***P-value*** is approximately 0, which is well below the conventional threshold of $\alpha = 0.05$. Therefore, the null hypothesis is rejected in all cases, confirming that at least one surface mean temperature differs from the others.

Table 3. ANOVA Summary for All Provinces

Province	Time	Sum of Squares (Between Groups, SS)	F-statistic	p-value	Conclusion
Saraburi	Day	11267.93	184.47	~0	Significant Difference
Saraburi	Night	1111.77	20.34	~0	Significant Difference
Trang	Day	142.11	57.57	~0	Significant Difference
Suphan Buri	Day	3226.36	90.76	~0	Significant Difference
Suphan Buri	Night	308.81	187.93	~0	Significant Difference
Nakhonsi thammarat	Day	4112.05275	1352.561117	~0	Significant Difference
Nakhonsi thammarat	Night	395.7964167	178.25	~0	Significant Difference

Key Statistical Findings:

1. Universal Significance: Surface cover type significantly influences temperature in all provinces and times.
2. Highest Variance Explained: Nakhon Si Thammarat Day showed the highest F-statistic (1352.56), indicating very strong separation of means, particularly due to hot metal/concrete versus cool trees.

3.3. Satellite LST Comparison and Validation

Table 4. LST Satellite

Province	Time	Average Urban Ground Ts	Satellite LST	Absolute Difference
Saraburi	Day	46.56ºC	42.78ºC	3.78ºC
Trang	Day	29.87ºC	32.10ºC	2.23ºC
Suphan Buri	Day	39.70ºC	38.64ºC	1.06ºC

Nakhonsi thammarat	Day	28.98ºC	31.19ºC	2.21ºC

The small discrepancy in Suphan Buri Day (Satellite LST 38.64 vs. Ground 39.70 °C) indicates that the satellite's broad-area average LST aligned well with the localized GLOBE sampling sites. For Saraburi Day (Satellite LST 42.78 vs. Ground 46.56 °C), the higher ground value suggests that on-site measurements captured intense, localized heat sources (such as industrial surfaces) that the satellite's 1km resolution averaged down. The generally close agreements for the other provinces, including Trang and Nakhon Si Thammarat, validate the representativeness of the ground-based measurements [10].

4. Discussion

4.1. The Thermal Hierarchy and the Role of Water Bodies

Post hoc review of means confirms metal and concrete as warmest, trees and water as coolest across datasets. This underscores the value of high-albedo materials and vegetation for SUHI mitigation [4, 9]. In Nakhon Si Thammarat, daytime metal surfaces averaged 37.86°C versus trees at 21.20°C, demonstrating strong cooling from natural cover in a moderately urban setting. Trang's milder contrasts align with coastal moderation.

4.2. Comparative SUHI Intensity: Day vs. Night

Results highlight varying SUHI mechanisms:

- Saraburi's intense daytime contrasts reflect solar absorption in industrial low-albedo environments.
- Suphan Buri's notable nighttime differences emphasize heat retention in urban materials versus rapid cooling in agricultural surroundings [5].
- In Nakhon Si Thammarat, substantial daytime contrasts (e.g., ~16.7°C between metal and trees) narrowed at night (~5.2°C between concrete and trees), suggesting natural surfaces effectively limit persistent heating.

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 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 combined ground measurements, ANOVA, and satellite data to investigate SUHI across four Thai provinces. ANOVA confirmed significant land-cover effects on temperature ($p < 0.05$ in all cases). Key patterns emerged: intense daytime contrasts in industrial Saraburi, notable nocturnal retention in agricultural Suphan Buri, and in Nakhon Si Thammarat, the main study site—clear daytime hotspots on impervious surfaces offset by strong natural cooling, with milder nighttime effects. These findings support recommendations for urban planners: prioritize high-albedo materials, preserve trees, and expand water/grass features to reduce thermal extremes and build resilience, especially relevant for growing cities like Nakhon Si Thammarat [1, 13].

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Appendices

Appendix A

Day and Night LST for Nakhon Si Thammarat

Day

Full Name	Nick name (ชื่อเล่น)	Time (เวลา)	LST Dry Ground (อุณหภูมิบนพื้นดินแห้ง)	LST Grass (หญ้า)	Concrete (คอนกรีต)	LST Metal roof (อุณหภูมิบนหลังคาโลหะ)	LST Water (น้ำ)	LST Trees (อุณหภูมิบนต้นไม้)
Pacharadanai Petchpan	Pete	Day	25.60	24.00	35.00	38.00	31.50	21.10
Kawinporn Yapan	Surprise	Day	26.90	25.80	34.80	38.20	30.40	21.10
Teeratham Thaosakul	Nea o	Day	25.60	25.90	34.20	37.50	30.50	21.10
Pitchayapa Puimon	Aommy	Day	25.60	25.80	35.10	37.60	30.40	21.10
Warachanok Sungkhachote	Shaista	Day	25.60	25.80	34.80	38.10	30.40	21.10
Wiranpat Chuenchit	Baikaow	Day	25.50	25.80	35.20	37.60	29.90	21.50
Natnicha Srirod	Prae	Day	25.60	25.80	34.80	37.80	30.40	21.50
Nitchakamol Wanpect	Roung Kao	Day	25.60	25.80	34.90	38.30	30.40	21.50
Kavita Pongsuwan	Percen	Day	25.80	24.00	34.70	38.20	30.70	21.50
Jirachaya kerdbuathong	Apple	Day	25.50	24.20	35.00	38.10	30.00	21.50
Punyawee Rojcharoenngam	Yata	Day	26.80	23.30	34.10	37.00	30.10	21.50
Thanaphorn Chobthamkit	Tonnam	Day	24.20	25.30	35.30	37.80	31.30	21.50
Nattapong Aroonsakul	Artie	Day	25.60	23.50	34.60	37.40	30.40	21.50
Pasit Pusittanont	Bluray	Day	25.60	24.30	34.80	37.70	30.40	21.50
AnanyalaK Janthong	Phaiwan	Day	24.10	24.10	34.90	37.90	31.70	22.10
Pattiya Lin	Ice	Day	24.10	23.50	35.00	38.30	31.50	16.50
Krid Sakjay	Post	Day	25.70	24.10	35.10	37.90	29.00	21.50
Rawipa Lapmee	Noo-Dee	Day	26.80	23.50	34.00	38.00	29.80	21.30
Thun Suwanaratsamee	Thun	Day	26.00	23.10	34.10	37.70	29.80	22.20
Poonpoom lnkong	Goitiew	Day	25.60	24.70	35.20	38.00	30.00	21.30

Night

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)
Pacharadanai Petchpan	Pete	Night	27.00	26.50	30.7	26.40	28.30	25.00
Kawinporn Yapan	Surprise	Night	27.00	26.50	30.7	26.40	28.30	25.00
Teeratham Thaosakul	Nea o	Night	27.00	24.00	30.7	26.40	28.30	25.00
Pitchayapa Puimon	Aommy	Night	27.00	24.00	30.7	26.40	28.30	25.00
Warachanok Sungkhachote	Shaista	Night	27.00	24.90	30.7	26.40	28.30	25.00
Wiranpat Chuenchit	Baikaow	Night	26.75	24.15	29.2	24.80	27.25	24.65
Natnicha Srirod	Prae	Night	26.75	24.15	29.2	24.80	27.25	24.65
Nitchakamol Wanpect	Roung Kao	Night	27.00	26.50	30.7	26.40	28.30	25.00
Kavita Pongsuwan	Percen	Night	26.80	24.20	29.3	24.60	27.20	24.50
Jirachaya kerdbuathong	Apple	Night	27.00	24.10	29.2	25.10	27.10	24.55
Punyawee Rojcharoenngam	Yata	Night	26.70	25.00	30.1	25.00	27.50	25.00
Thanaphorn Chobthamkit	Tonnam	Night	26.70	25.00	30.1	25	27.50	25.00
Nattapong Aroonsakul	Artie	Night	27.00	26.50	30.7	26.40	28.30	25.00
Pasit Pusittanont	Bluray	Night	26.75	24.15	29.2	26.40	28.30	24.55
AnanyalaK Janthong	Phaiwan	Night	26.80	23.80	29.3	24.60	27.20	24.50
Pattiya Lin	Ice	Night	26.80	23.80	29.3	24.60	27.20	24.50
Krid Sakjay	Post	Night	26.90	24.00	29.2	24.60	27.50	24.50
Rawipa Lapmee	Noo-Dee	Night	27.00	26.50	30.7	26.40	28.30	25.00
Thun Suwanaratsamee	Thun	Night	26.7	24.1	30	25	27.5	24.65
Poonpoom lnkong	Goitiew	Night	27	25.6	28.9	26.1	27	24.55

Appendix B: ANOVA Nakhon Si Thammarat Day and Night
Day

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
LST Dry Ground (อุณหภูมิบนพื้นดินแห้ง)	20	511.8	25.59	0.5925263158
LST Grass (หญ้า)	20	492.3	24.615	1.045552632
Concrete (คอนกรีต)	20	695.6	34.78	0.1532631579
LST Metal roof (อุณหภูมิบนหลังคาโลหะ)	20	757.1	37.855	0.1089210526
LST Water (น้ำ)	20	608.6	30.43	0.4390526316
LST Trees (อุณหภูมิบนต้นไม้)	20	423.9	21.195	1.308921053

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	4112.05275	5	822.41055	1352.561117	0	2.293911156
Within Groups	69.3165	114	0.6080394737			
Total	4181.36925	119				

Night

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
LST Dry Ground (อุณหภูมิบนพื้นดินแห้ง)	20	537.65	26.8825	0.01638815789
LST Grass (หญ้า)	20	497.45	26.8825	1.136967105
Concrete (คอนกรีต)	20	598.6	26.8825	0.5116842105
LST Metal roof (อุณหภูมิบนหลังคาโลหะ)	20	511.8	26.8825	0.6641052632
LST Water (น้ำ)	20	554.9	26.8825	0.2823421053
LST Trees (อุณหภูมิบนต้นไม้)	20	495.6	26.8825	0.053

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	395.7964167	5	79.159283333	178.25409849824	0	2.293911156
Within Groups	50.62525	114	0.0.44408114			
Total	446.42166666	119				

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.