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Exploring the Surface Urban Heat Island (SUHI) Effect in Metro Vancouver

A Multi-Factor Analysis of Land Use and Cover, Vegetation Index, Soil Moisture, and Solar Reflectance

While the world's population keeps growing, more vegetation has been replaced by concrete and asphalt, increasing energy consumption, socioeconomic disparities, and pollution. The population living in cities is expected to increase from 50% to 66% by 2050, leading to UHI effect intensification (Gaur, Eichenbaum, & Simonnovic, 2018).

1.

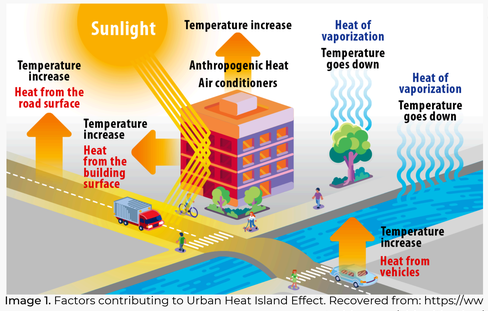


Image 1. Factors contributing to Urban Heat Island Effect. Recovered from: https://www.pavetechinc.com/uhi-mitigation/

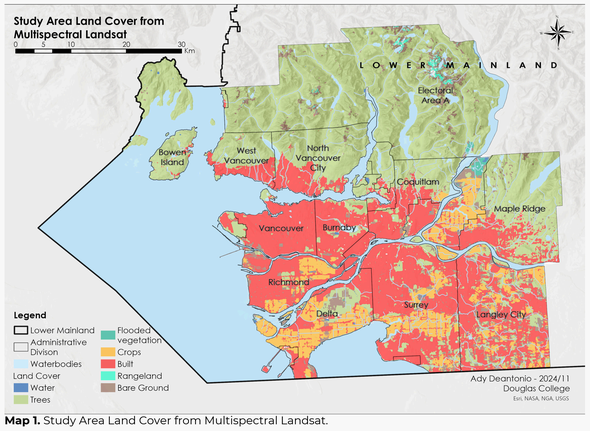
Urban Heat Island effect and Vancouver complexity

- The Urban Heat Island (UHI) effect is a critical environmental issue in many cities where urban areas are warmer than rural peripheries (U.S. Environmental Protection Agency, 2008).
- Factors impacting: albedo, land use, and cover, urban geometries, heat released by human activity, weather, and geography (Hannah, 2023).
- Vancouver is surrounded by coasts and mountains creating microclimates and a complex topography.
- As surface temperatures rise, heat waves are more frequent, making Vancouver the Census Metropolitan Area with the most Surface Heat Islands in Canada (U.S. Environmental Protection Agency, 2008).
- Consequences: mental health issues, heat strokes, and aggravations of heart and respiratory diseases (Climate Atlas of Canada, 2019).

2.

Methodology and Data

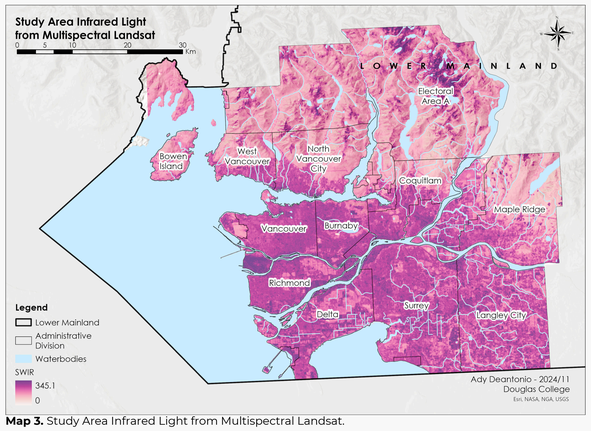
Multispectral Landsat imagery from 2024-08-01 during the daytime was used to analyze surface temperature variations across Metro Vancouver combining land use and cover, vegetation index (NDVI), soil moisture (SWIR), and solar reflectance to assess their impact on the Surface Urban Heat Island (SUHI) effect.



Map 1. Study Area Land Cover from Multispectral Landsat.

Normalized Difference Vegetation Index (NDVI)

- Bare soil: close to waterbodies.
- Low vegetation: built areas (Vancouver and Burnaby).
- Green spots: healthy and dense vegetation growing mainly in the surrounding rural areas.



Map 3. Study Area Infrared Light from Multispectral Landsat.

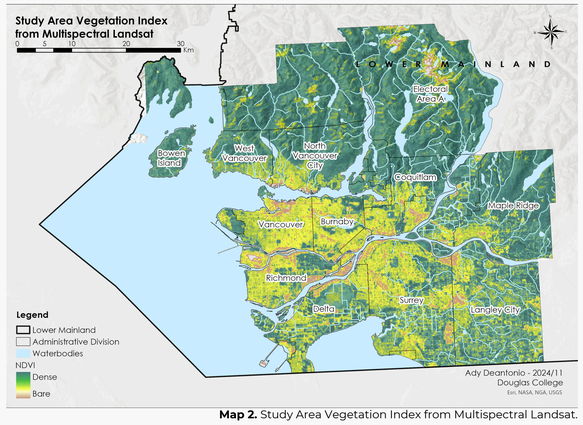
Factor selection:

- Direct influence on the SUHI effect.
- Availability for consistent analysis.
- Land use and cover: contribution to heat retention.
- NDVI: vegetation density.
- Surface temperature: hotspots.
- SWIR: variations in soil moisture and surface dryness, key factors in heat absorption and retention.

3.

7 **Land cover** classes were identified within the study area.

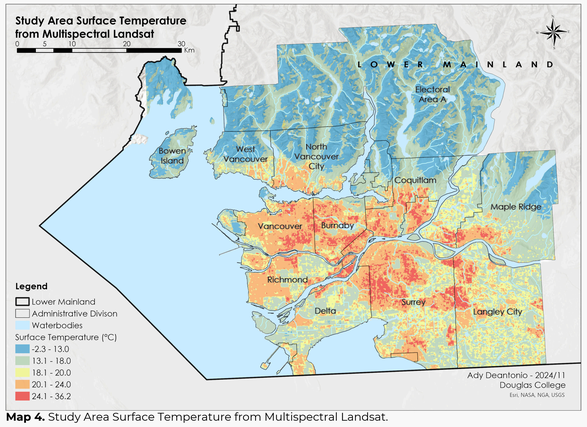
- Northeastern area: trees and vegetation.
- Southeastern area: buildings and crops.
- Western area: (Strait of Georgia, Burrard Inlet, and rivers such as the Fraser River, etc.).



Map 2. Study Area Vegetation Index from Multispectral Landsat.

Short-wave infrared (SWIR) spectra reveal affectations on land cover that might lead to increased surface temperatures since it is highly sensitive to water content in soils and vegetation.

- Higher values = Dry surfaces such as bare soil.
- Low values = moist surfaces with low heat retention potential.
- Drier surfaces often have lower albedo and higher surface temperatures.
- Moist soils reflect more sunlight, which helps cool the environment.

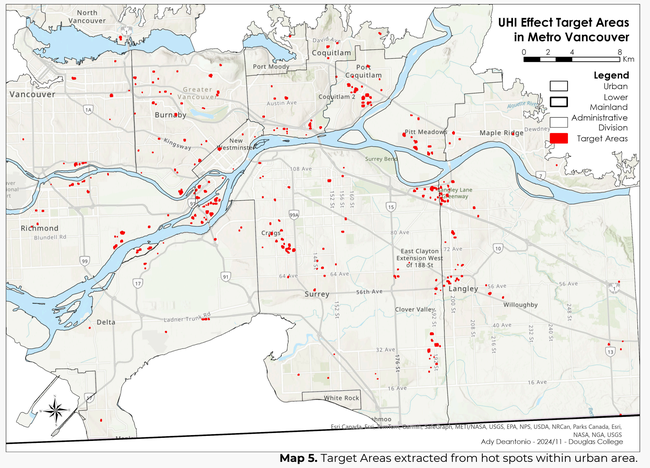


Map 4. Study Area Surface Temperature from Multispectral Landsat.

4.

Surface temperature

- Rural surroundings: -2.3 °C - 18 °C (cool spots).
- Urban areas: 18.1 °C - 36.2 °C (hot spots).
- Urban zones include dense commercial, industrial, or residential areas while highly vegetated areas cover parks, trees, and areas near rivers, lakes, or coastline.
- The correlation between factors will focus on the increase of surface temperatures in the built area, which directly impacts the SUHI effect.

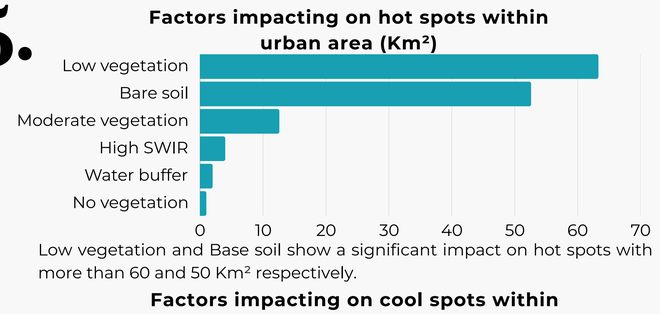


Map 5. Target Areas extracted from hot spots within urban area.

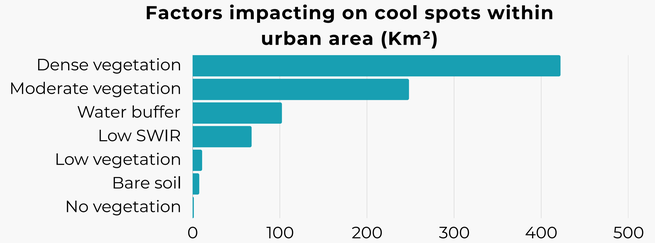
Target areas = hot spots ∩ built area ∩ (none to low vegetation ∪ bare soil) ∩ high SWIR values

- These areas are situated outside the water buffer zones, ensuring that the cooling effects of water bodies do not influence the analysis.
- Key factors have been integrated, focusing on locations where all negatively contributing factors, such as dry surfaces, low vegetation, and heat-retaining materials, overlap.

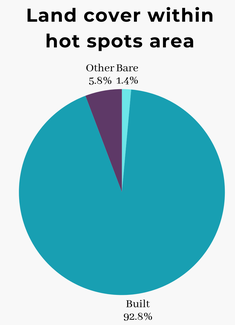
5.

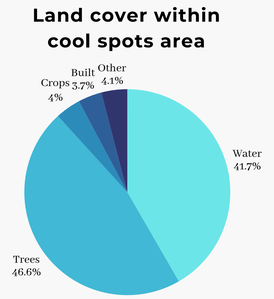


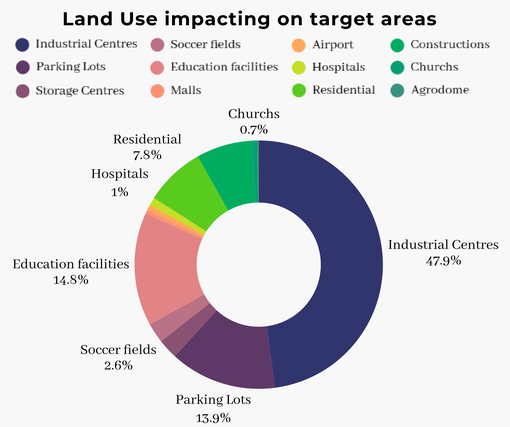
Low vegetation and Base soil show a significant impact on hot spots with more than 60 and 50 Km² respectively.



Dense vegetation and Moderate vegetation show a significant impact on cool spots with more than 400 and 250 Km² respectively.







6.

Analysis

An individual GIS-based spatial analysis was conducted for each factor before combining the data. Cool spots and hot spots were identified based on surface temperature and analyzed separately. Areas with low vegetation coverage, dry surfaces, and built-up land had the highest impact on SUHI, helping the selection of targeted areas where these conditions overlapped with temperatures above 18.1°C. Statistical analysis was performed to quantify the impact of each factor by calculating their coverage within hot and cool spot areas. Specific land uses were identified using Google Earth, enabling the creation of a pie chart showing the most significant contributors to SUHI in Metro Vancouver. As 94.8% of hot spots were located within built-up areas, further analysis was focused on urban zones in the southeastern portion of the study area. Dry surfaces, particularly in dense commercial, industrial, and residential areas, exhibited low albedo materials like asphalt, intensifying heat retention. Conversely, dense and moderate vegetation, proximity to water, and low SWIR helped mitigate SUHI effects. Parks, tree-covered zones, and high-albedo materials like white roofs contributed to localized cooling. Industrial centers, including warehouses, education facilities, and densely populated residential areas, had a particularly notable impact.

7.

Conclusion

By conducting a spatial analysis of all factors, it was possible to determine the direct impact of UHI effect on target areas within the urban zone of the study area. Even though every factor has a different level of impact on surface temperature, when they overlap, it becomes significant, targeting specific areas that need to be addressed with mitigation strategies. The findings indicate that UHI hotspots are predominantly found in densely urbanized areas, particularly those with limited vegetation, dry surfaces, and heat-retaining materials like asphalt. This study emphasizes the need for strategic urban planning incorporating green infrastructure, water features, and high-albedo surfaces to reduce heat accumulation, especially in the targeted areas highlighted in Map 5.

References

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