

Tackling and evaluating Urban Heat Island (UHI) effect in Singapore: *Greeneries Perspective*

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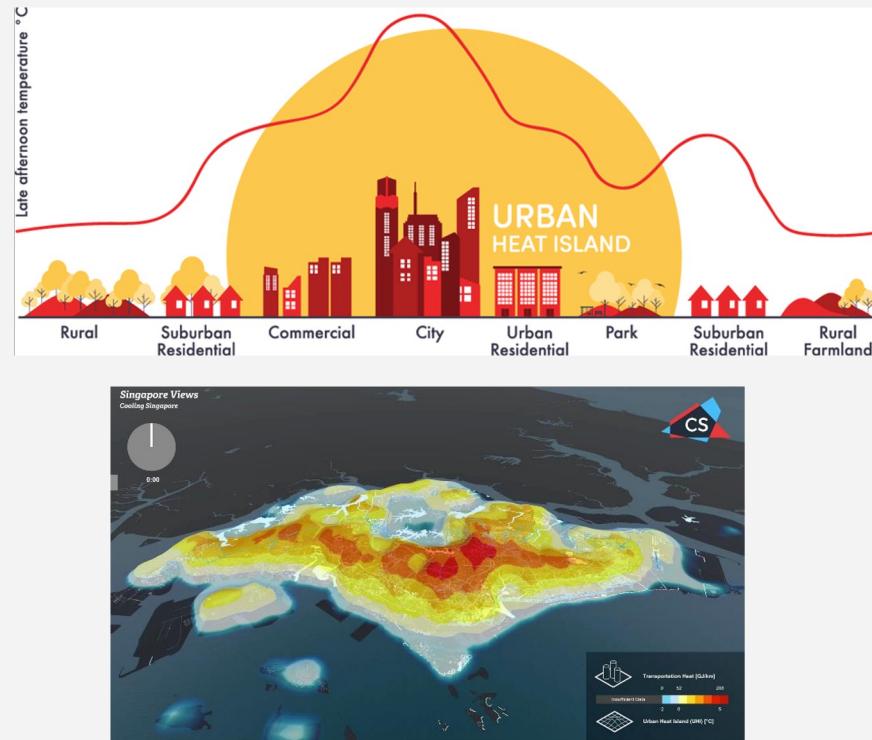
1.1. Motivation and Objective

Urban Heat Island (UHI) Effect:

The phenomenon of cities or urban regions' temperatures is higher than their surrounding rural areas.

Influences of UHI Effect:

- ❖ Air-pollution levels
- ❖ More occurrences of heat-related illnesses



COOL IT DOWN!

TACKLING URBAN HEAT ISLAND EFFECT IN SINGAPORE

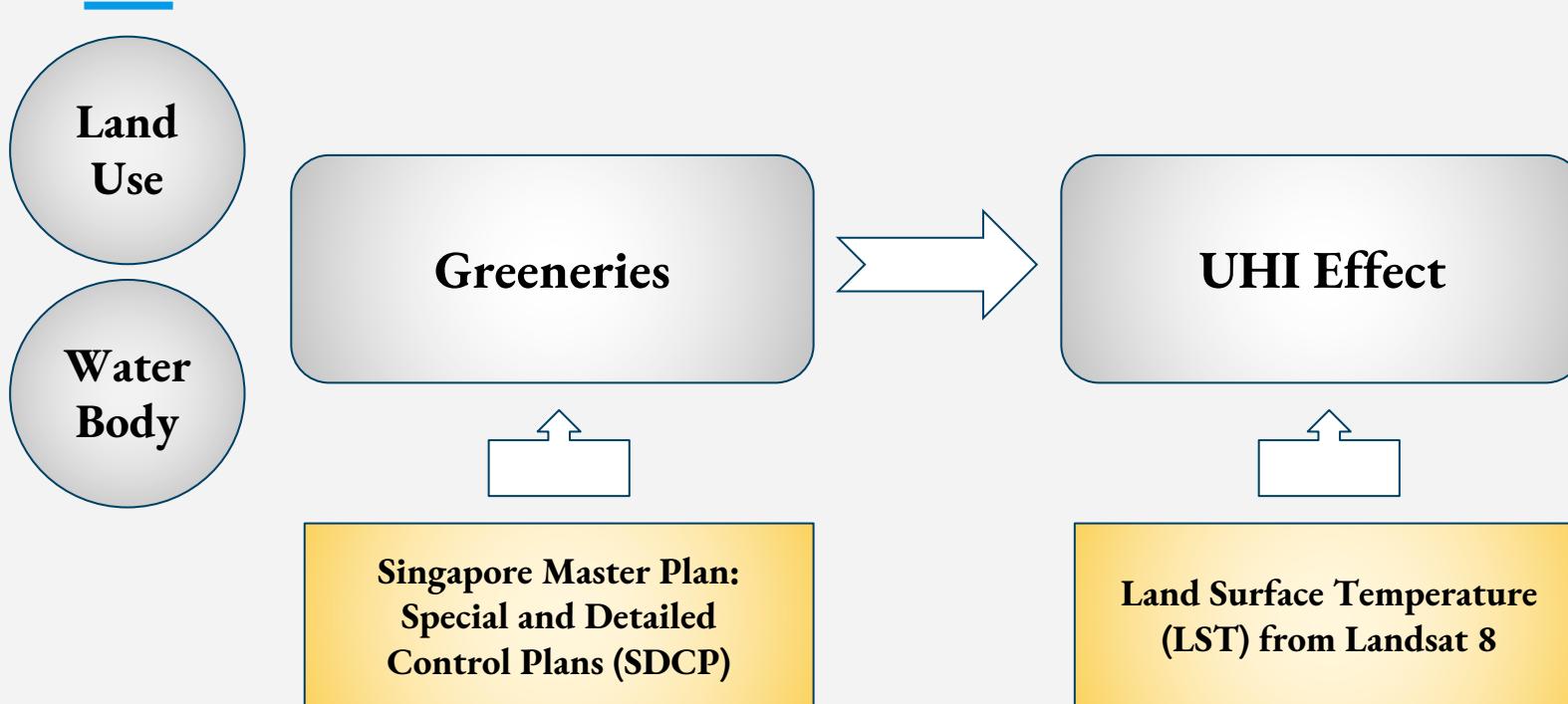


2. Spatial Research Questions

We are interested in the *effectiveness of urban green spaces* as a role in improving against *UHI effect* in Singapore.

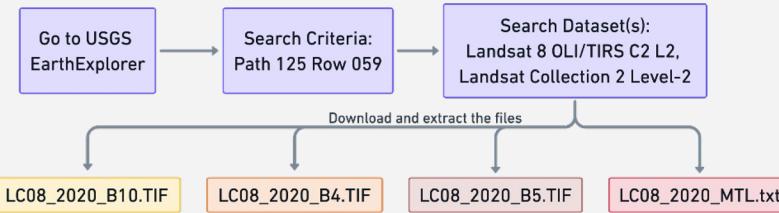
1. How do **greeneries in general**, and how do different types of greeneries contribute to the various distribution of **Land Surface Temperature (LST)** in Singapore?
2. How would **other factors** (e.g. land uses, water bodies) influence the effectiveness of newly constructed green spaces in reducing the local Land Surface Temperature (LST) in Singapore?

3.1.1. Methods - Data



3.1.2. Methods - Data

Landsat 8 Data Pre-Processing



Calculate the temperature data by raster calculator function in QGIS:

1. Calculate Top of Atmosphere (TOA) Radiance:

$$L\lambda = ML * Qcal + AL$$

2. Top of Atmosphere (TOA) Brightness Temperature:

$$BT = K2 / \ln(K1 / (\lambda + 1)) - 273.15$$

3. Normalized Differential Vegetation Index (NDVI):

$$NDVI = (NIR - RED) / (NIR + RED)$$

4. Land Surface Emissivity (LSE):

$$E = ((NDVI - \min(NDVI)) / (\max(NDVI) + \min(NDVI)))^2 * 0.004 + 0.986$$

5. Land Surface Temperature (LST):

$$LST = BT / 14380 * \ln(E) * 10.8$$

We use Landsat 8 satellite data to derive the *distribution of Land Surface Temperature (LST)* in Singapore.

Processes

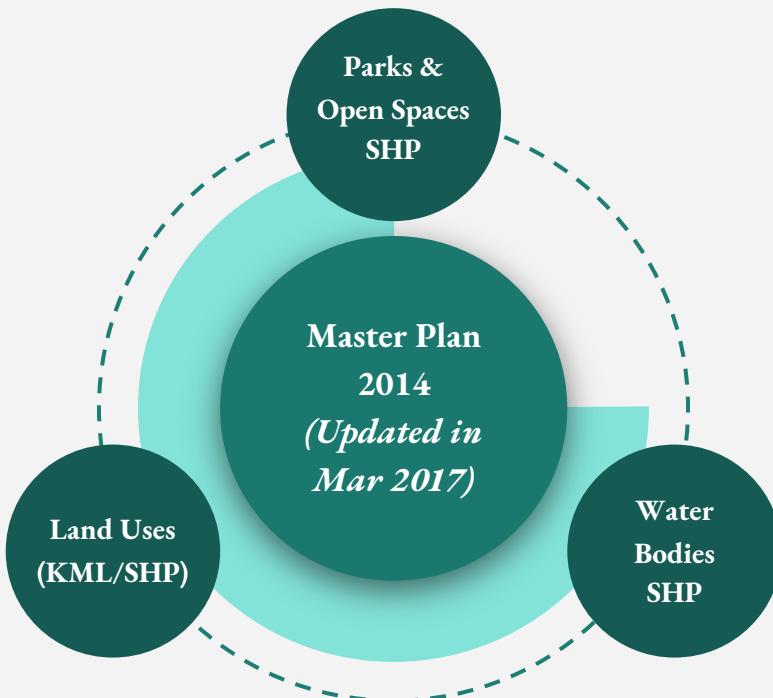
Other

Calculation

Output



3.1.3. Methods - Data



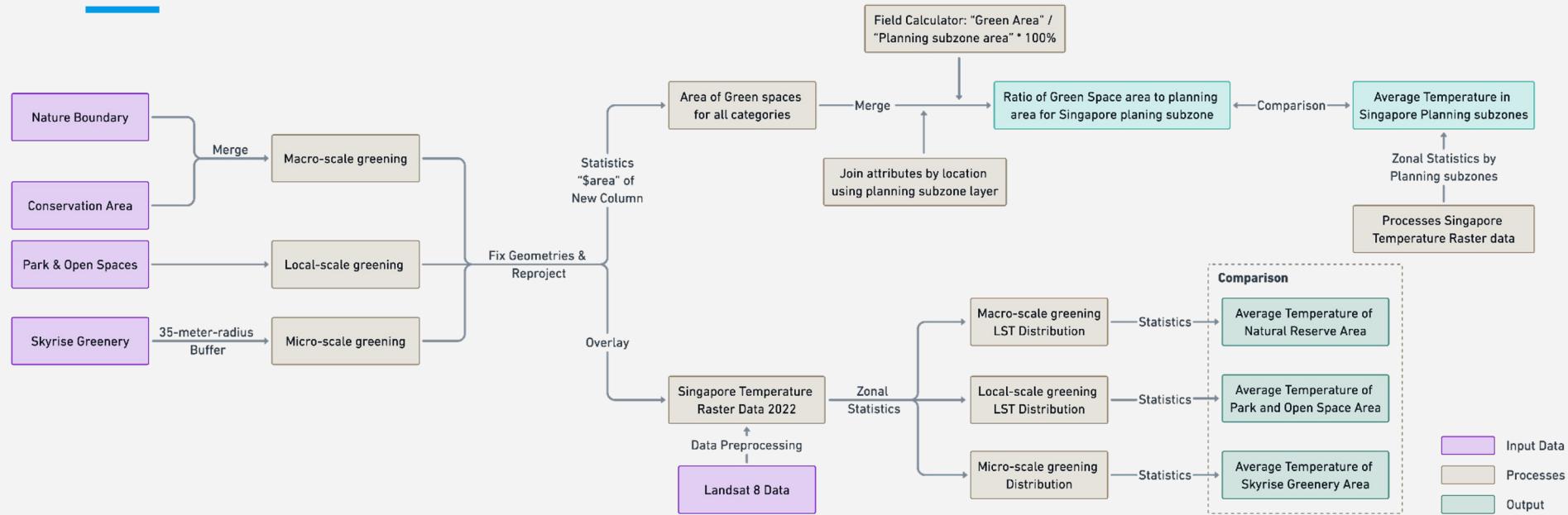
Wait a minute!

Q: “What do you mean by different types of greeneries, and how it relates to the greeneries SHP files you mentioned in the last slide?”

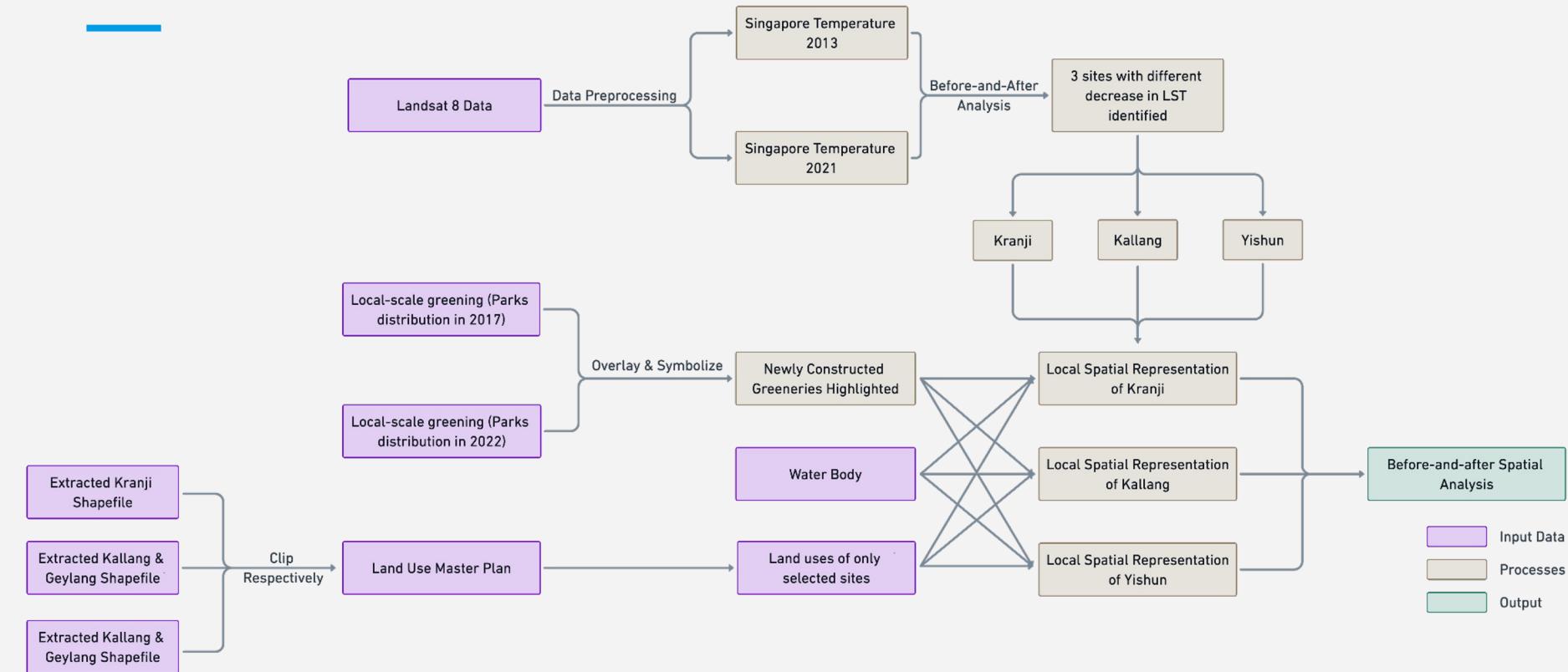
A:

Greeneries Types	Corresponding SHP files in <i>Singapore's open data portal</i>
 Macro-scale greening	National Boundary & Conservation Area
 Local-scale greening	Parks & Open Spaces
 Micro-scale greening	Skyrise Greenery

3.2.1. Spatial Methods for Question 1



3.2.2. Spatial Methods for Question 2



4.1.1. Findings - Research Question 1

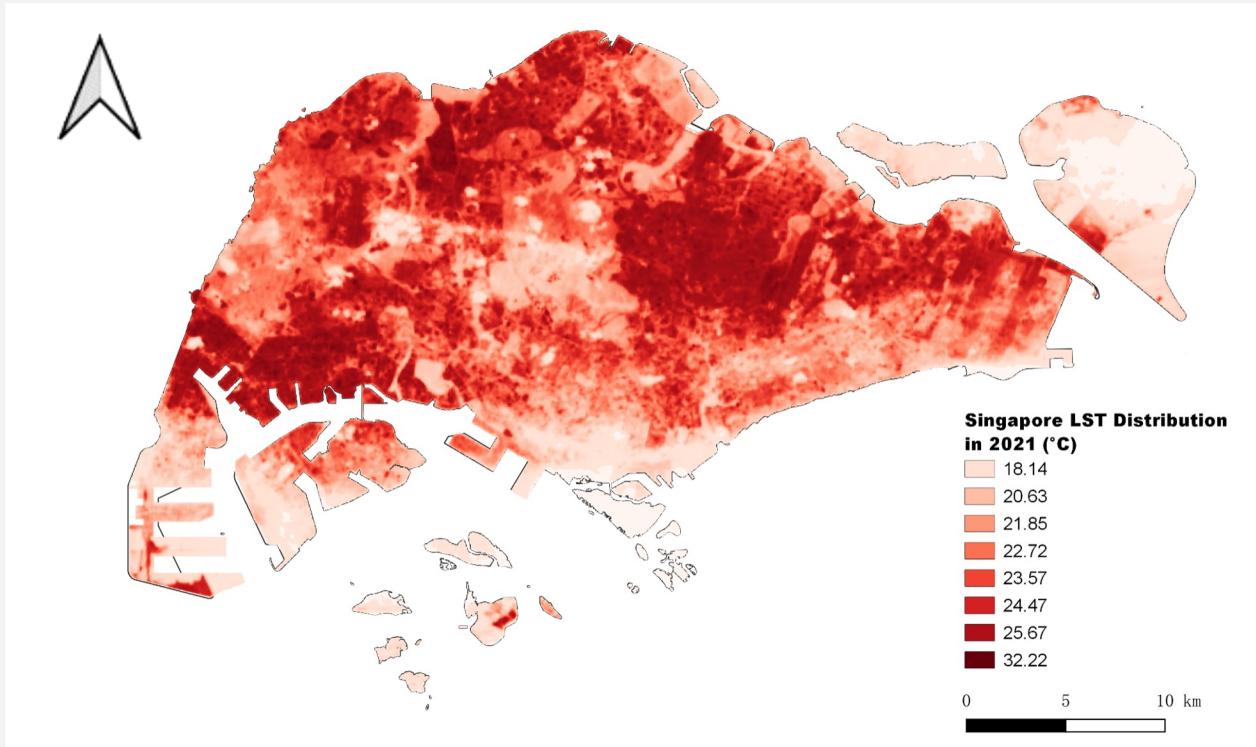


Figure 1: The Raster Layer of Continuous Average Land Surface Temperature (LST) in 2021 in Singapore
(Created on 06/04/2022 by Tianyu Wu & Simon Han)

4.1.2. Findings - Research Question 1

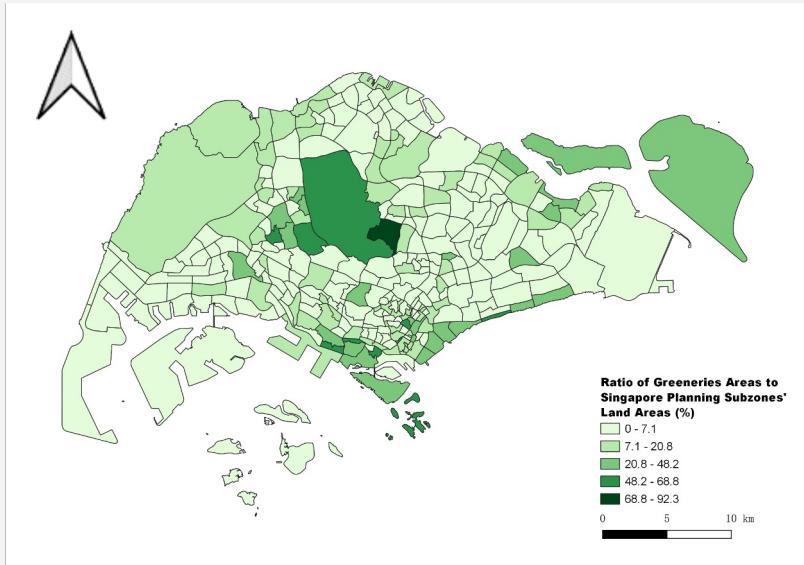


Figure 2: The Distribution of Greenery Ratio out of Singapore Planning Subzones in 2021
(Created on 06/04/2022 by Tianyu Wu & Simon Han)

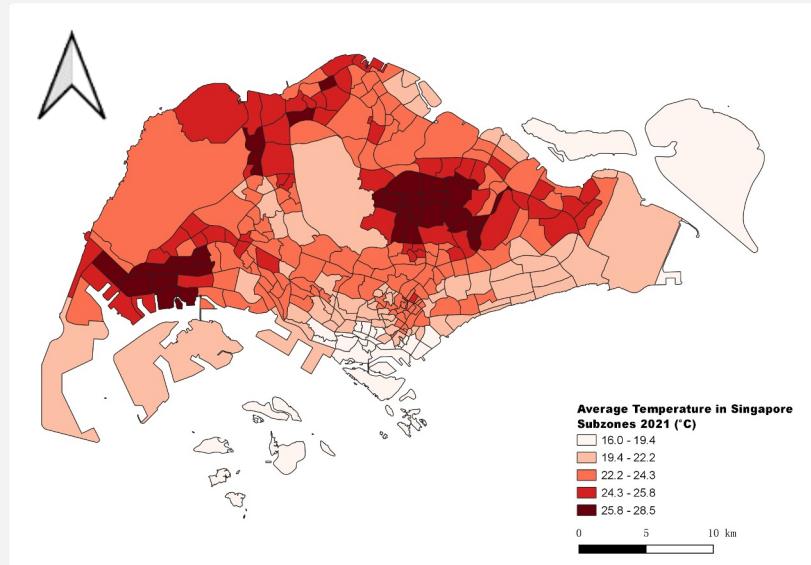


Figure 3: The Distribution of Average LST in Singapore Planning Subzones in 2021
(Created on 06/04/2022 by Tianyu Wu & Simon Han)

4.1.3. Findings - Research Question 1

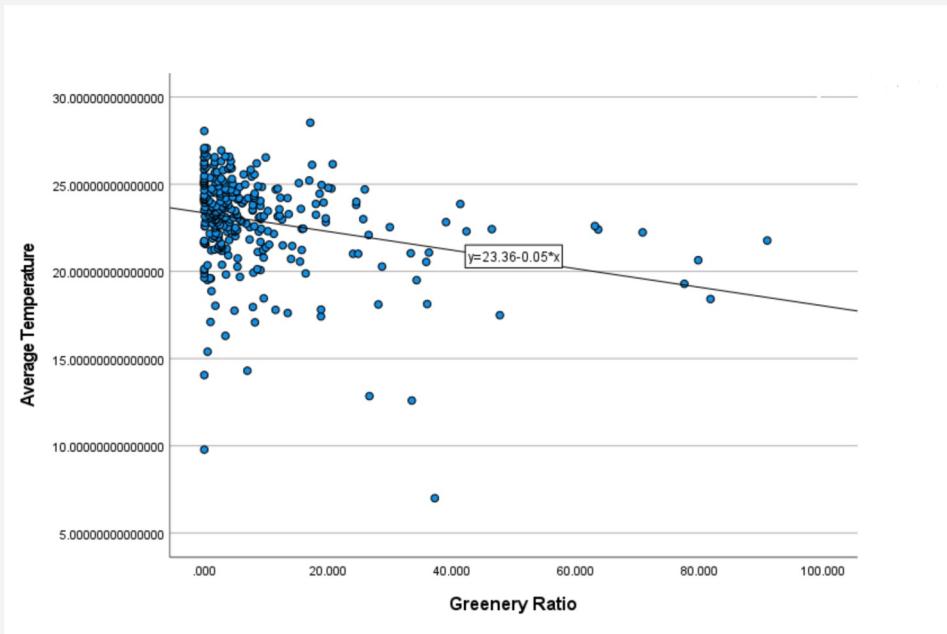


Figure 4: Regression Analysis between Greenery Ratio and Average LST of Singapore Planning Subzones in 2021
(Created on 07/04/2022 by Tianyu Wu & Simon Han)

- Scatter plots of the average temperature and percentages of greenery areas out of total land areas out of all Singapore Planning Subzones.
- **The Linear Regression Model**
 - X-axis: greenery ratio
 - Y-axis: average temperature
 - Regression Line: $Y = 23.36 - 0.05 * X$
- **Interpretation**
 - Ceteris paribus, 1% increase in the greenery ratio will result in a 0.05°C decrease in subzone average temperature.
- $R^2: 0.132$
 - Other explanatory variables may also account for the decrease of temperature.

4.1.4. Findings - Research Question 1

Greeneries Types	Average Temperature
National Boundary & Conservation Area 	19.63 °C
Parks & Open Spaces 	22.20 °C
Skyrise Greenery (with buffer) 	22.91 °C

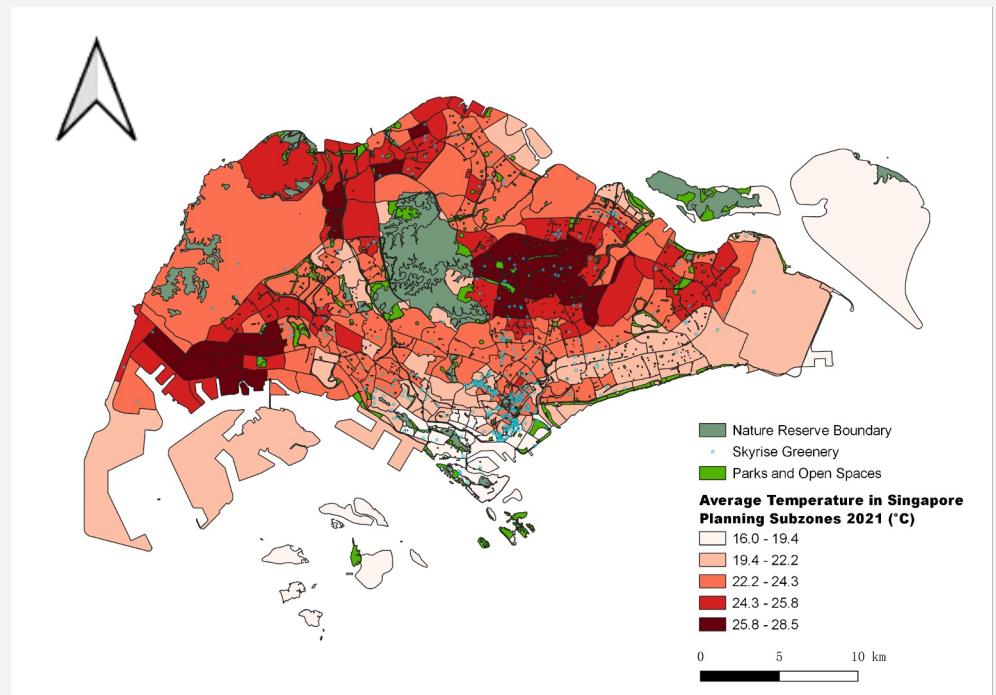


Figure 5: The Distribution of Different Categories of Greeneries in Singapore
(Created on 08/04/2022 by Tianyu Wu & Simon Han)

4.2.1. Findings - Research Question 2 (Before-and-after Analysis)

Comparison of the Average Temperature between 2013 and 2021:

- Overall trend is **decreasing**.
- Interested sites of research:
 - Increase in greeneries area (e.g. parks);
 - Decrease OR remain in temperature.
- Among the above sites, we are curious why particular places decreased in temperature, while some did not?

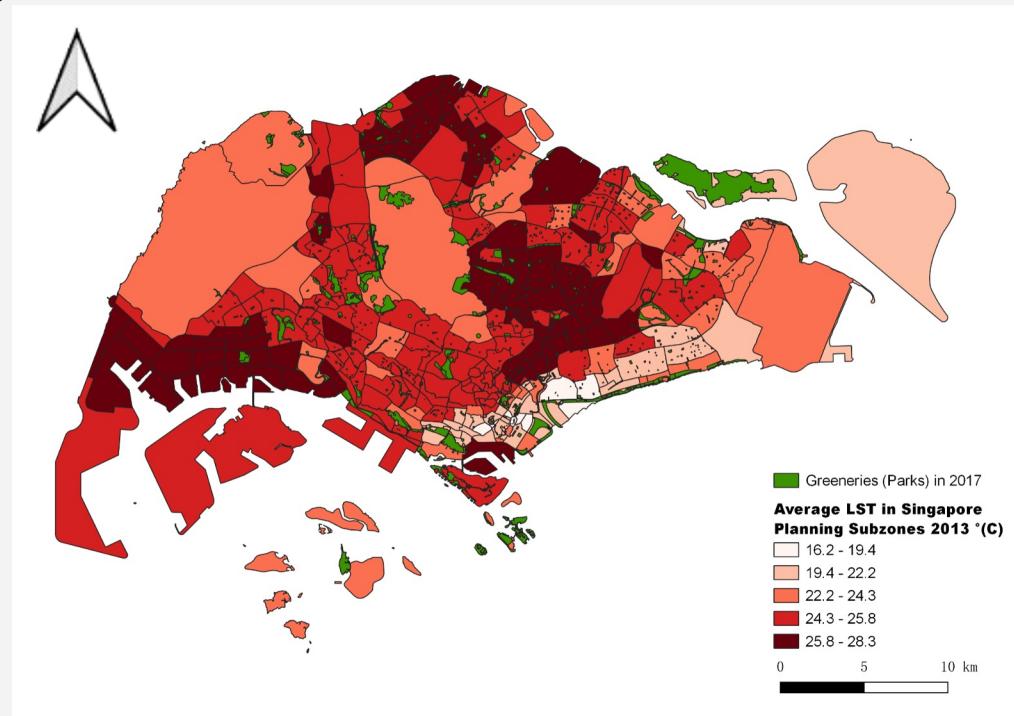


Figure 6: Greeneries Distributions and Average LST of Singapore in 2013
(Created on 09/04/2022 by Tianyu Wu & Simon Han)

4.2.2. Findings - Research Question 2 (Before-and-after Analysis)

Comparison of the Average Temperature between 2013 and 2021:

- Overall trend is **decreasing**.
- Interested sites of research:
 - Increase in greeneries area (e.g. parks);
 - Decrease OR remain in temperature.
- Among the above sites, we are curious why particular places decreased in temperature, while some did not?

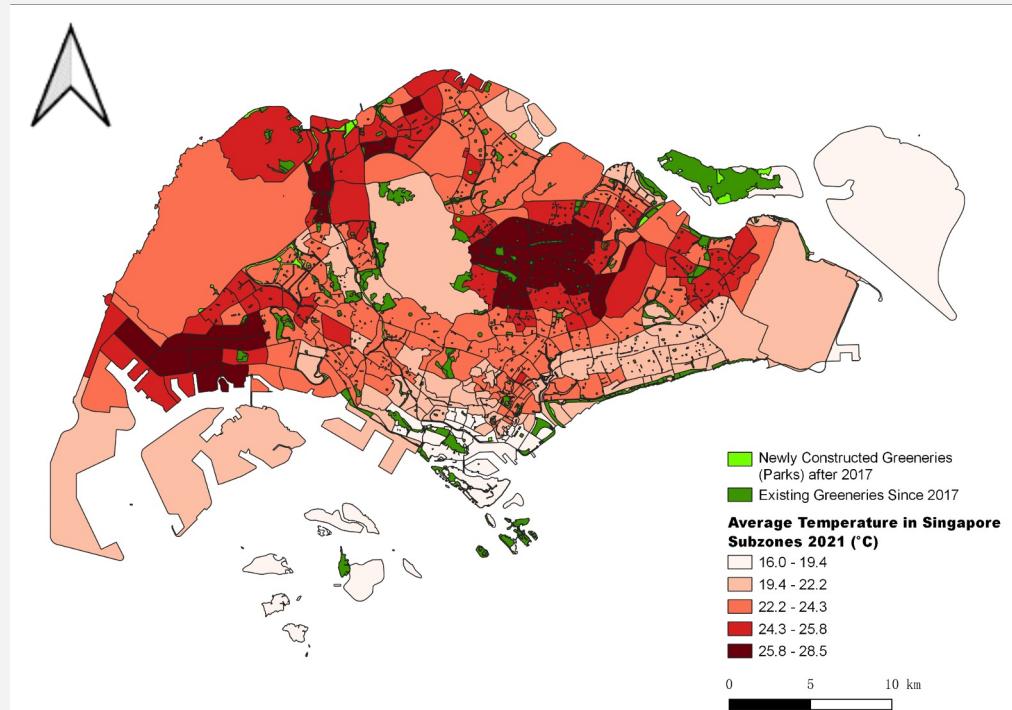


Figure 7: Greenery Distributions and Average LST of Singapore in 2021
(Created on 09/04/2022 by Tianyu Wu & Simon Han)

4.2.3. Findings - Research Question 2 (Selected Sites)

Site Selections:

Within Kranji, Kallang and Yishun

- Two sites had a significant decrease in the average temperature.
- One site's average temperature barely decreased.
- All sites had newly constructed green spaces after 2017.

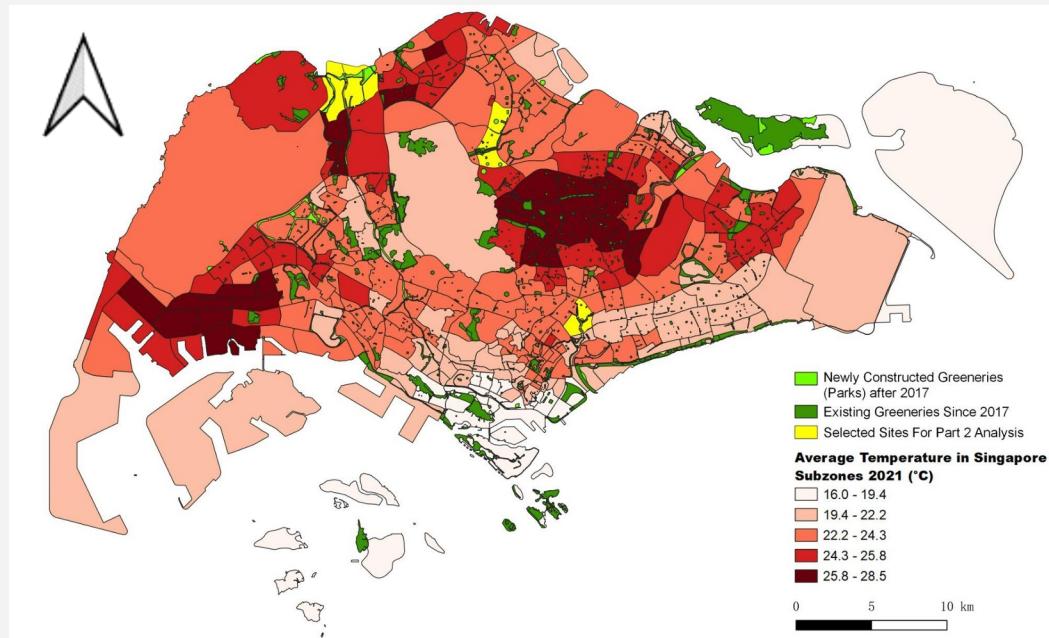


Figure 8: Three Selected Sites of Interest for Localized Analysis
(Created on 09/04/2022 by Tianyu Wu & Simon Han)

4.2.4. Findings - Research Question 2 (Selected Site: *Kallang*)

- **Average Temperature Change:**
 - 26.07°C (2013)
 - 20.92°C (2021)

- **Local Land Use and Water**

Features:

- Significant increase of **green spaces** in the center and along the river;
- Significant presence of **water body**;
- Decent amount of both **business**, **industrial** and **residential** land uses, with **slightly more** residential uses.



Figure 9: Detailed Land Uses Map of Selected Planning Subzones in Kallang
(Created on 10/04/2022 by Tianyu Wu & Simon Han)

4.2.5. Findings - Research Question 2 (Selected Site: *Yishun*)

- **Average Temperature Change:**
 - 26.05 °C (2013)
 - 23.57 °C (2021)
- **Local Land Use and Water Features:**
 - Decent increase in **green space** in the south, between gaps of buildings and along the boundary;
 - Lack of presence of **water body**;
 - Majority lands are dedicated to **residential uses**.

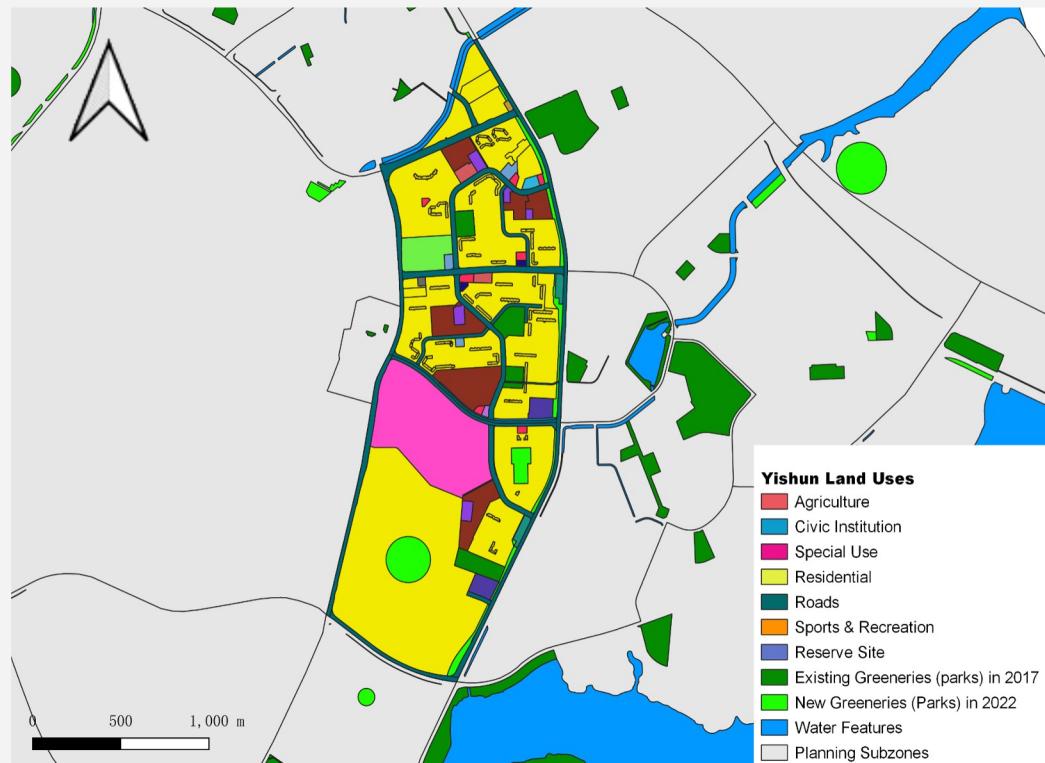


Figure 10: Detailed Land Uses Map of Selected Planning Subzones in Yishun
(Created on 10/04/2022 by Tianyu Wu & Simon Han)

4.2.6. Findings - Research Question 2 (Selected Site: *Kranji*)

- **Average Temperature Change:**
 - 25.55 °C (2013)
 - 25.21 °C (2021)
- **Local Land Use and Water Features:**
 - Significant increase in **green spaces** in the north and along the water body;
 - Significant presence of **water body** in the west and middle;
 - But most of lands are dedicated to **industrial and utilities uses** (e.g. vehicle factories).

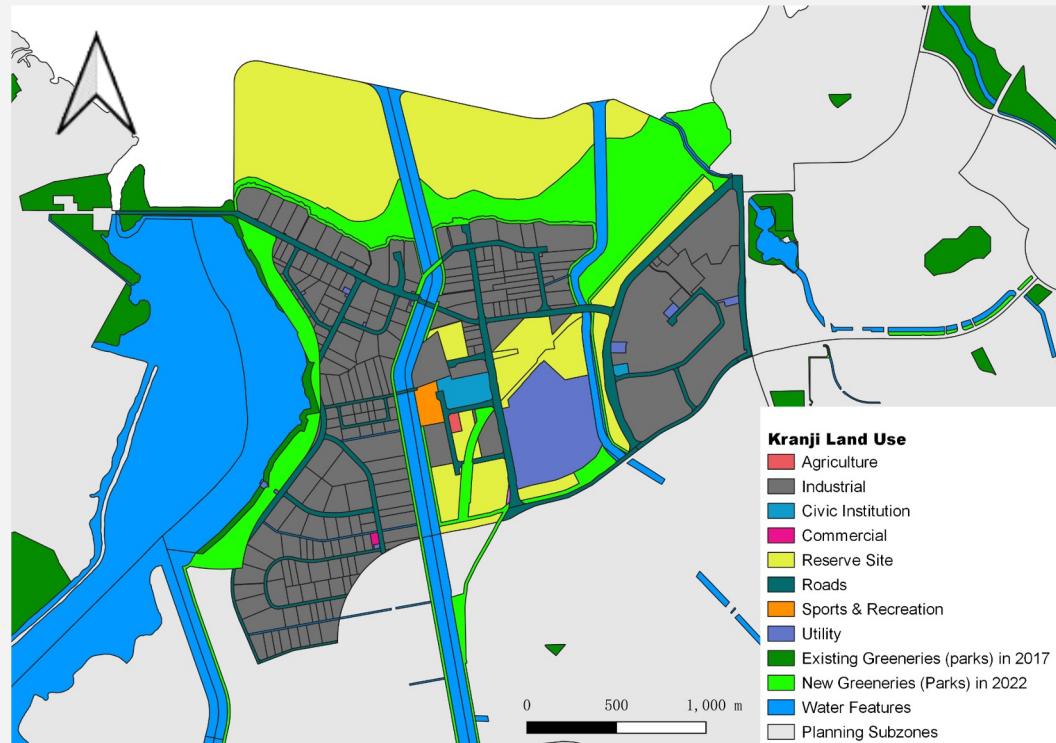


Figure 11: Detailed Land Uses Map of Selected Planning Subzones in Kranji
(Created on 10/04/2022 by Tianyu Wu & Simon Han)

5.1. Implications

Negative correlation between greeneries ratio
and average temperature



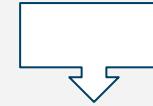
Increase of greeneries has an impact to
reducing the Land Surface Temperature



Improve against the UHI effect

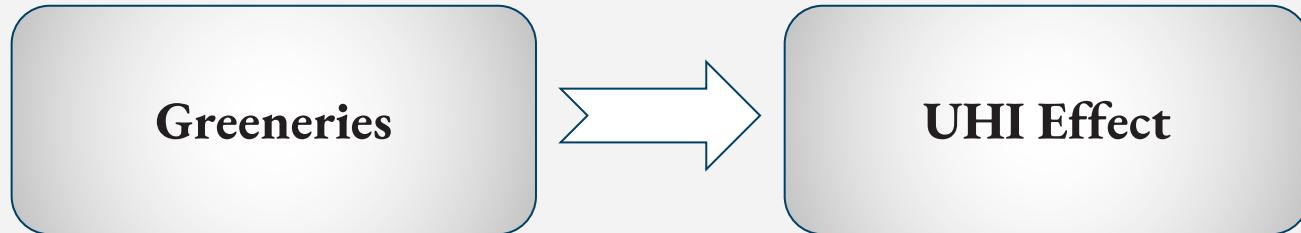
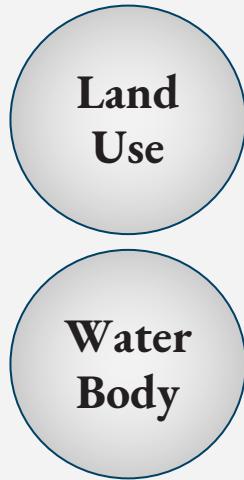
Yes, **BUT...**

The **size** of the greeneries
would affect the decrease
degree of the temperature



The **larger** the greeneries sizes
are, the **more** that the
temperatures is likely to drop

5.2. Implications



Presence of water body

! **Industrial/Commercial**
land uses

5.3. Implications

Last but not least ...

- Our findings corroborate with Masoudi and Tan's work (2019) on the effects of spatial pattern of urban green spaces on urban land surface temperature.
- Our findings corroborate with Li and Norford's work (2016) on evaluating the mitigation effect of the greeneries in Singapore.

- Our findings corroborate with Hart and Sailor's work (2008) on how land uses interact with other natural factors (e.g. greeneries, water body) to co-influence the UHI effect.
- Our findings supports Ruefenacht and Acero's Cooling Singapore project (2017) on greeneries construction strategies to cool Singapore, but also evaluate effectiveness of different types of greeneries strategies proposed and provide a critical scope , showing that greeneries strategies alone may not solve UHI effect problem sufficiently.

6.1. Limitations

- Did not include **all** the factors that can make a difference to the spatial differences in Land Surface Temperature (LST).
 - It is technically difficult.
 - There is limited open data to measure some factors, including energy uses and transportation.
- It is assumed that natural climate **would not** change significantly over the years when conducting the **before-and-after analysis**.
- For the **localized** analysis, other local contexts which may contribute to temperature differences are assumed to be ignored.

6.2. Future Work - Multivariate Analysis

- **Research Direction 1: Statistical & Econometric Regression**

- Construct the regression between temperature and other independent variables;
- Add more independent variables such as water body & land uses;
- Investigate if the R² value would increase.

$$y = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \dots + \beta_k x_k + u$$

Intercept
Dependent variable, explained variable, response variable, ...
Slope parameters
Independent variables, explanatory variables, regressors, ...
Error term, disturbance, unobservables, ...

- **Research Direction 2: Explore Other Influencing Factors**

- As supposed by other resources and the “Cooling Singapore” project, there are also other factors which contributes to the UHI Effect.
- For example, energy use, transportation, building materials.....
- But ... hard to quantify.



Acknowledgment

- We would like to express our gratitude to Prof Chaewon Ahn and her student Arina Anisha Koul who kindly shared the methodology and related tutorials of extracting the Land Surface Temperature (LST).



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Thanks For Listening!



