

## From Area-Based Greening to Morphology-Based Cooling: Rethinking Urban Heat Mitigation in Global South Megacities

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### INTRODUCTION & AIM

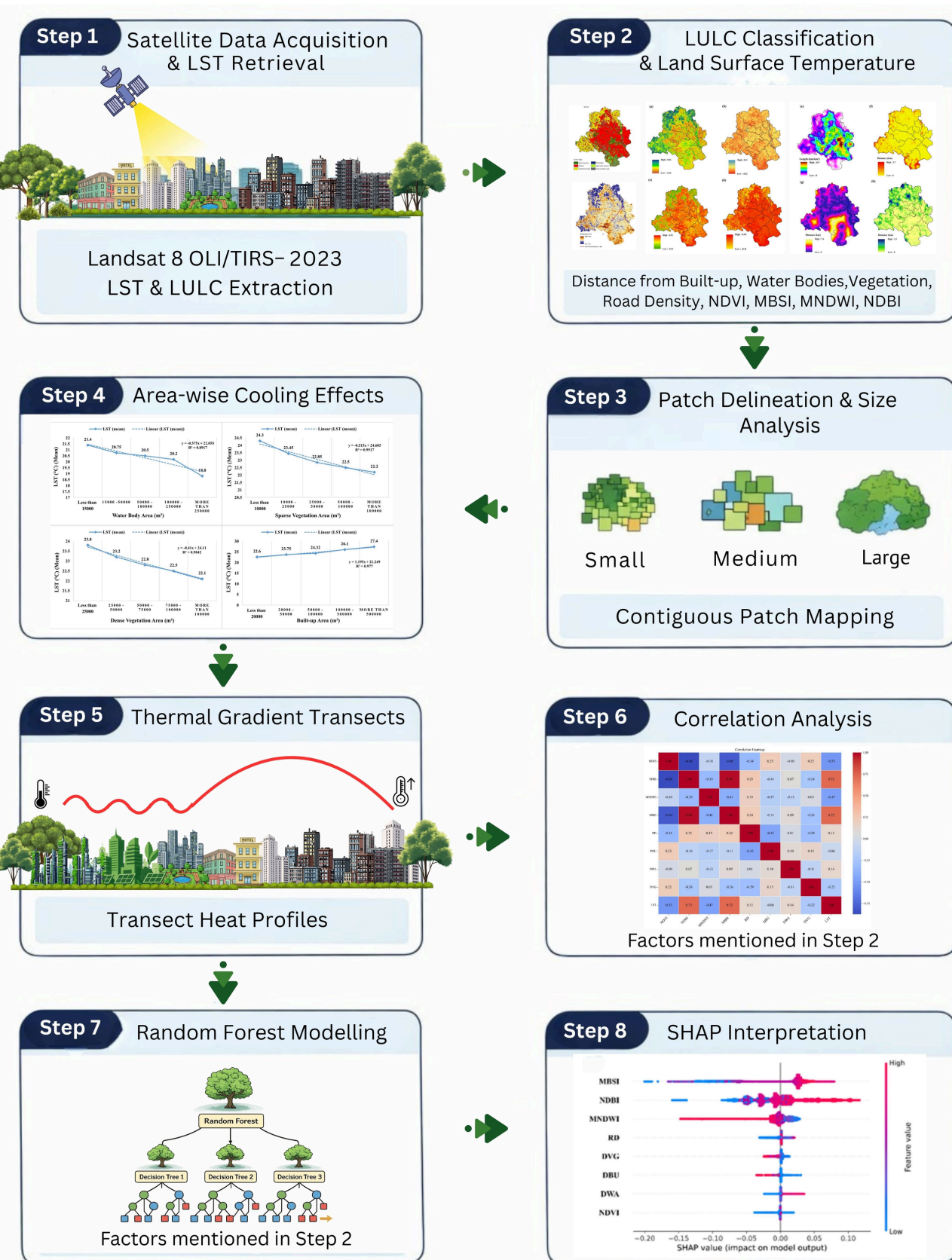
- Cities like Delhi are becoming extremely hot because **natural land** is being replaced by **concrete and buildings**.
- Although **parks, trees, and water bodies** are known to **reduce heat**, most urban planning focuses only on **how much green space exists**, not on **how it is arranged** or connected.
- As a result:
  - Small and fragmented green spaces **fail to reduce heat** effectively.
  - Large built-up areas** continue to trap and store heat.
  - Urban heat keeps **increasing despite greening efforts**.

The key problem is we have **limited knowledge about how the size, connectivity, and spatial arrangement of blue-green spaces** influence cooling.

**Objective:** To evaluate the cooling effects of blue-green spaces in Delhi.

### METHOD

#### Methodological Workflow



#### 01. LULC Classification

- Supervised classification into 6 land-cover classes
- Cross-sectional transects showed sharp cooling in BGS and rapid warming in built-up areas

#### 02. Surface Indices

- Derived NDBI, MBSI, NDVI, and MNDWI
- Calculated distance to built-up, vegetation, and water bodies

#### 03. Spatial Configuration & Patch Analysis

- Delineated land-cover patches and grouped into size classes
- Analysed LST variation to detect scale and fragmentation effects

#### 04. Thermal Gradient

- Examined spatial heating and cooling patterns across land-cover types

#### 05. Correlation Analysis

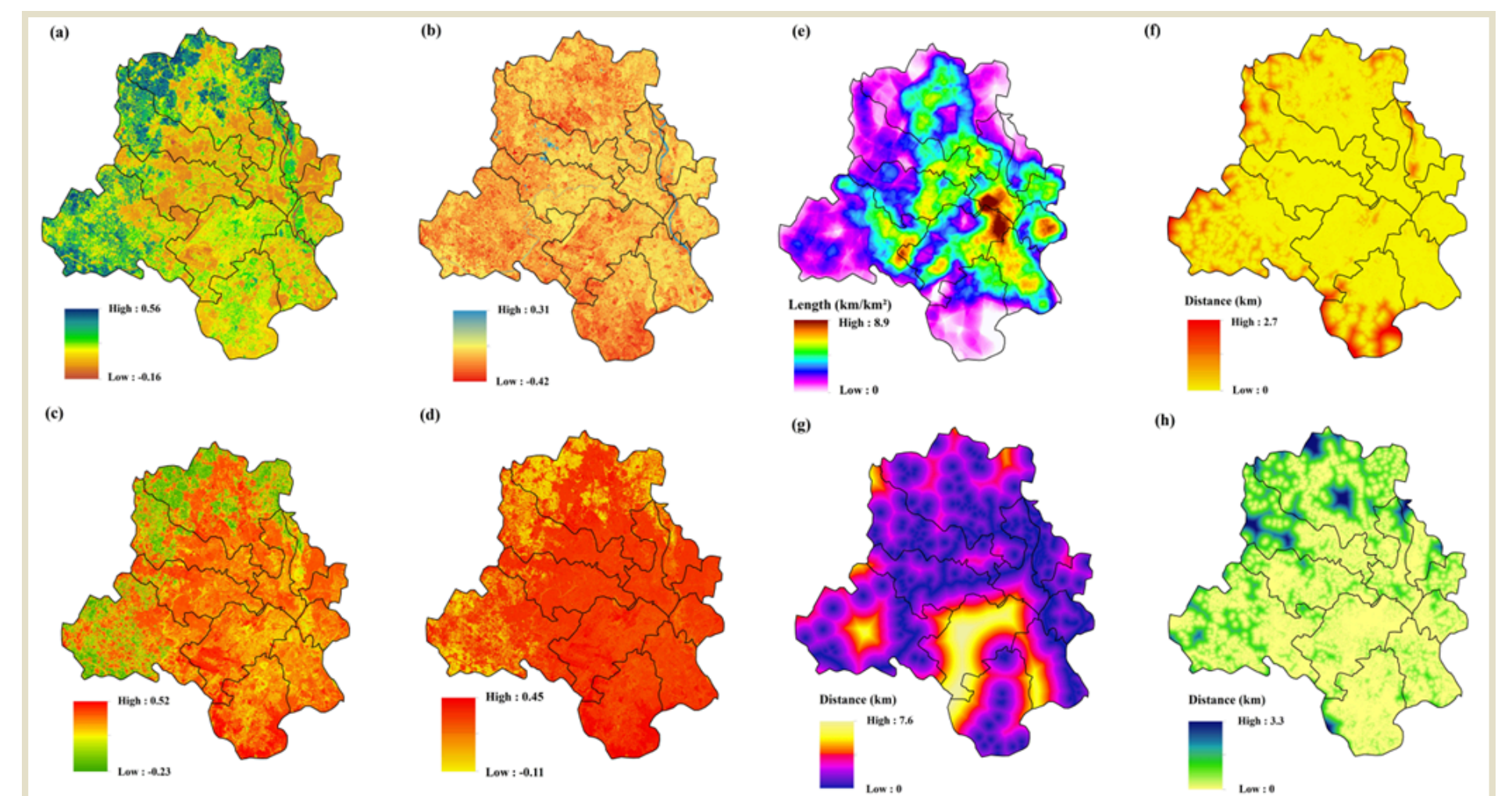
- Pearson correlation between LST and surface indices

#### 06. Machine Learning Modelling

- Random Forest + SHAP used to identify dominant heat drivers and cooling effects

### Spatial Patterns of Land-Cover and Configuration

- Vegetation & moisture:** High NDVI and MNDWI values are concentrated in the Ridge and Yamuna corridor of Delhi.
- Urban heat cores:** High NDBI and MBSI indicate extensive impervious and bare surfaces in central and southern Delhi.
- Fragmented BGS:** Cooling effects remain localized due to small, disconnected green patches.
- Urban configuration:** High road density and large distances from water bodies limit citywide cooling benefits.



### Urban Heat Drivers (Random Forest + SHAP)

- RF-SHAP analysis: **MBSI** is the strongest driver of LST in Delhi, followed by **NDBI**.
- Warming effect: **High MBSI and NDBI** values strongly **increase LST**.
- Cooling effect: **MNDWI and NDVI** reduce LST.

#### (a) Relative importance and (b) influencing directional effects of surface predictors on LST

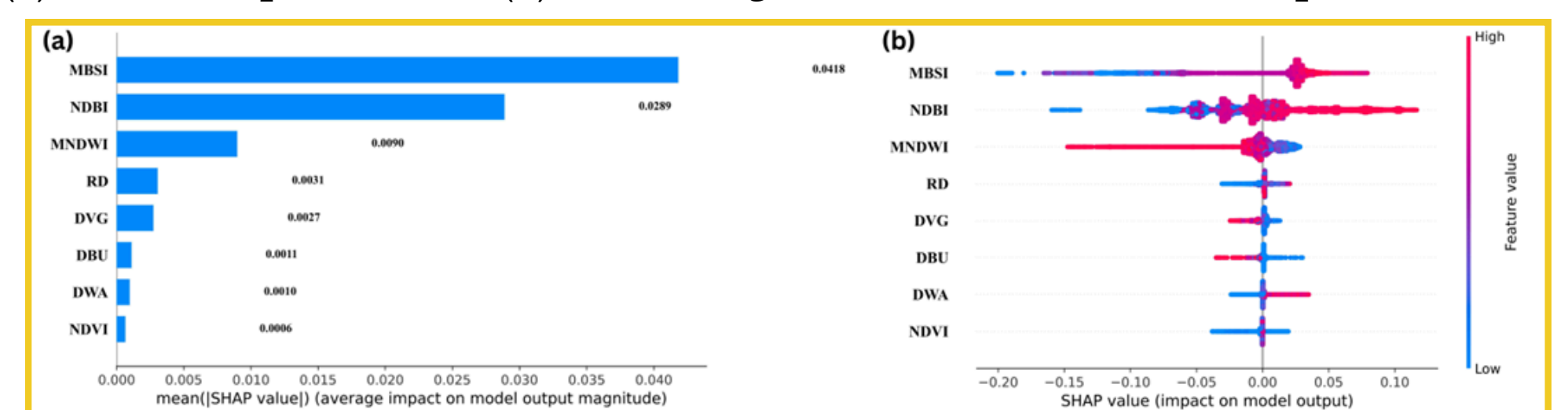
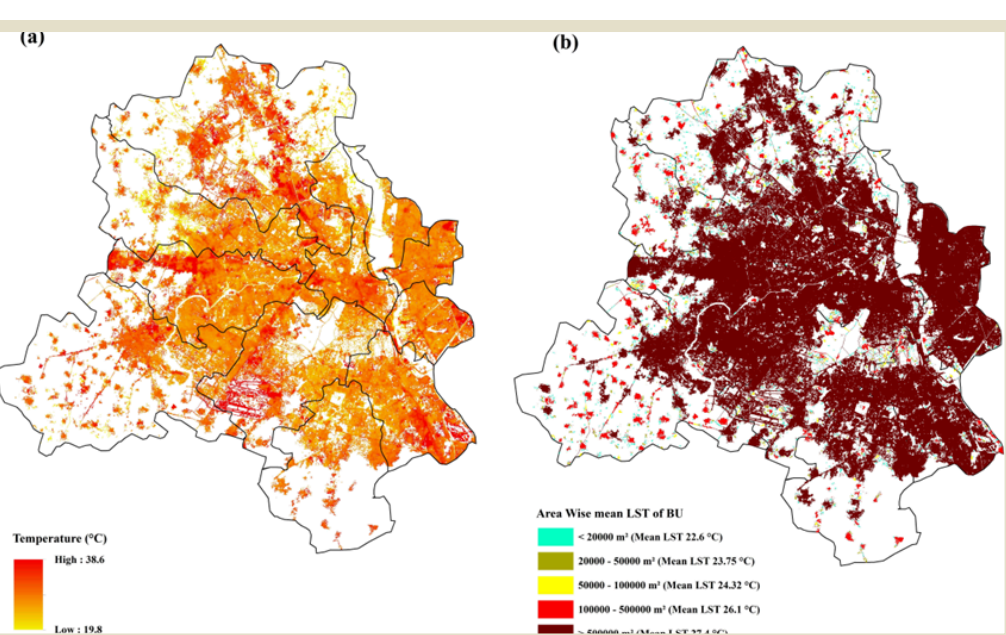


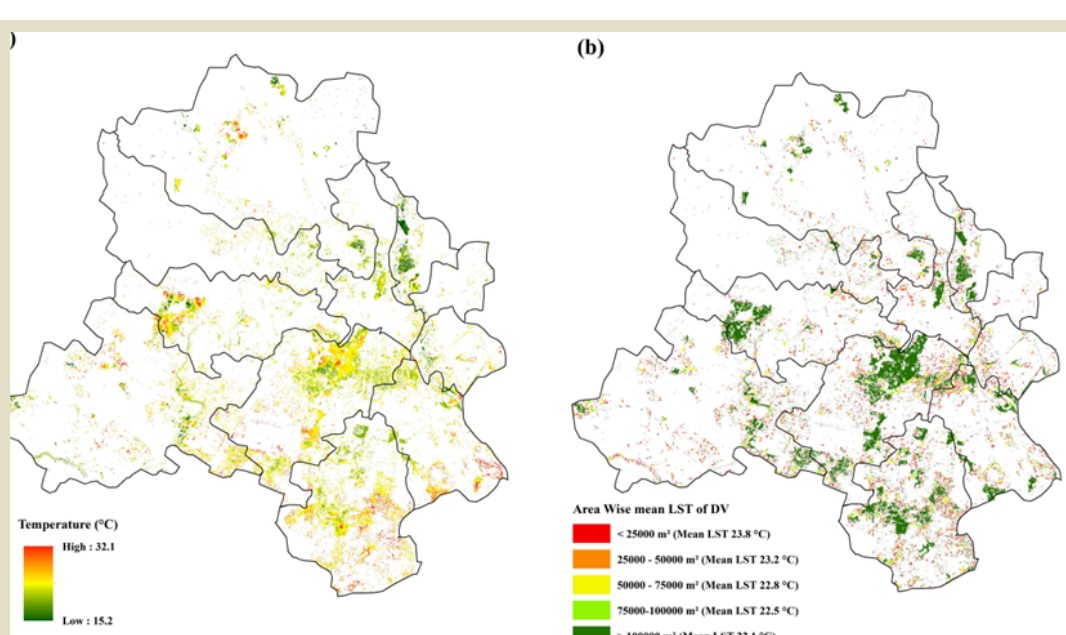
Figure: Scale-dependent variation of mean LST across patch sizes of (a) water bodies, (b) sparse vegetation, (c) dense vegetation, and (d) built-up areas.

### RESULTS & DISCUSSION

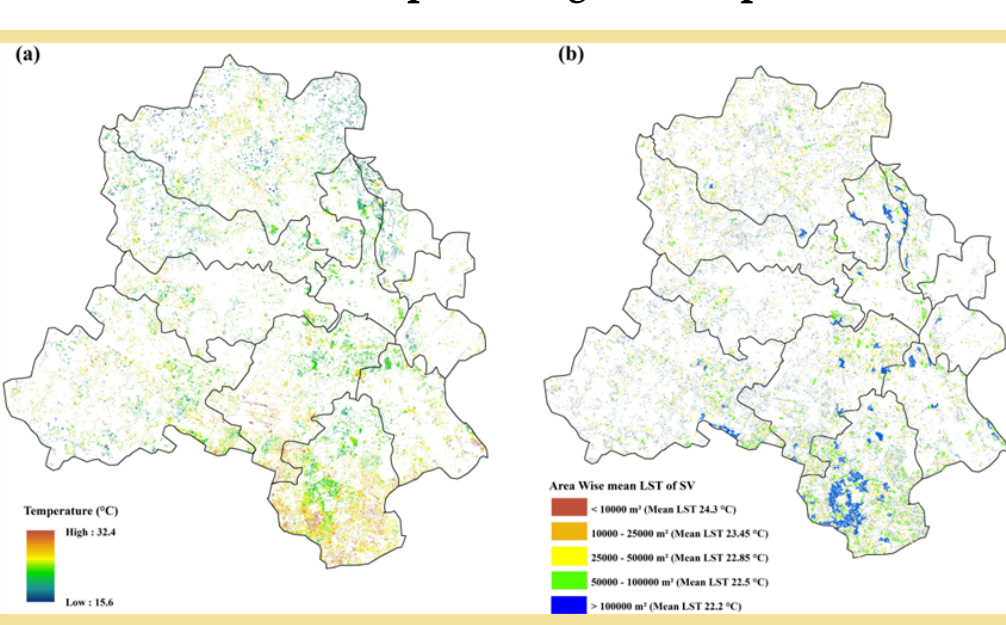
(a) Spatial distribution of LST and (b) mean LST across the built-up area



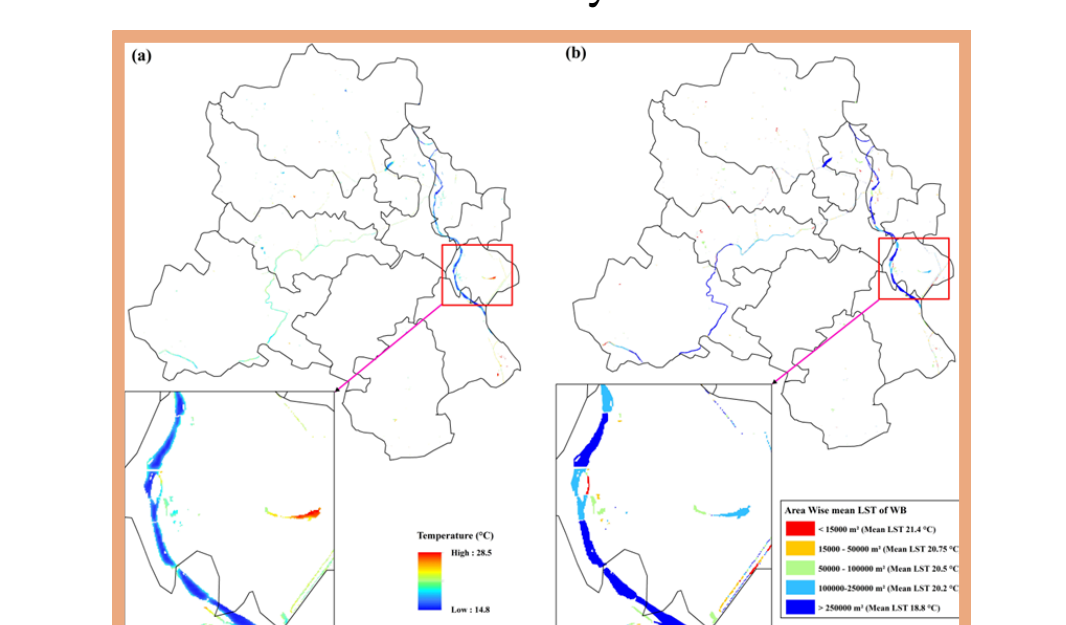
(a) Spatial distribution of LST over dense vegetation (b) area-wise mean LST across dense vegetation patch.



(a) LST over sparse vegetation and (b) area-wise mean LST across sparse vegetation patch sizes.

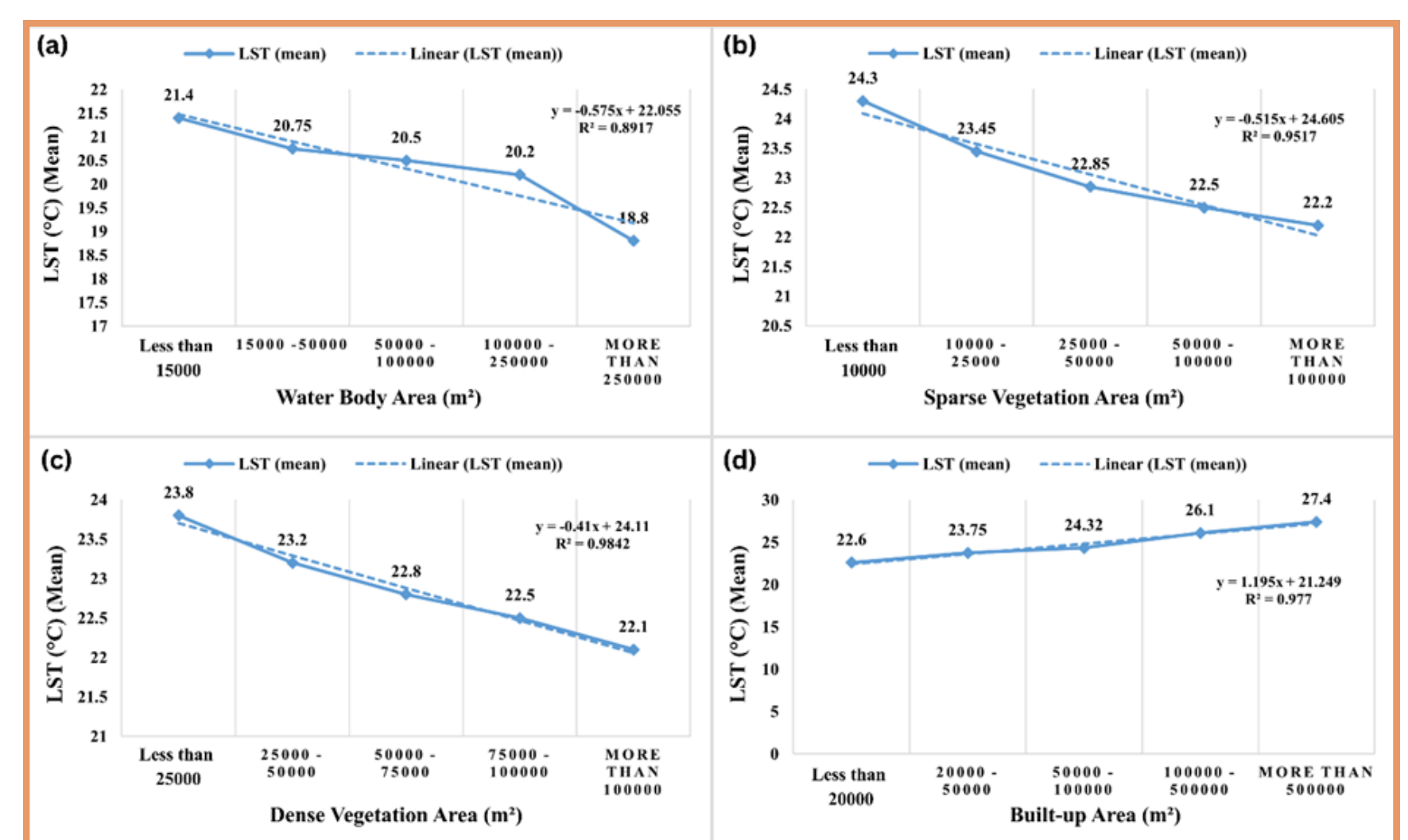


(a) LST over water bodies and (b) area-wise mean LST across waterbody size classes



- LST in Delhi shows **strong spatial variation** (19.8°C–38.6°C).
- Large **built-up areas** create intense urban **heat cores**.
- Impervious **patch expansion strongly increases LST** ( $R^2 = 0.98$ ).

- Large, connected **dense vegetation patches** provide **stronger cooling**.
- Sparse vegetation** offers **limited cooling when fragmented**.
- Water bodies** deliver the **strongest cooling**, especially at larger sizes.



### Asymmetric Scale Effects of Warming and Cooling Surfaces

- Water bodies:** **Strong cooling effect**; LST reduced by 2.6°C with increasing size.
- Sparse vegetation:** **Moderate cooling**; LST reduced by 2.1°C.
- Dense vegetation:** **Higher cooling efficiency** with larger patches.
- Built-up areas:** **Strong warming effect**; LST increased by 4.8°C with expansion.
- Warming from **impervious expansion is stronger and linear** than cooling from **fragmented BGS**.

### CONCLUSION

- Urban heat in Delhi is mainly driven by **extensive impervious surfaces**.
- Blue-Green Spaces **cool effectively** only at **larger, connected scales**.
- Small fragmented green patches** provide limited **thermal relief**.
- Water bodies** offer the **strongest cooling**, but benefits remain **spatially limited**.

### FUTURE WORK / REFERENCES

- Jha, P., Joy, M. S., Yadav, P. K., Begam, S., & Bansal, T. (2024). Detecting the role of urban green parks in thermal comfort and public health for sustainable urban planning in Delhi. *Discover Public Health*, 21(1). <https://doi.org/10.1186/s12982-024-00368-7>
- Tran, V., & Hoang, N. (2025). Machine Learning Insight into the Cooling Intensity of Urban Blue-Green Spaces During Heatwaves. *Sustainability*, 17(21), 9824. <https://doi.org/10.3390/su17219824>