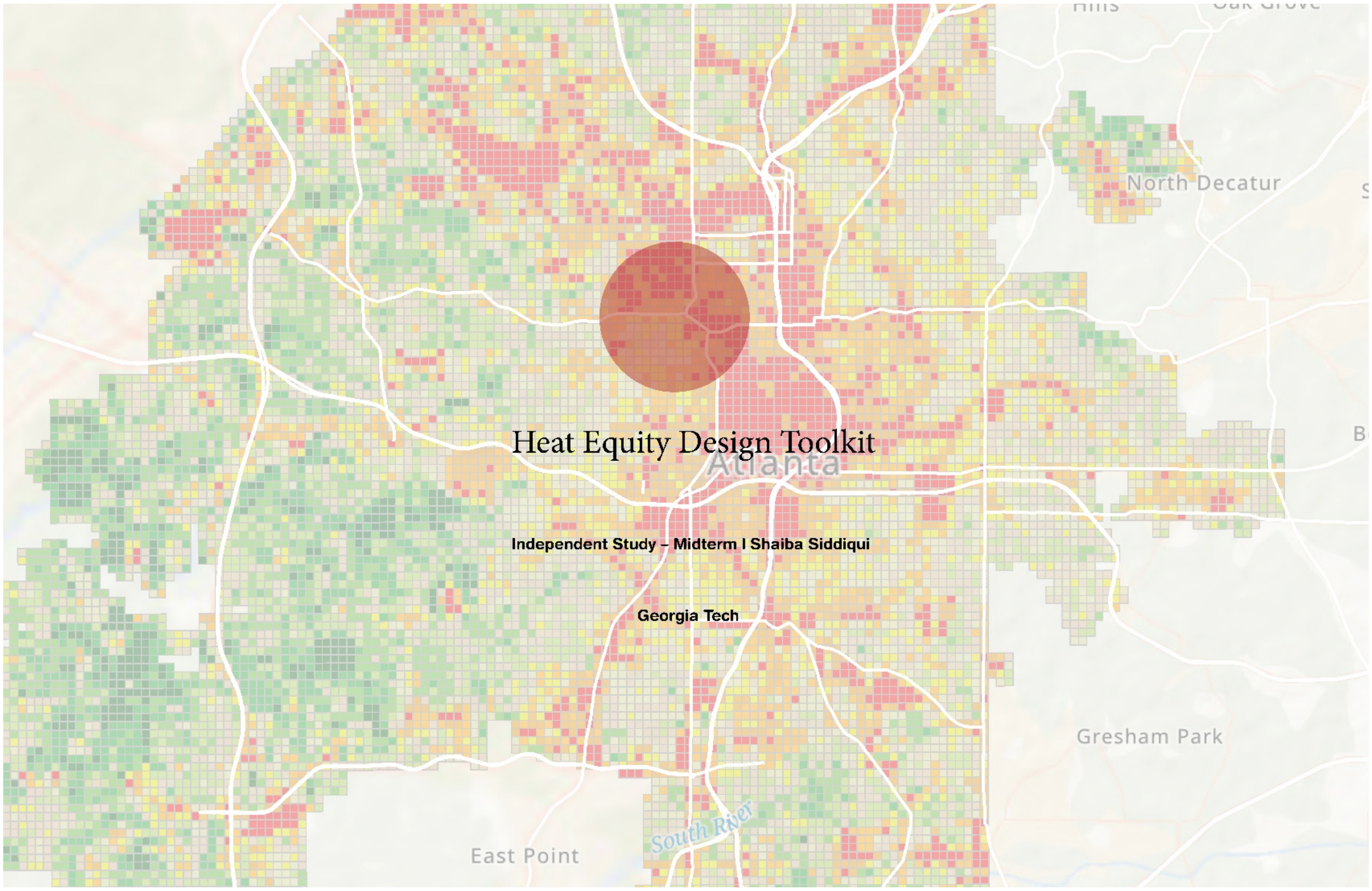


Heat Equity Design Toolkit

Street-Tree Canopy Configuration for Pedestrian Thermal Comfort in Atlanta

Independent Study - MS Urban Design
Georgia Institute of Technology
Author: Shaiba Bano Siddiqui
Advisor: Patrick Kastner
Secondary Advisor: Rounaq Basu
Semester: Fall 2025

Project Overview

Urban heat exposure disproportionately impacts low-income and transit-dependent neighborhoods, where limited tree canopy, wide asphalt corridors, and fragmented shade create unsafe pedestrian conditions. While urban trees are widely recognized as a cooling strategy, **how trees are spatially configured along streets**, their spacing, side placement, and clustering, plays a critical role in determining thermal comfort at the pedestrian scale.

This independent study investigates how **street-tree canopy configuration** can reduce **Mean Radiant Temperature (MRT)** and heat exposure for pedestrians and transit users in **heat-vulnerable neighborhoods across Atlanta**, with a focused corridor-scale simulation along **Joseph E. Boone Boulevard (Vine City / English Avenue)**.

The outcome is a **design-driven Heat Equity Toolkit** that translates climate data and microclimate simulations into **actionable, equitable street-design guidance**.

Research Question

How does the spatial configuration of street-tree canopy (spacing, side placement, clustering) reduce heat exposure for pedestrians and transit users in low-income neighborhoods across Atlanta?

Study Area

- **City Scale:** Atlanta, Georgia
- **Neighborhood Focus:** English Avenue / Vine City (Westside Atlanta)
- **Corridor Focus:** Joseph E. Boone Boulevard
- **Context:**
  - Low tree canopy
  - High urban heat intensity
  - Transit-dependent population
  - High displacement and green gentrification risk

Methodology

1. Citywide Spatial Analysis (GIS)

Datasets Used

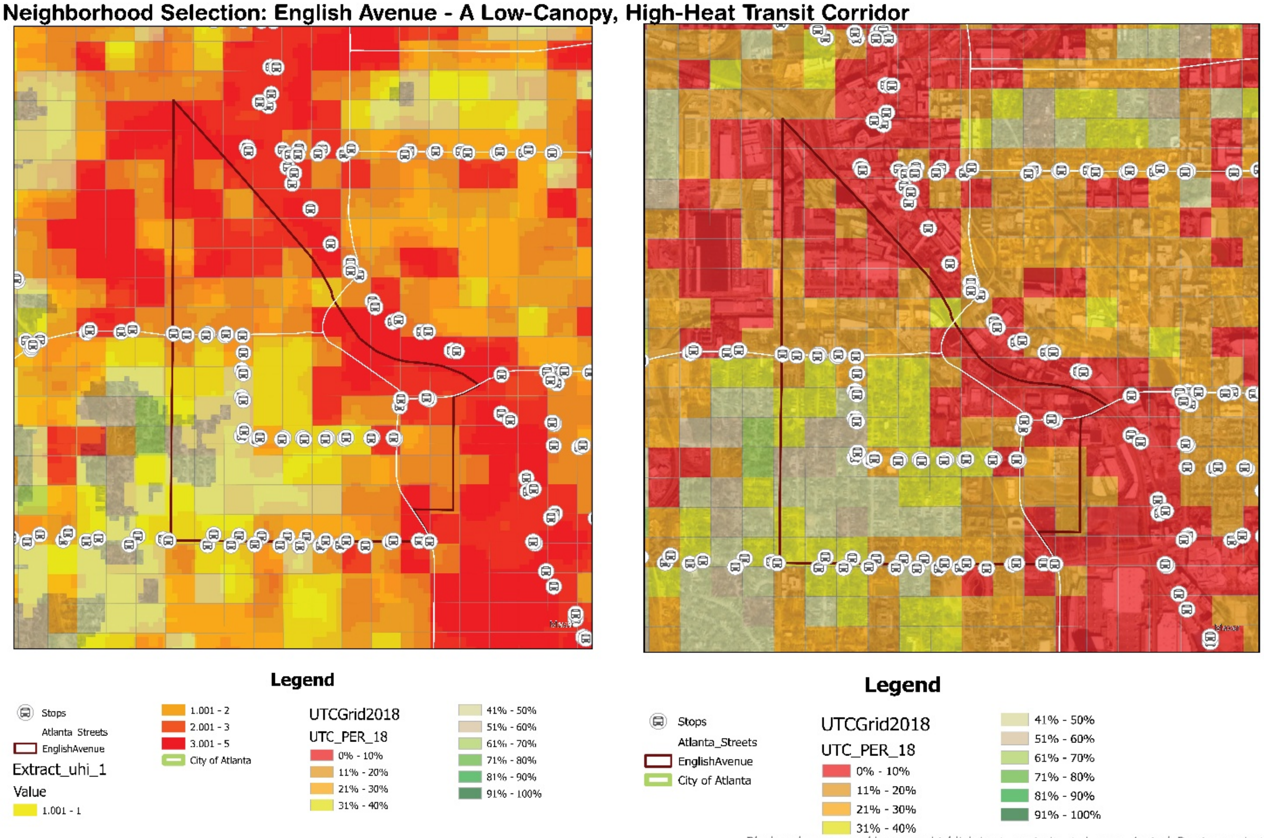
- Urban Tree Canopy (UTC, 2018)
- Urban Heat Intensity Raster (City of Atlanta)
- Median Household Income (ACS 2022)
- Transit routes and stops

Analytical Steps

- Standardized all datasets to a common projection and city boundary
- Conducted zonal statistics to extract heat and canopy values by census tract
- Joined socioeconomic data to environmental layers
- Produced composite overlays identifying **low-canopy + high-heat + low-income** priority zones

---

Neighborhood Selection: English Avenue - A Low-Canopy, High-Heat Transit Corridor



Block-scale canopy and heat maps highlighting two priority study areas: Antioch Baptist transit stop and Rodney Cook Sr. Park edge, selected for contrasting microclimatic conditions and transit exposure.

2. Corridor & Block Selection

High-vulnerability corridors were identified along transit routes in English Avenue and Vine City. Joseph E. Boone Boulevard was selected due to:

- Wide right-of-way (~150 ft)
- Sparse and fragmented canopy
- High pedestrian and bus-stop exposure
- Proximity to community assets and BeltLine development pressure

Microclimate Simulation – Eddy3D Outdoor+ (Joseph E. Boone Blvd)

To assess how strategic street-tree placement influences pedestrian thermal comfort along Joseph E. Boone Blvd, a set of new canopy configurations was introduced into the simulation model. Tree locations and spacing were based on precedents from Rodriguez et al. (2025), who tested different street-canyon tree arrangements, including one-sided rows, dual-sided rows, and clustered groupings,to quantify heat reduction at pedestrian level. Following this approach, trees were spaced at approximately 10–12 meters (30–40 ft) along both sides of the corridor, reflecting typical municipal planting standards and maximizing shade continuity.

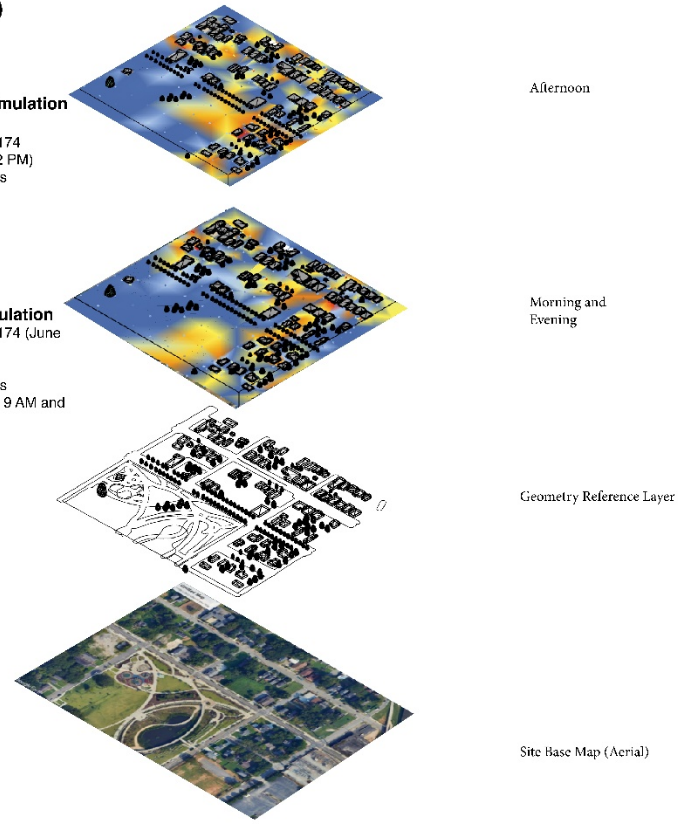
The updated canopy geometry was then integrated into the Outdoor+ microclimate model. Simulations were conducted for two critical time periods—morning (10:00) and afternoon (14:00)-aligning with the hours of highest human exposure and strongest solar loads. The resulting Mean Radiant Temperature (MRT) and wind-flow maps show that added trees significantly reduce heat intensity near sidewalks and bus stops, especially in areas where continuous canopy cover is achieved. This confirms the role of tree placement and spacing as key determinants of cooling performance in low-canopy neighborhoods like Vine City.

Scenario	Start Day	Start Time	Duration	Reason
Morning cool phase	172–174	7	2hrs	Low sun → long shadows → testing if trees help commuters
Afternoon peak heat	172–174	14	2hrs	MOST critical MRT exposure
Evening cooling period	172–174	18	2hrs	Trees help delay heat release

Figure 4. Mean Radiant Temperature (MRT) distribution for Joseph E. Boone Blvd corridor under existing conditions, shown for morning (7–9 AM) and afternoon (2–4 PM) in Peak Summer June - July Month . Simulations conducted using Outdoor+ microclimate modeling.

Afternoon Simulation (Peak Heat)
Start Day: 172–174
Start Time: 14 (2 PM)
Duration: 2 hours
2 PM to 4 PM

Morning Simulation
Start Day: 172–174 (June 21–23)
Start Time: 7
Duration: 2 hours
-Covers 7 AM to 9 AM and 4-7 PM



Aerial and contextual map of Joseph E. Boone Blvd showing existing sparse tree canopy and wide unshaded sidewalks, supporting its selection as a high-exposure, high-need cooling corridor.

3. Microclimate Simulation

Tool

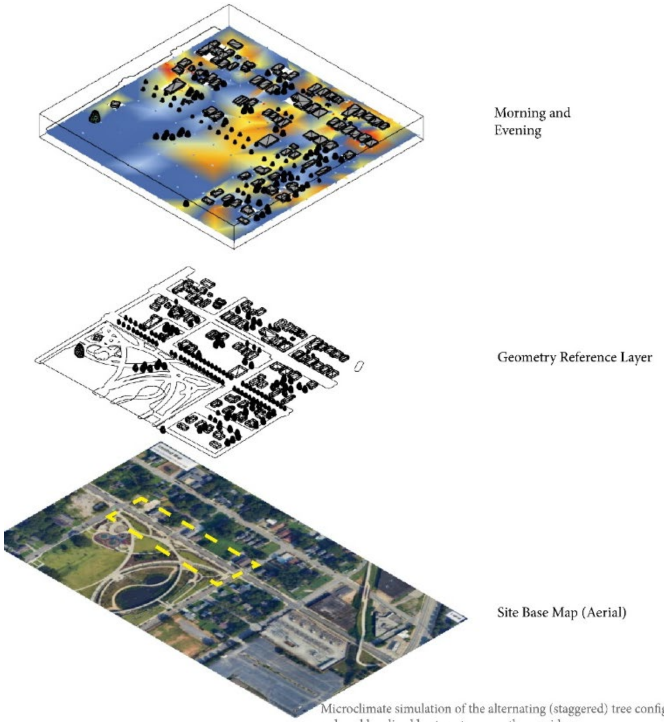
- **Eddy3D Outdoor+** (Rhino + Grasshopper)

Parameters Simulated

- Mean Radiant Temperature (MRT)
- Air temperature
- Surface temperature
- Solar exposure
- Wind flow

Simulation Periods (Peak Summer)

- Morning: 7–9 AM
- Afternoon (Peak Heat): 2–4 PM
- Evening: 6–8 PM
  (Days 172–174: June 21–23)



Microclimate simulation of the alternating (staggered) tree configuration showing expanded morning shade zones and reduced localized heat spots across the corridor.

Tree Configuration Scenarios Tested

1. **Existing Conditions**
    - Sparse, inconsistent canopy
    - Long unshaded sidewalk segments
2. **Uniform Dual-Sided Canopy**
    - Trees placed on both sides of the corridor
    - Approx. **20 ft (6–7 m) spacing**
    - Continuous shade rhythm
3. **Alternating (Staggered) Placement**
    - Trees offset left-right across the corridor
    - Reduced canopy overlap
4. **Clustered Planting at Nodes**
    - Increased density at bus stops, intersections, and crossings

---

Key Findings

- **Uniform dual-sided spacing performs best** on wide corridors like Joseph E. Boone Blvd
- Continuous canopy significantly reduces MRT along sidewalks and transit stops

- Alternating placement produces **patchy cooling**, effective only in narrower streets
- Tree clustering near transit nodes enhances localized comfort but must be paired with corridor continuity
- Peak benefits observed during **afternoon heat hours**, when pedestrian risk is highest

---

Equity & Gentrification Lens

Environmental improvements alone can increase development pressure. This study integrates:

- Heat vulnerability mapping
- Income and race overlays
- Literature on **green gentrification**

Key takeaway:
Cooling infrastructure must be paired with community stewardship, policy safeguards, and anti-displacement strategies to ensure benefits remain with existing residents.

Design Toolkit Output

The study culminates in a **Heat Equity Design Toolkit** with:

- Corridor-specific canopy spacing guidelines
- Tree placement typologies by street width
- Transit-stop shading strategies
- Native tree species recommendations for Atlanta
- Equity-first implementation principles

Recommended Native / Local Street Trees (Atlanta)

- Willow Oak (*Quercus phellos*)
- Southern Red Oak (*Quercus falcata*)
- American Elm (Dutch-Elm–resistant cultivars)
- Sweetgum (*Liquidambar styraciflua*)
- Blackgum / Tupelo (*Nyssa sylvatica*)
- Eastern Redbud (*Cercis canadensis*) –-understory
- Loblolly Pine (*Pinus taeda*) –-wind and winter buffering

Tools & Software

- ArcGIS Pro
- Rhino + Grasshopper
- Eddy3D Outdoor+
- Google Earth (basemap reference)
- Adobe Illustrator / InDesign (graphics)

Repository Contents

/data

├─ Urban Heat Raster

├─ Urban Tree Canopy (UTC)

├─ ACS Income Data

/maps

├─ Heat

├─ Canopy

├─ Income

├─ Vulnerability Overlays

/simulations

├─ Existing Condition

├─ Uniform Spacing

├─ Alternating Spacing

├─ Clustered Nodes

/report

└── Independent Study – Final PDF

References

- City of Atlanta (2018). *Urban Tree Canopy Assessment*
- City of Atlanta (2018). *Urban Heat Island Dataset*

- U.S. Census Bureau (2023). *ACS 5-Year Estimates*
- Rodriguez, L. et al. (2025). *Local impacts of street trees on thermal comfort*. *Urban Climate*
- Hoffman, J. S., Shandas, V., & Pendleton, N. (2020). *The effects of historical redlining on urban heat*. *Climate*
- Gould, K., & Lewis, T. (2017). *Green Gentrification*. Routledge

---

Acknowledgements

Special thanks to **Patrick Kastner** and **Rounaq Basu** for their guidance, and to Georgia Tech's urban climate research community for providing the intellectual and technical foundation for this work.

Limitations and Future Work

This study focuses on a limited number of representative street segments, with detailed microclimate simulations conducted for a selected portion of Joseph E. Boone Boulevard. While this approach enables controlled comparison of street-tree canopy configurations, results may vary across different street orientations, block lengths, and surrounding built environments.

Outdoor+ simulations rely on modeled assumptions related to surface materials, tree geometry, and meteorological inputs. Therefore, results should be interpreted as **comparative performance outcomes** rather than absolute temperature predictions.

Future research could expand this work by testing additional corridors across multiple low-income neighborhoods, examining seasonal and diurnal variations, and integrating housing and displacement indicators to better assess gentrification risk. Combining tree canopy strategies with complementary interventions—such as cool pavements, shade structures, and transit shelter retrofits—would further strengthen the applicability of microclimate-informed, equity-driven design strategies.

Citations

Rodriguez, F., Santana, J., & Krüger, E. (2025). Local impacts of street trees on outdoor thermal comfort in street canyons. *Urban Climate, 49*, 101528. https://doi.org/10.1016/j.uclim.2023.101528

City of Atlanta. (2015). *Atlanta Climate Action Plan*. https://www.atlantaga.gov

City of Atlanta & Trees Atlanta. (2018). *Urban Tree Canopy Assessment*. https://www.treesatlanta.org

Environmental Protection Agency. (2023). *Heat island effect and mitigation strategies*. https://www.epa.gov/heatislands

Hoffman, J. S., Shandas, V., & Pendleton, N. (2020). The effects of historical housing policies on resident exposure to intra-urban heat. *Climate, 8*(1), 12. https://doi.org/10.3390/cli8010012