Utilizing NASA Earth Observations to Evaluate Urban Tree Canopy and Land Surface Temperature for Green Infrastructure Development and Urban Heat Mitigation in Huntsville, AL

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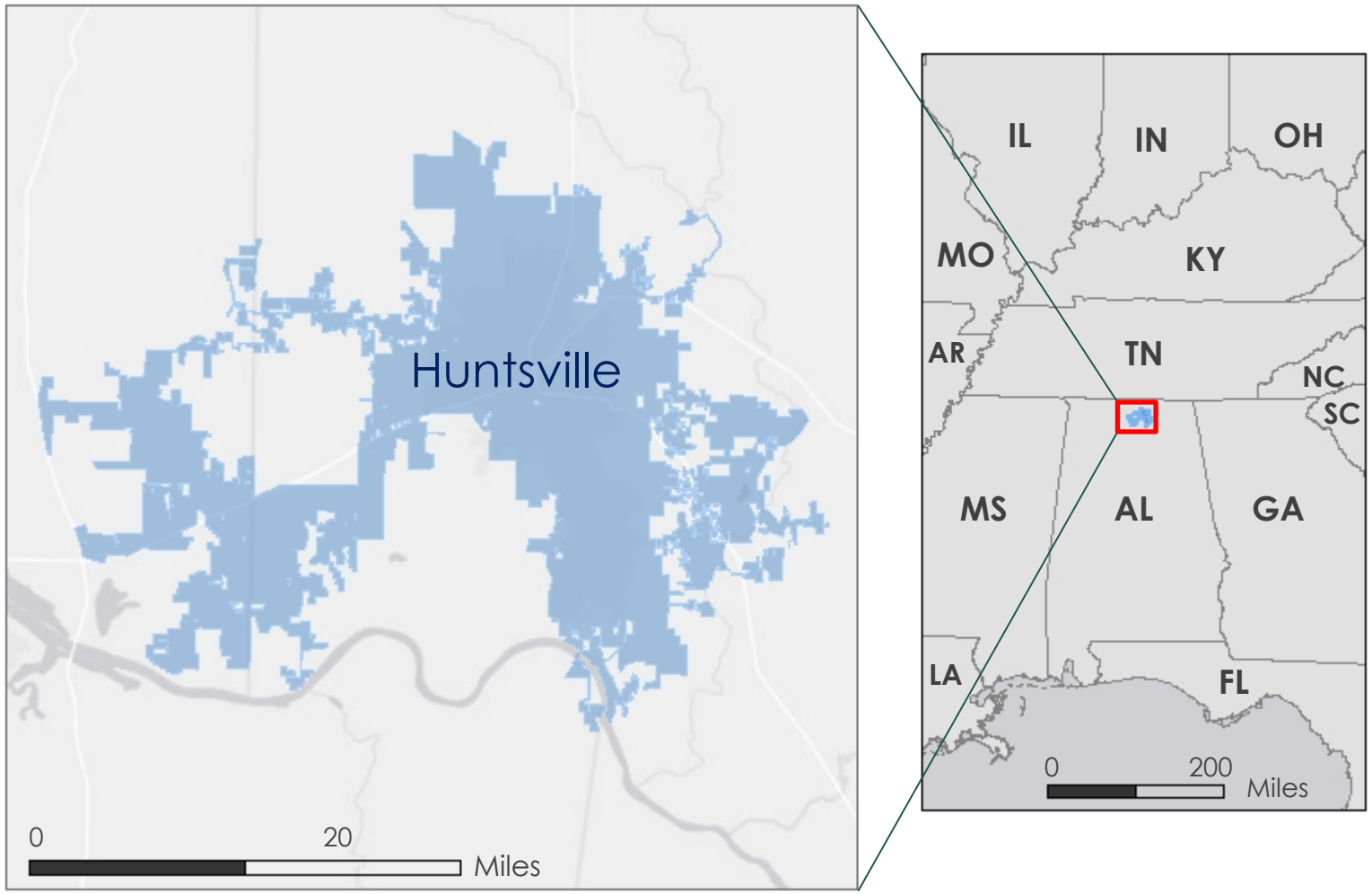
Project Overview

Study Area

- Huntsville, Alabama
  - Population: 200,574
  - Climate: Humid Subtropical
  - Case Study Areas: Downtown, Oak Park, Research Park, Owens Cross Roads, Harvest

Study Period

- 2010 to 2019
  - Summer Months: June 1st – August 31st



Community Concerns

- 20 million hectares of forest are projected to be lost in the US to **population growth** and associated **urban expansion** by 2040.
- **Tree canopy loss** could result in an enhanced **urban heat island** (UHI) effect.
- The UHI effect can lead to **health issues** for those with existing medical conditions such as asthma, diabetes, or COPD.

Image Credit: Anivron

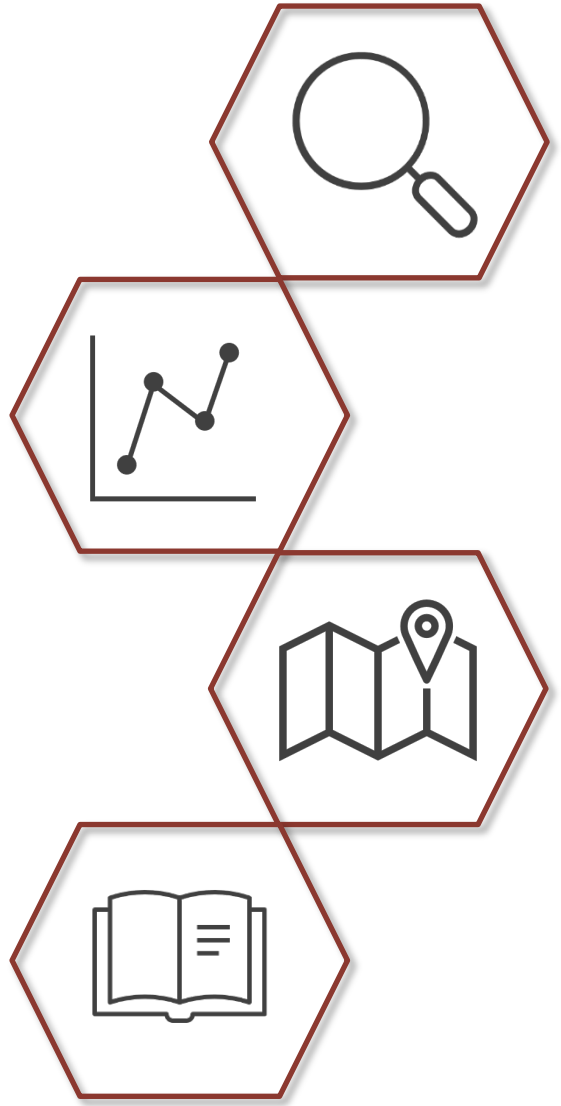
Partners

- The City of Huntsville
  - Urban and Economic Development
  - The City Council
  - Geographic Information Systems (GIS)
  - Urban and Long-Range Planning
  - City Planning
  - Landscape Management
  - City Engineering

Image Credit: Amanda Tomlinson

Project Objectives

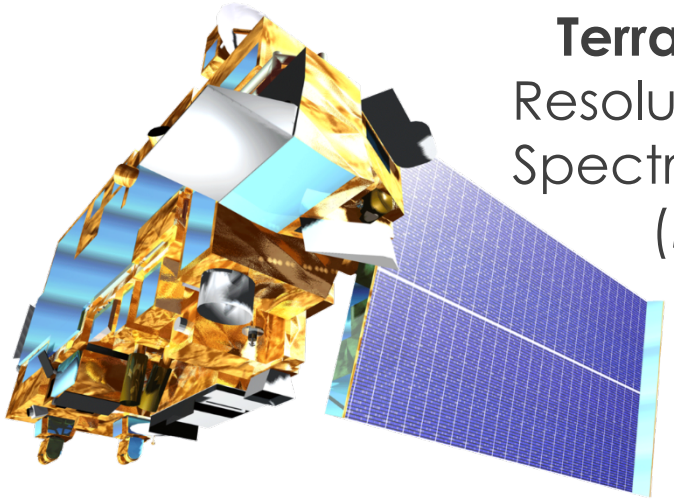
- **Investigate** and **analyze** correlations between tree canopy coverage and land surface temperature (LST)
- **Quantify** the impacts of Huntsville's urban expansion on **decreasing** tree canopy coverage and **increasing** impervious surface coverage
- **Identify** hot spots within the city that are **experiencing** the UHI Effect and the vulnerable populations within them
- **Communicate** our findings through an ArcGIS Story Map



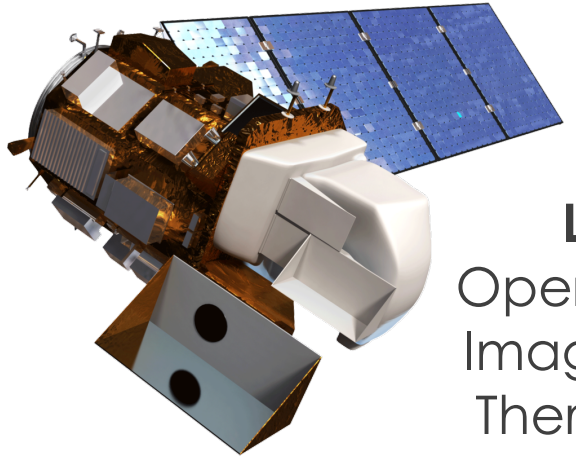
Satellites & Sensors

Landsat 5
Thematic Mapper (TM)

International Space Station (ISS)
ECOsystem Spaceborne Thermal Radiometer Experiment on Space Station (ECOSTRESS) and Global Ecosystem Dynamics Investigation (GEDI)



Terra Moderate Resolution Imaging Spectroradiometer (MODIS)

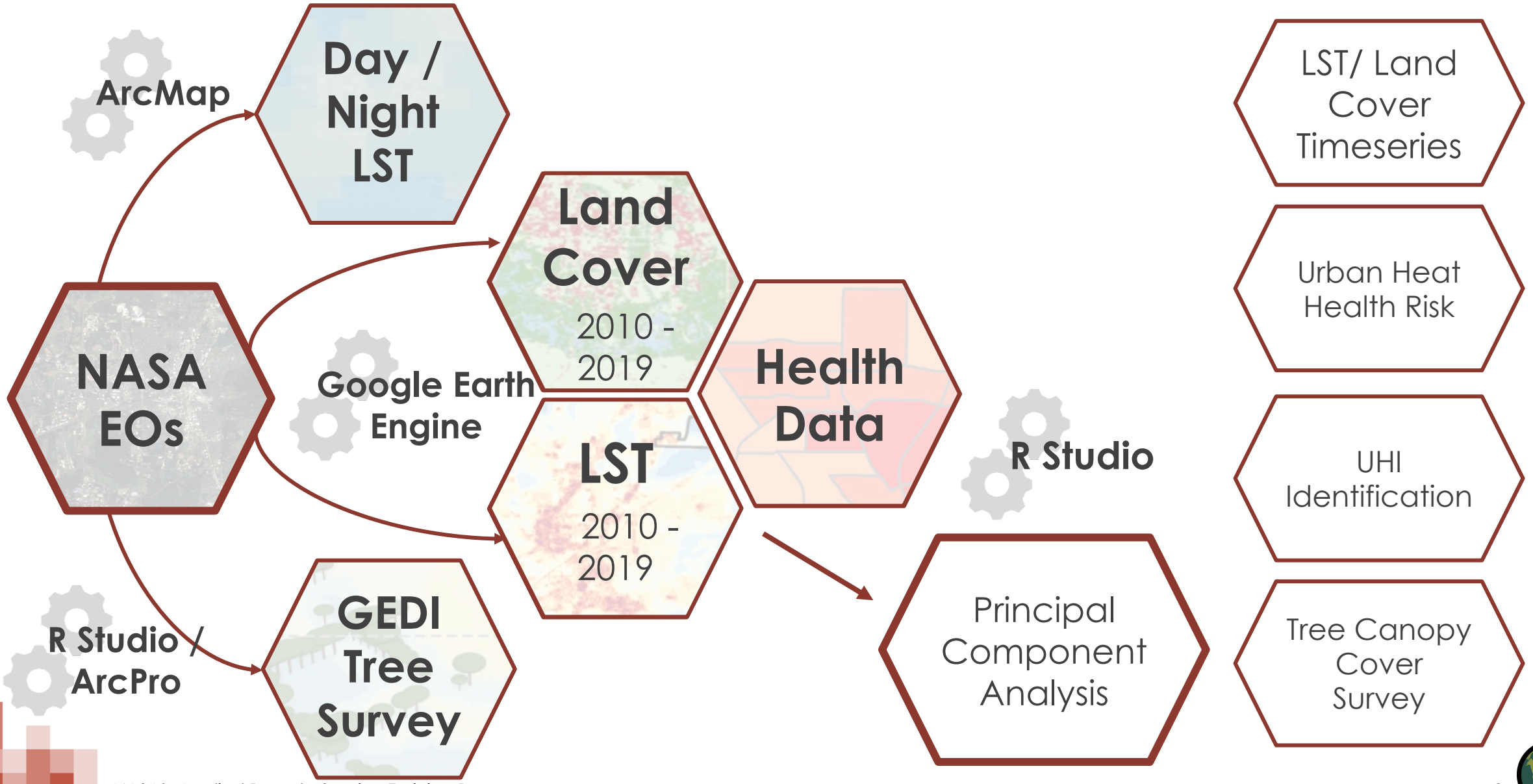


Landsat 8
Operational Land Imager (OLI) and Thermal Infrared Sensor (TIRS)

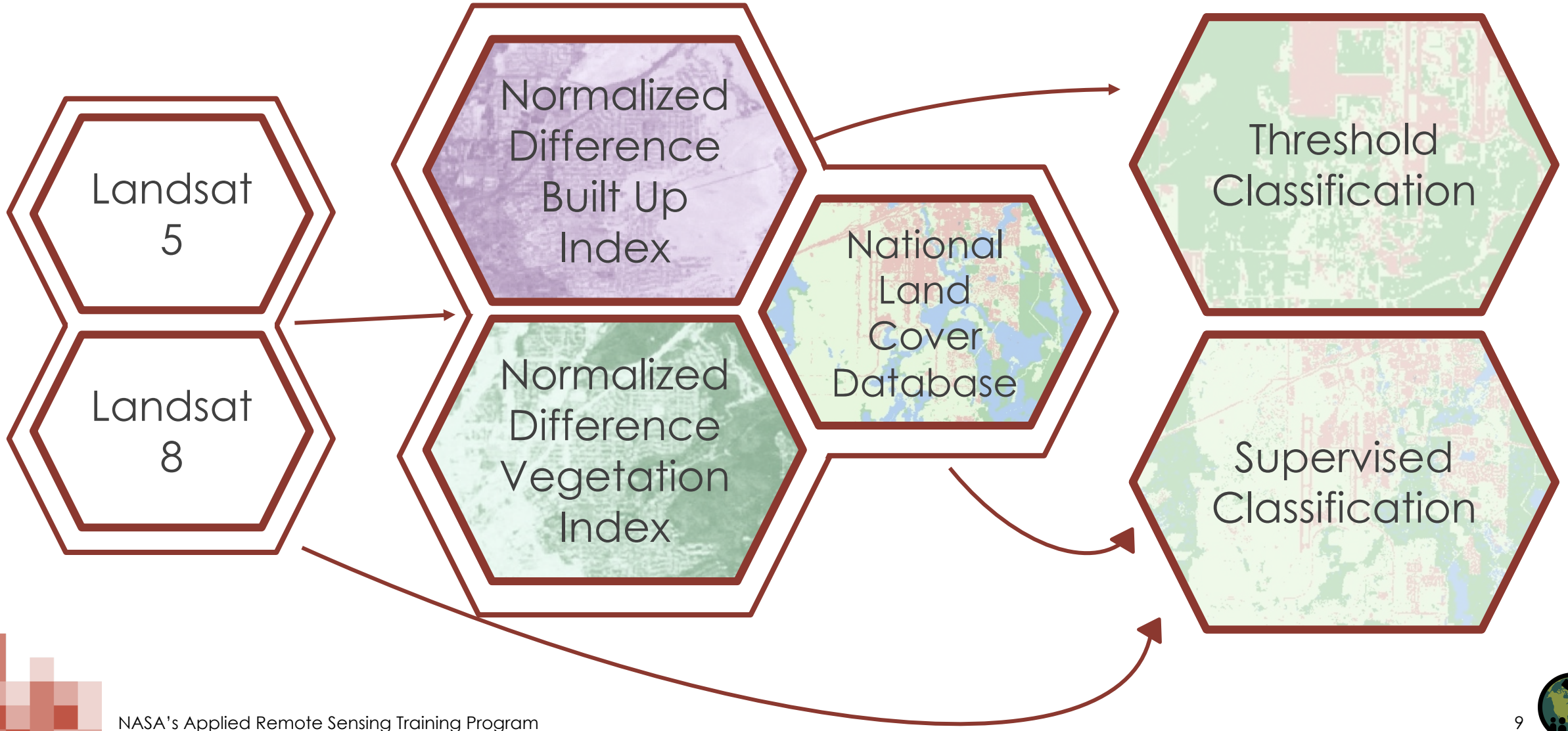
Ancillary Datasets

Data Source	Parameter
United States Census Bureau Topologically Integrated Geographic Encoding and Referencing	Population Data
Centers for Disease Control	Health Statistics
USGS National Land Cover Database	Land Cover Images
USDA National Agriculture Imagery Program	Digital Ortho-photography

Methodology: Overview

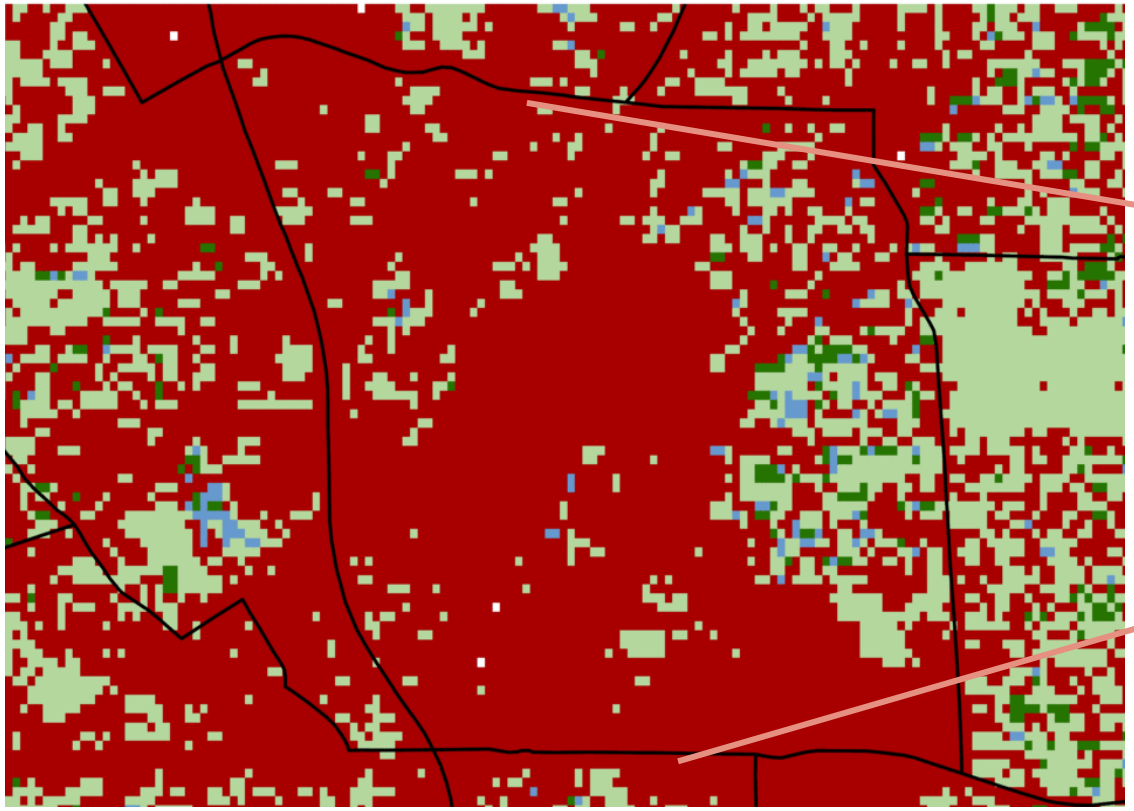


Methodology: Land Cover

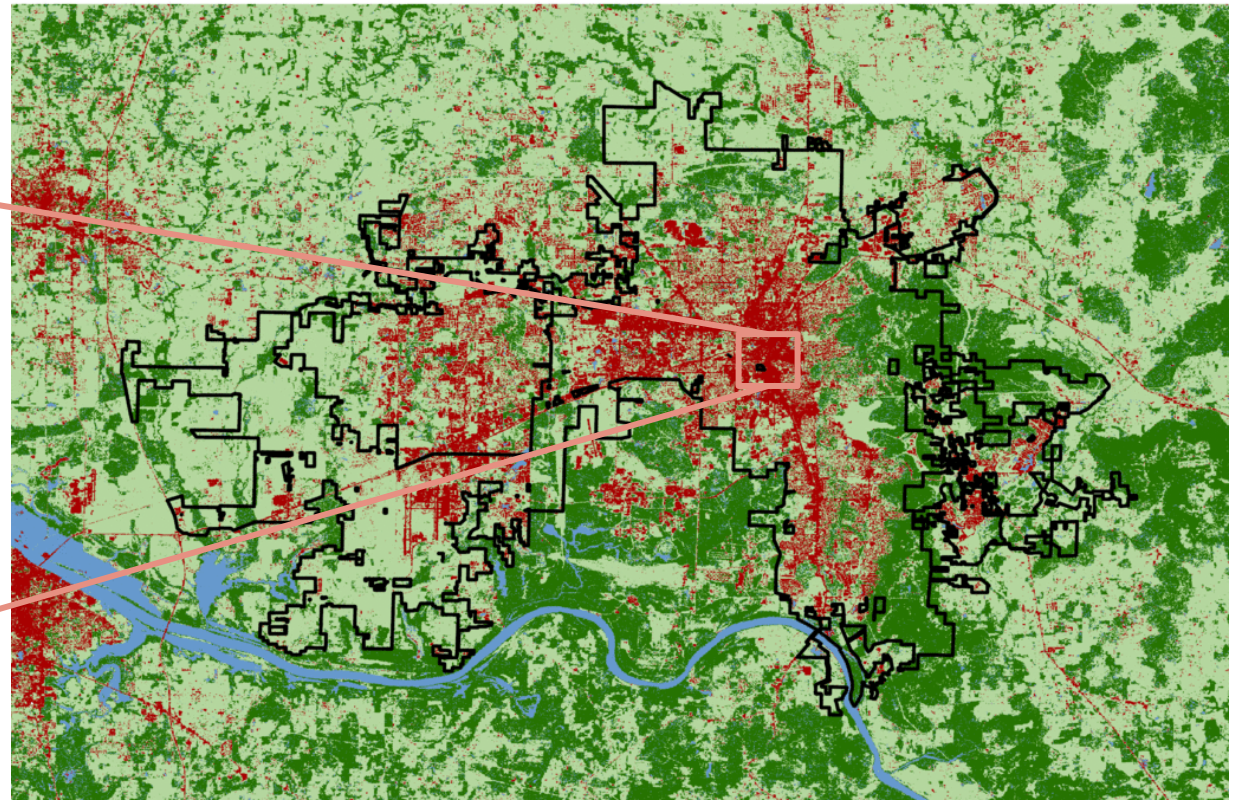


Results: Land Cover, 2010 to 2019

2010 Supervised Classification
Huntsville, AL; Downtown, Census Tract: 31



2010 Supervised Classification
Huntsville, AL



N

0 2 miles

Land Cover Classes
- Tree
- Other Pervious
- Impervious
- Water

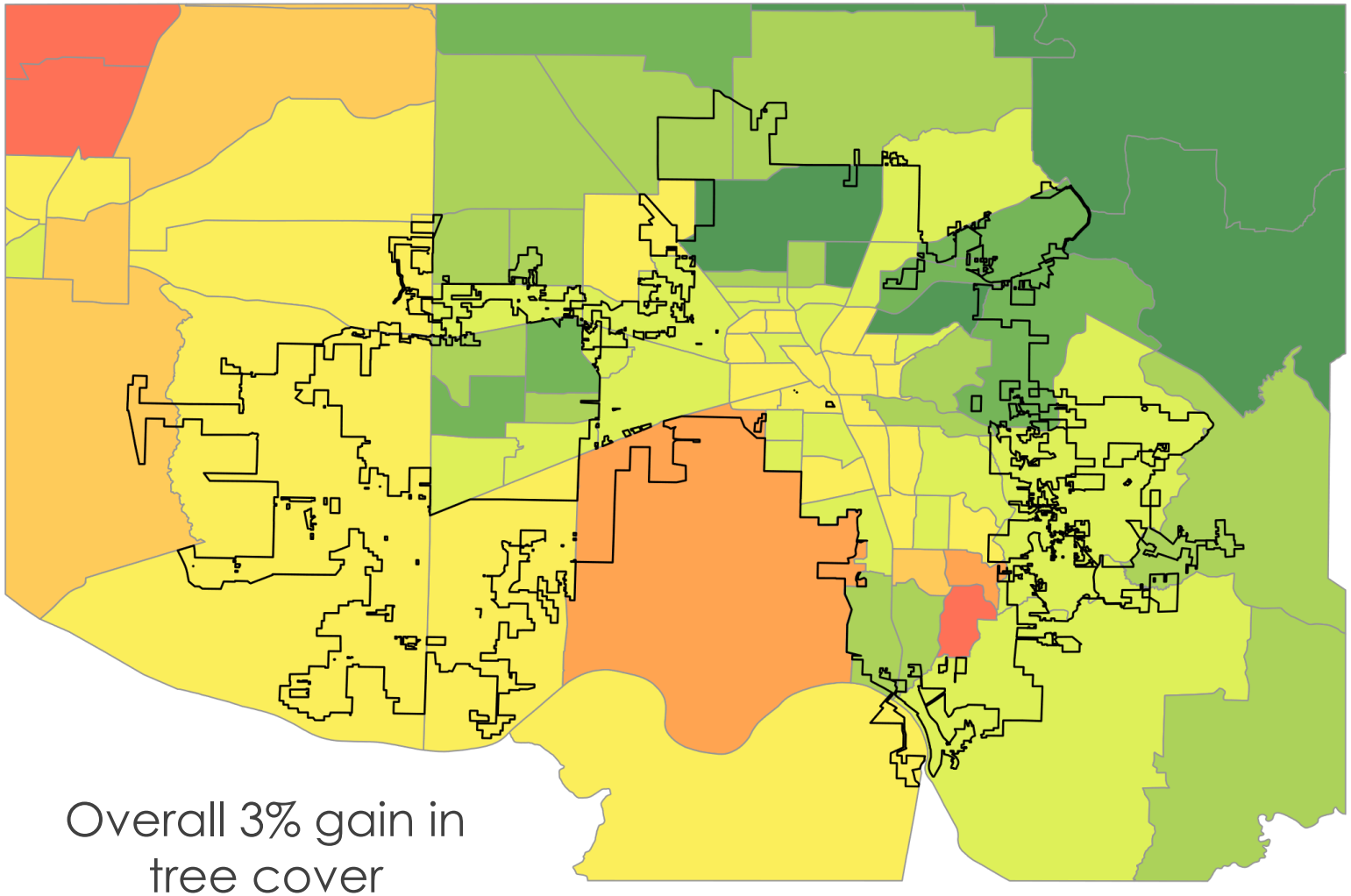
0 32 miles

Results: Land Cover Validation

- Manually classified 152 random points on 2011 and 2017 NAIP Imagery
- Overall accuracy ranged from 70.0% to 75.0%

2017 Reference	2017 Classification: Tree	Non-Tree Vegetation	Impervious	Water	
Tree	41	8	1	0	50
Non-Tree Vegetation	19	51	6	0	76
Impervious	0	6	9	0	15
Water	5	1	0	5	11
	65	66	16	5	**152**

Results: Tree Cover, 2010 to 2019



Overall 3% gain in tree cover

Percent Difference in Tree Cover

- ≤ -4%
- ≤ -2%
- ≤ 0%
- ≤ 2%
- ≤ 4%
- ≤ 6%
- ≤ 8%
- ≤ 14%
- City of Huntsville
- Census Tracts

N

0 10 20 miles

Methodology: Tree Canopy Survey

Data Acquisition

Level 2B LiDAR

Esri World DEM

2019 LST Map

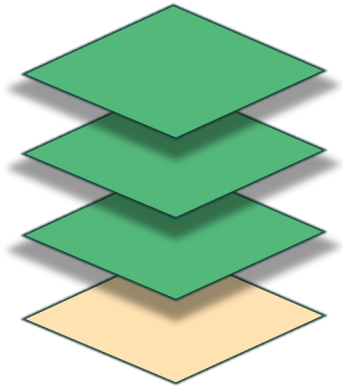
Processing

Tree Cover > 40%

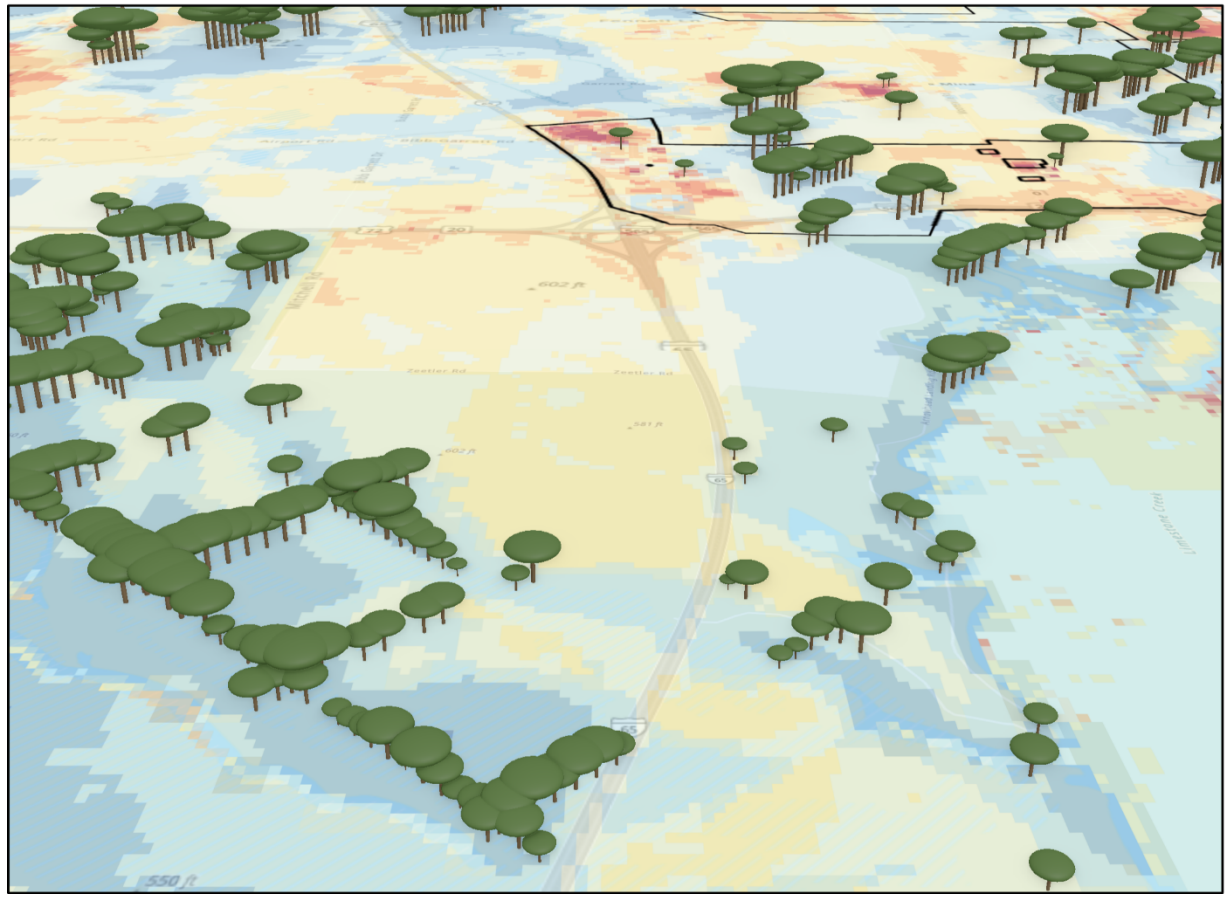
Pass Quality Inspection

First and Last Return Subtraction

Histograms of Plant Area Index (PAI) and Height



Results: GEDI Tree Canopy Survey



LST (°F)

106

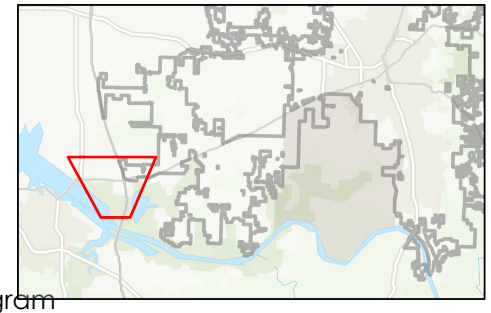
70

City of Huntsville

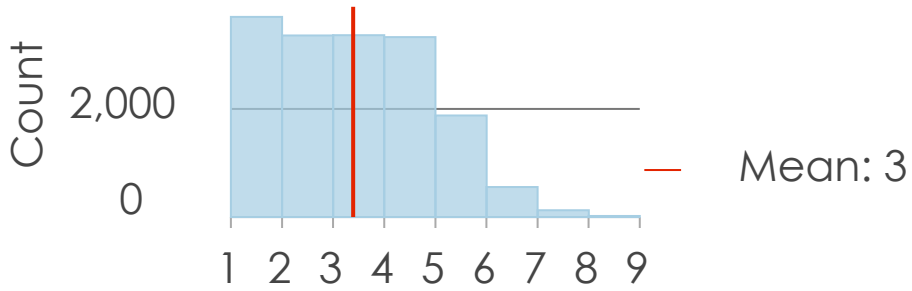
Trees

0 0.2 miles

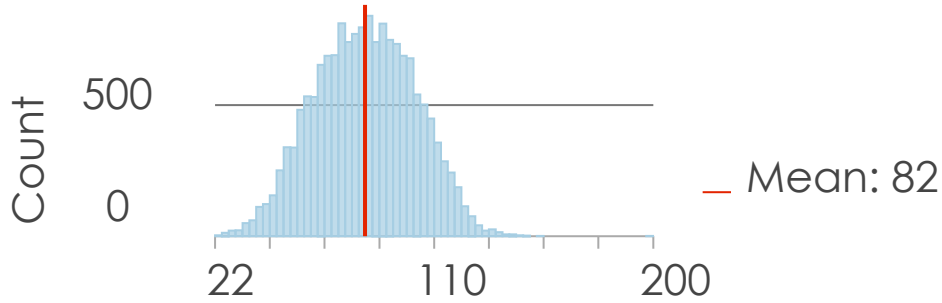
N



Distribution of Plant Area Index

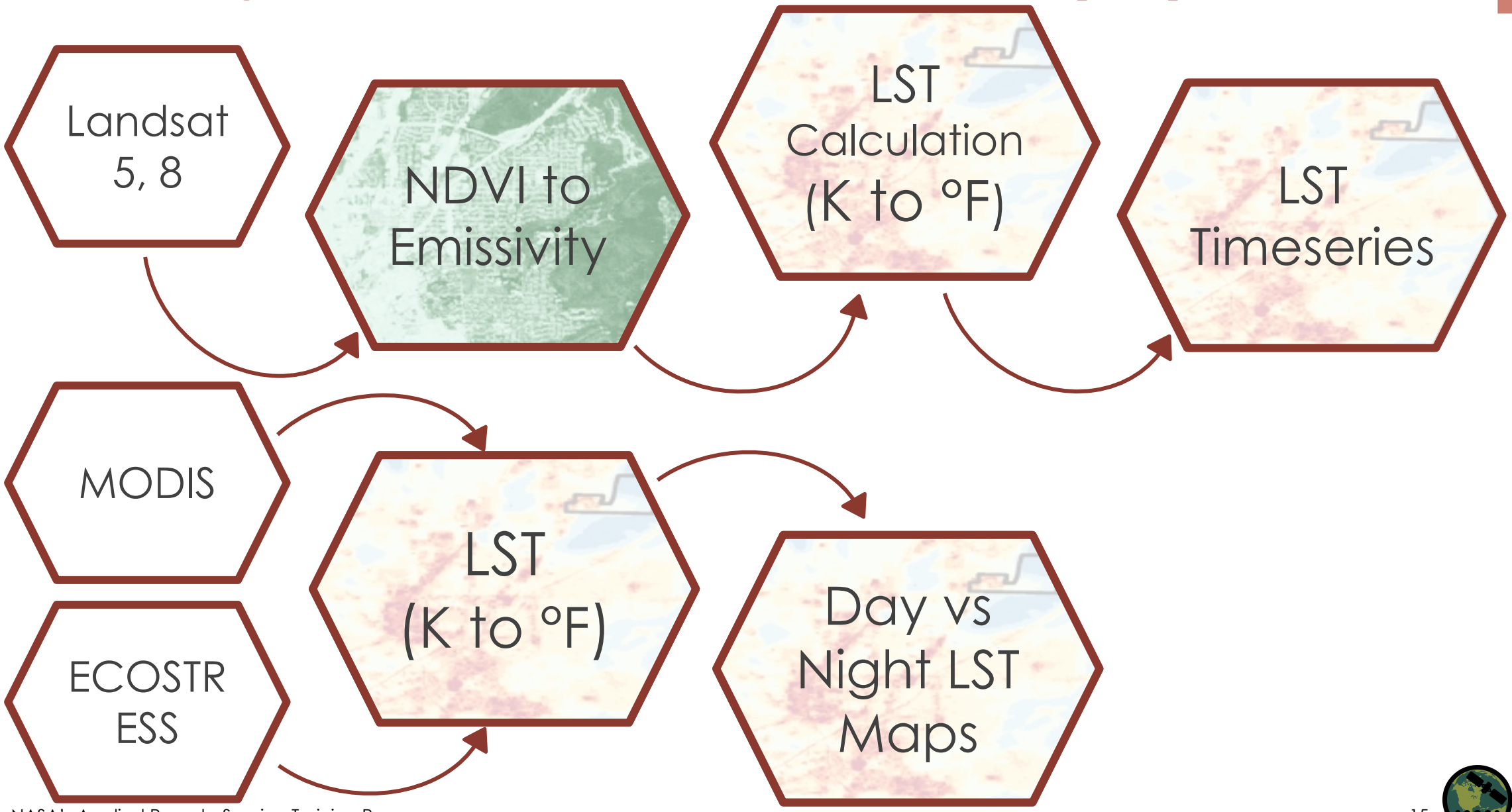


Distribution of Tree Height (feet)

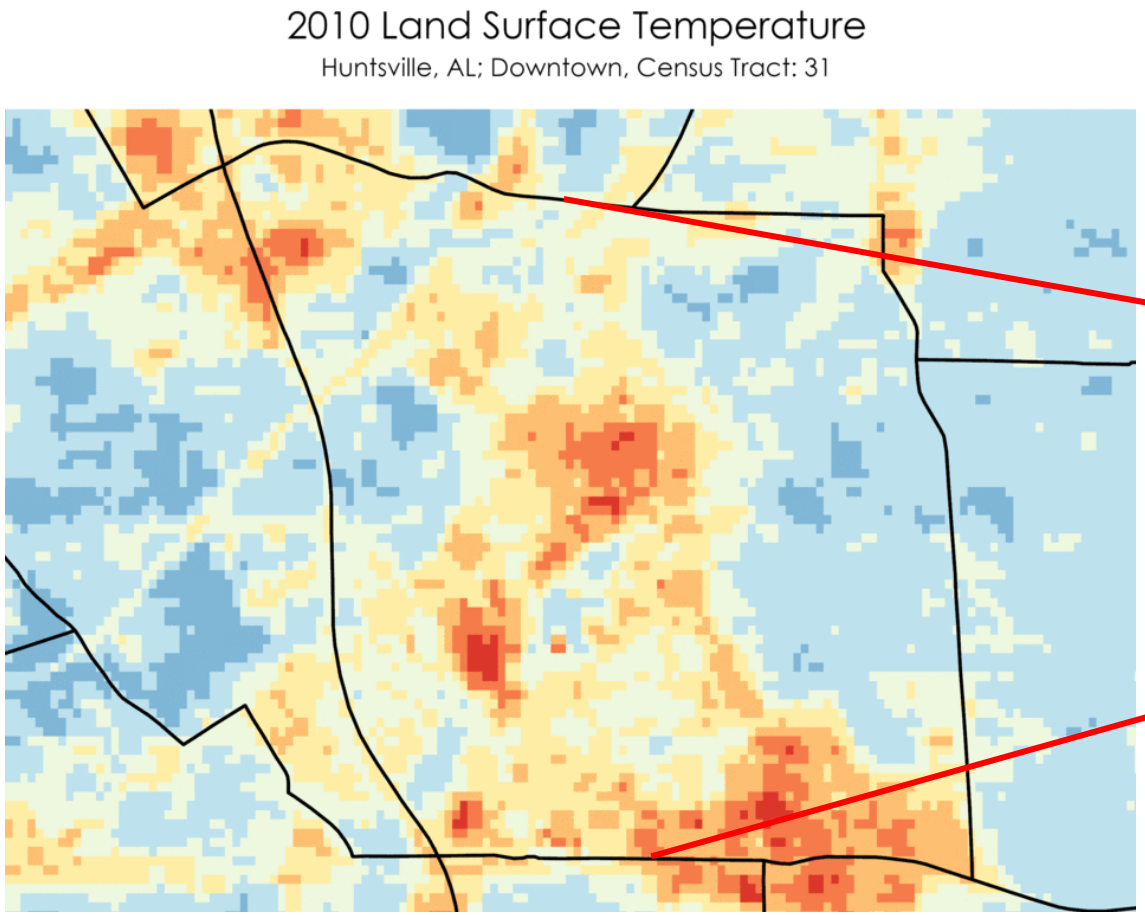


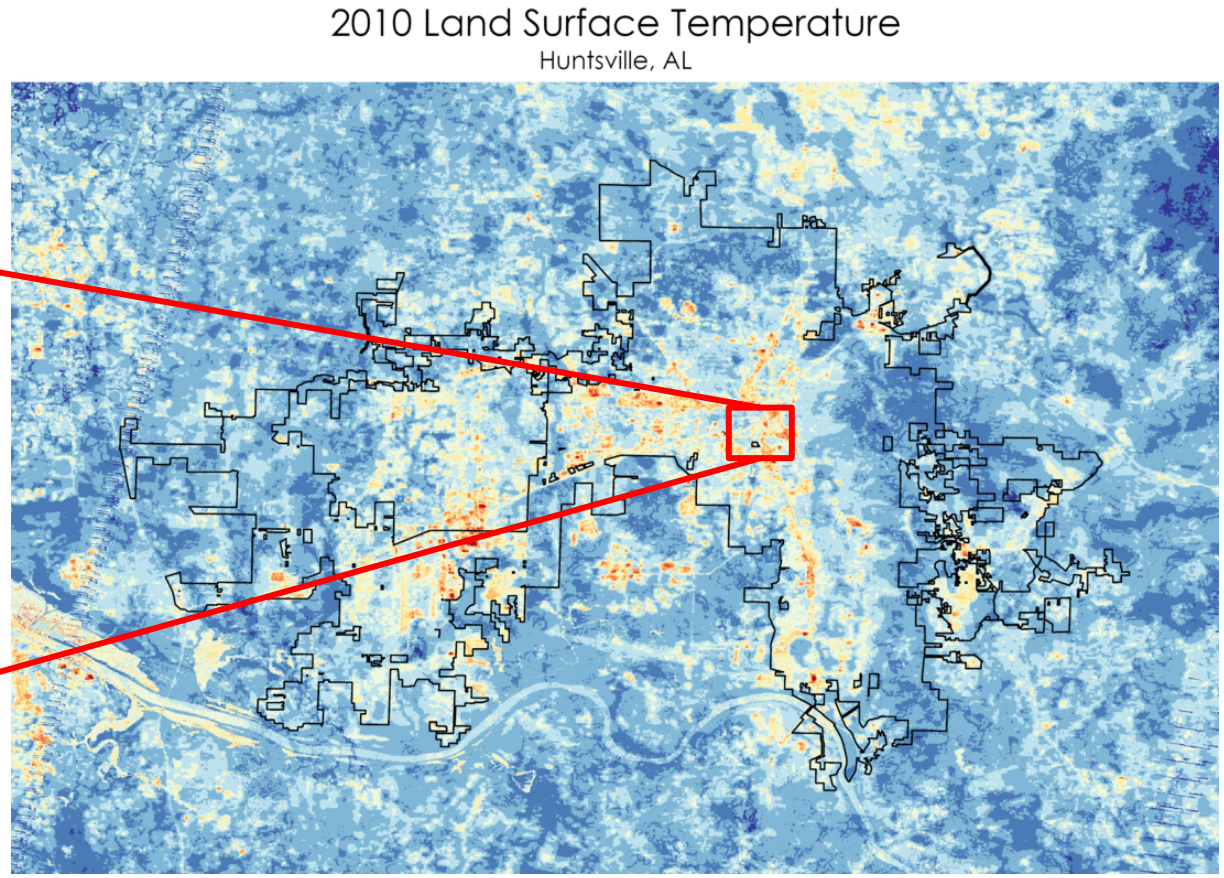
GEDI – Global Ecosystem Dynamics Investigation

Methodology: Land Surface Temperature (LST)



Results: LST, 2010 to 2019





N

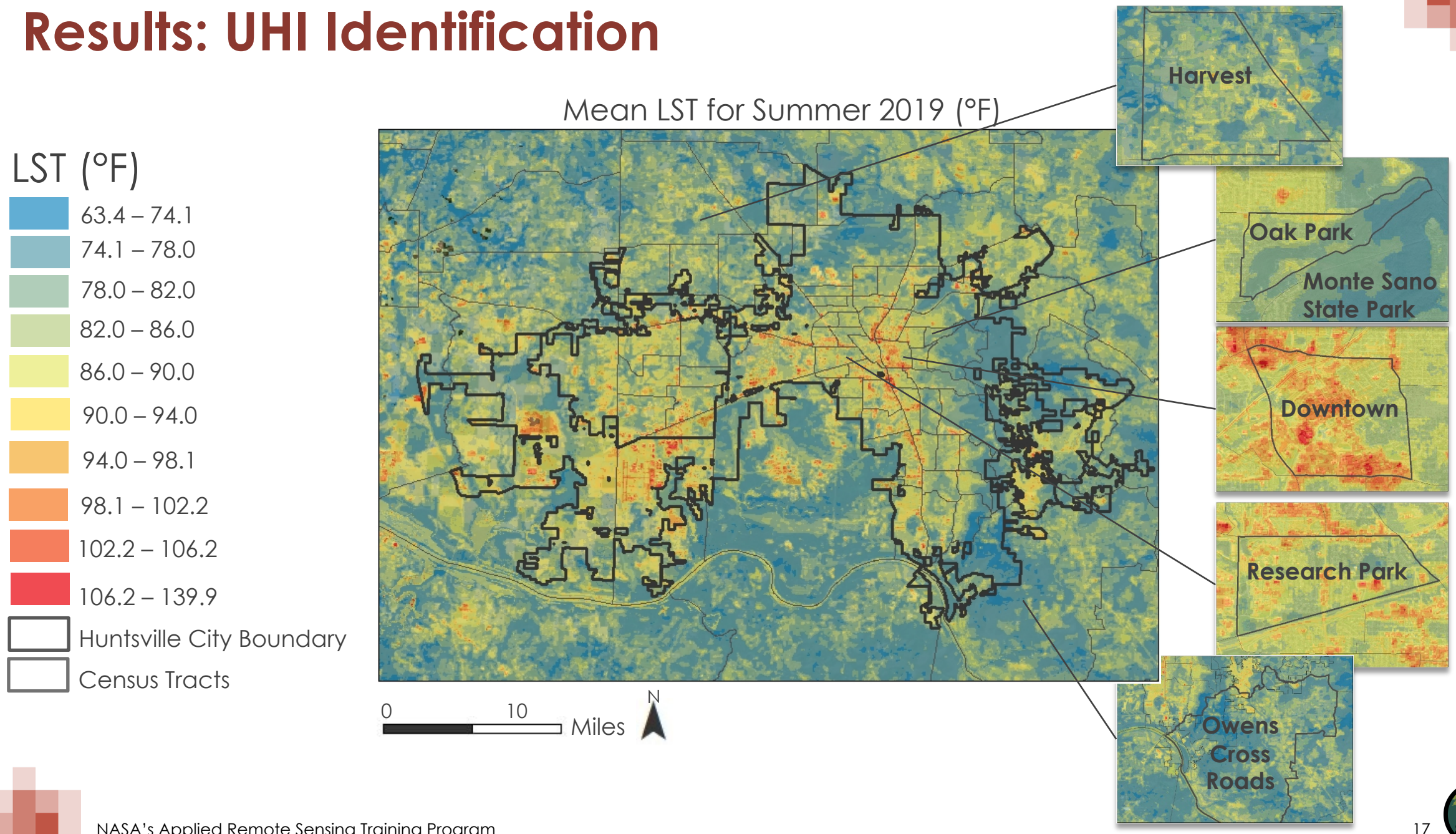
0 2 miles

LST (°F)

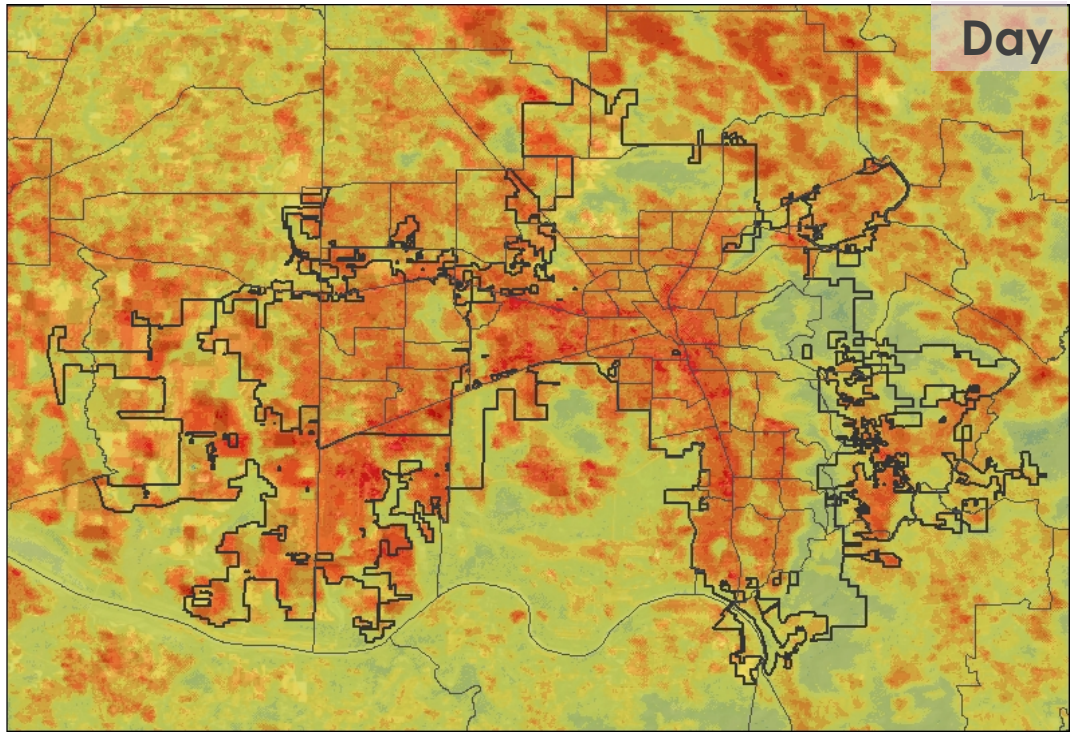
<70	86-90
70-74	90-94
74-78	94-98
78-82	98-102
82-86	102-106

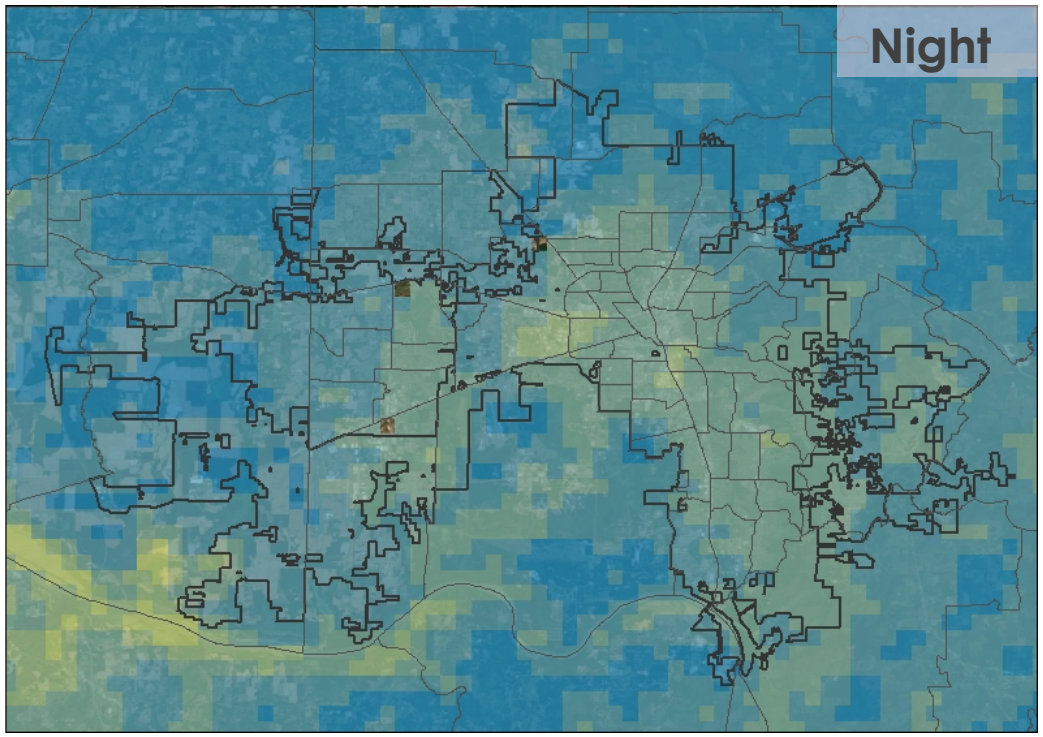
0 32 miles

Results: UHI Identification



Results: UHI Identification





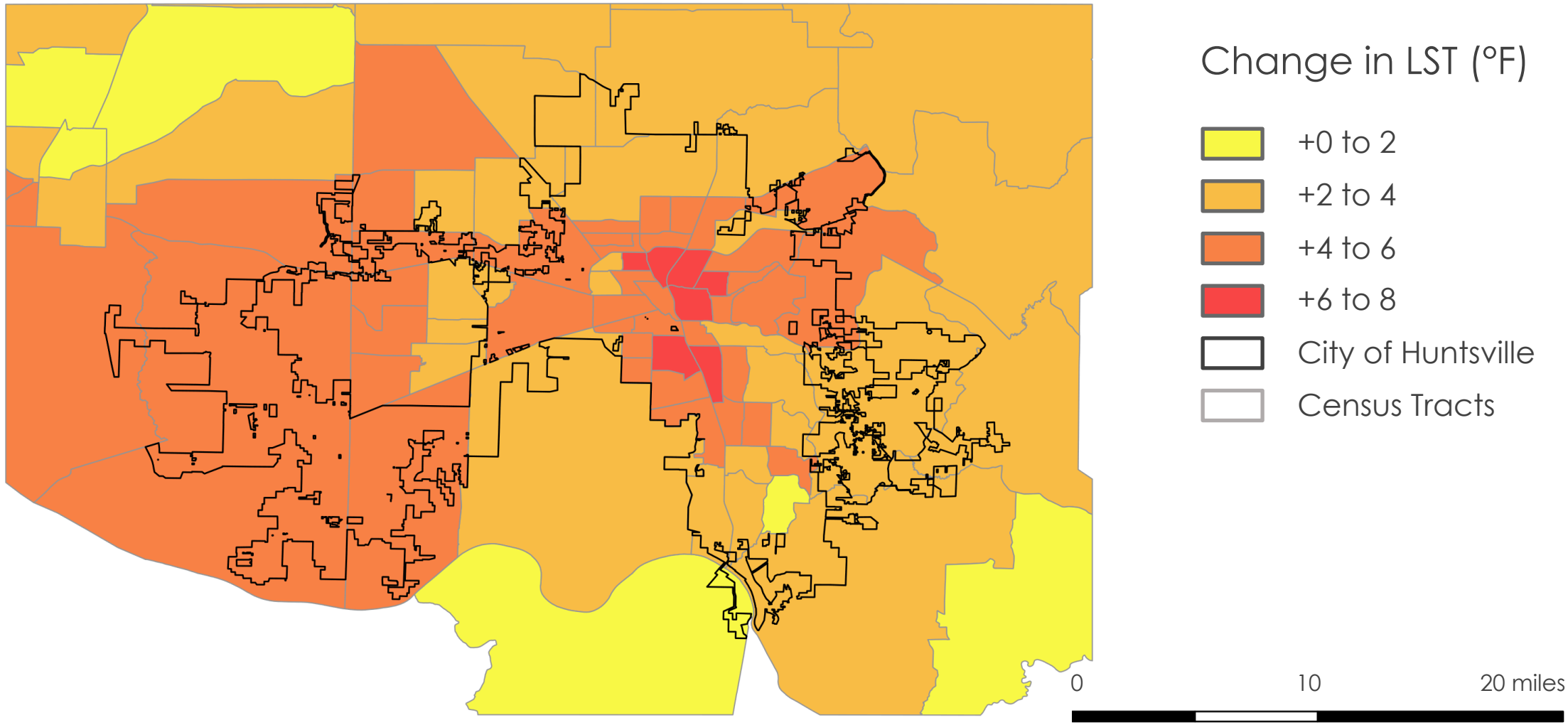
Daytime and Nighttime LST Comparison for June 12, 2020 (°F)

N

0 10 Miles

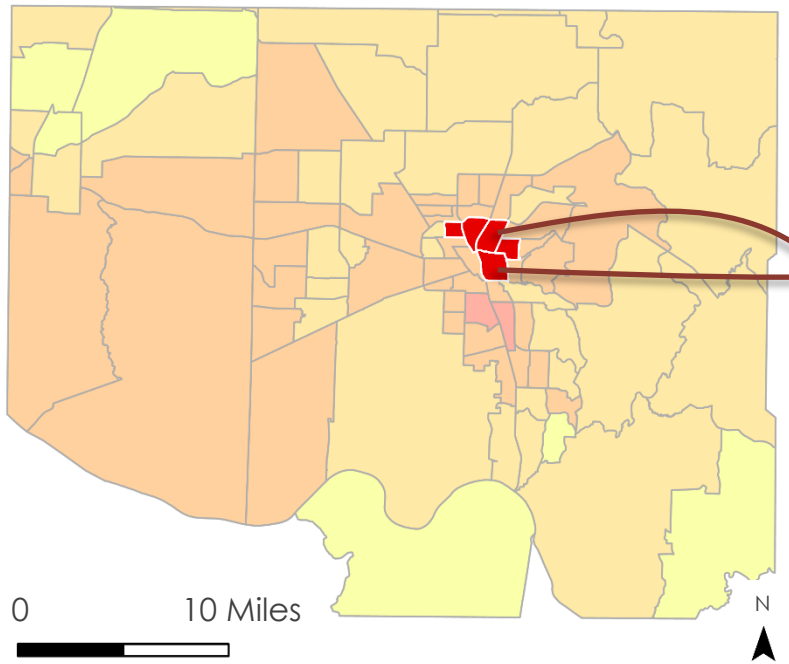
62.2 – 64.5
64.5 – 67.1
67.1 – 70.4
70.4 – 73.6
73.6 – 77.1
77.1 – 80.5
80.5 – 84.3
84.3 – 87.7
87.7 – 91.1
91.1 – 95.0
95.0 – 98.9
98.9 – 110.2
Huntsville City Boundary
Census Tracts

Results: LST Change, 2010 to 2019



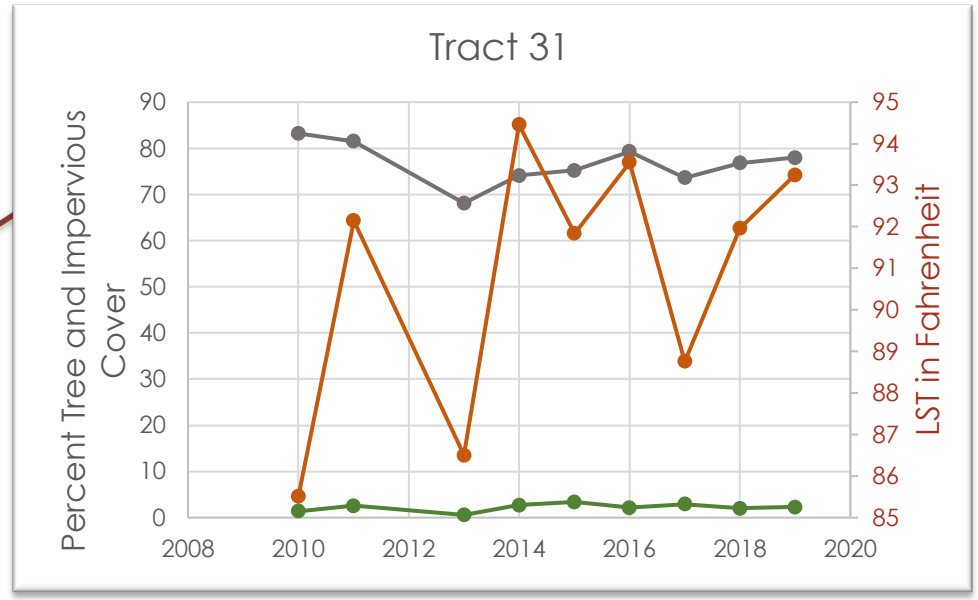
Results: Time Series – LST Increase

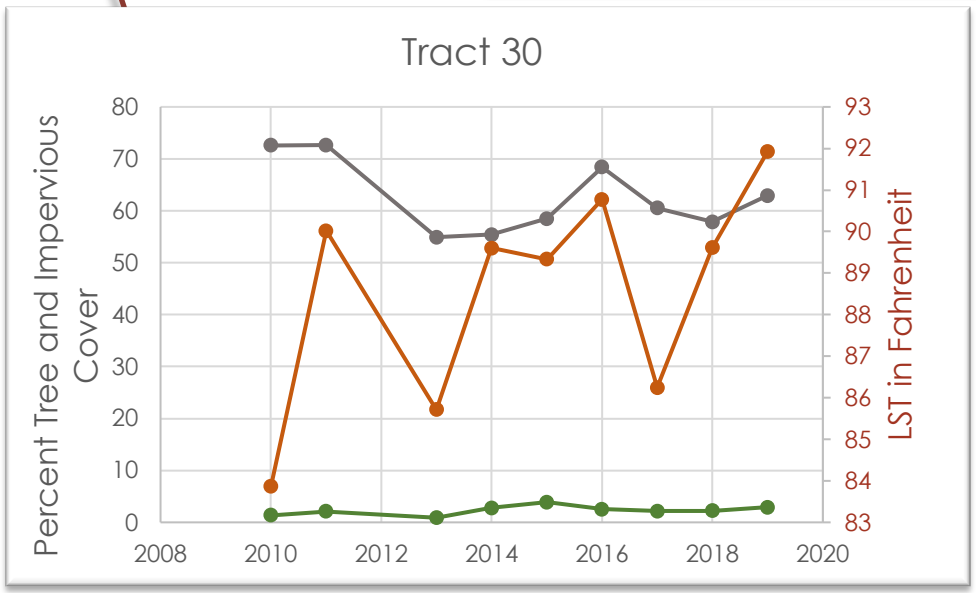
Tracts with Highest LST Increase



LST Change (2010 – 2019) °F

- + 0 to 2
- + 2 to 4
- + 4 to 6
- +6 to 8
- Census Tracts

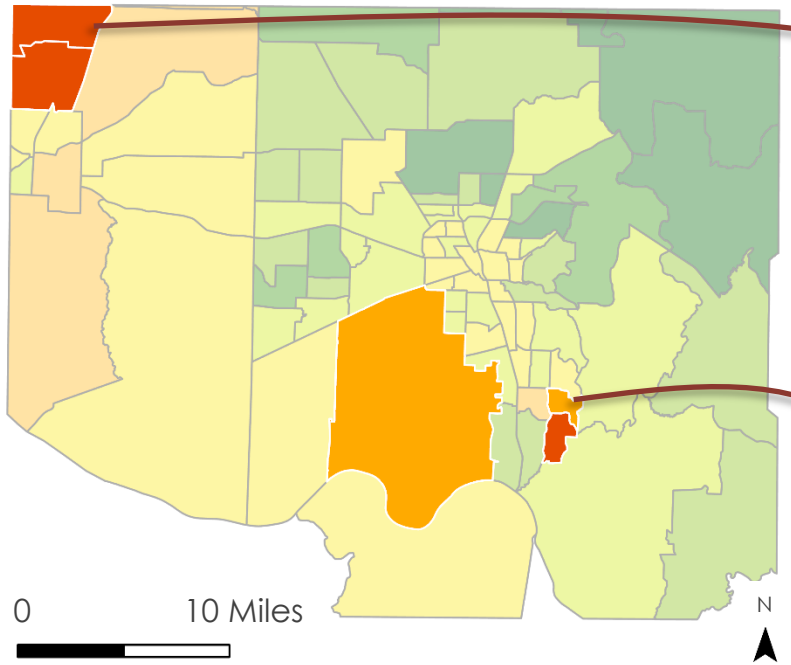




- Tree Cover
- Impervious Cover
- LST

Results: Time Series – Tree Loss

Tracts with Most Tree Cover Loss



Tree Cover Change (2010 to 2019)

- ≤ -4%
- ≤ -2%
- ≤ 0%
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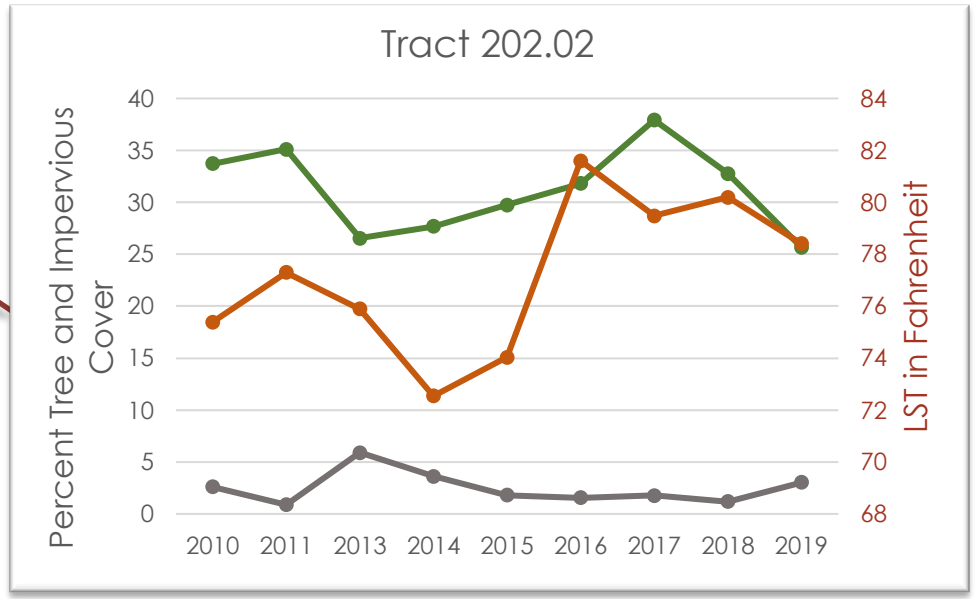
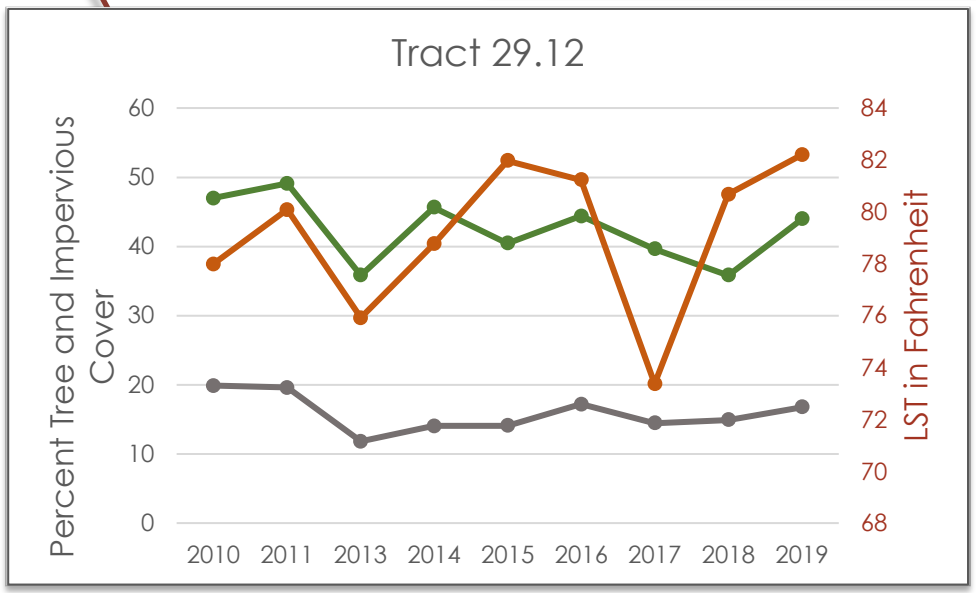
- ≤ 8%
- ≤ 14%
- City of Huntsville
- Census Tracts

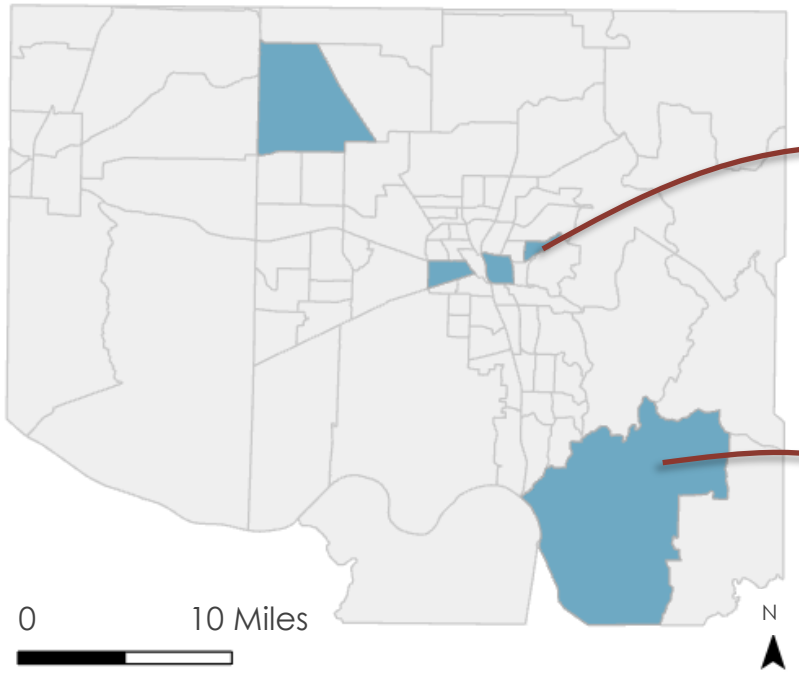




Tree Cover
Impervious Cover
LST

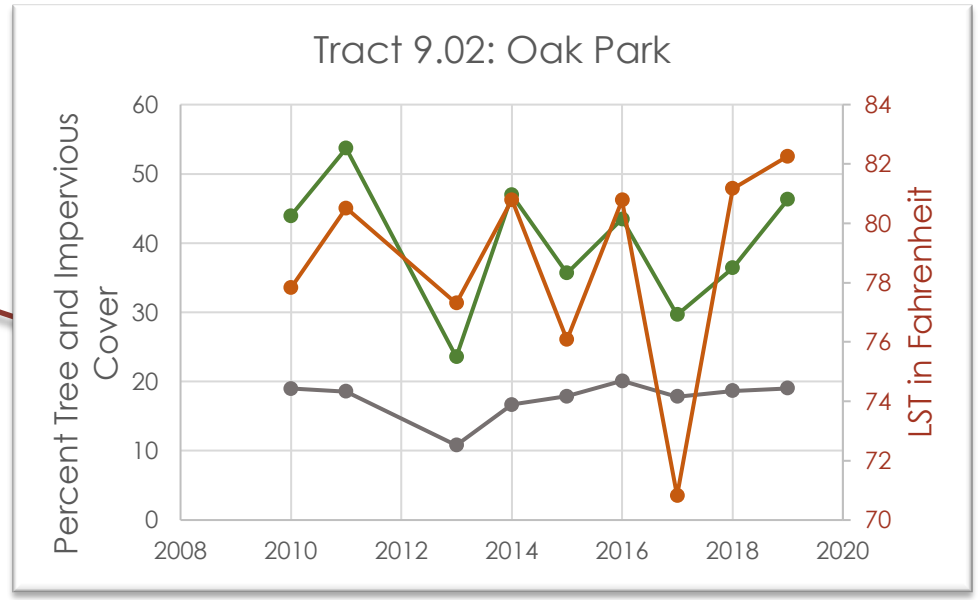
Results: Time Series – Case Study Tracts

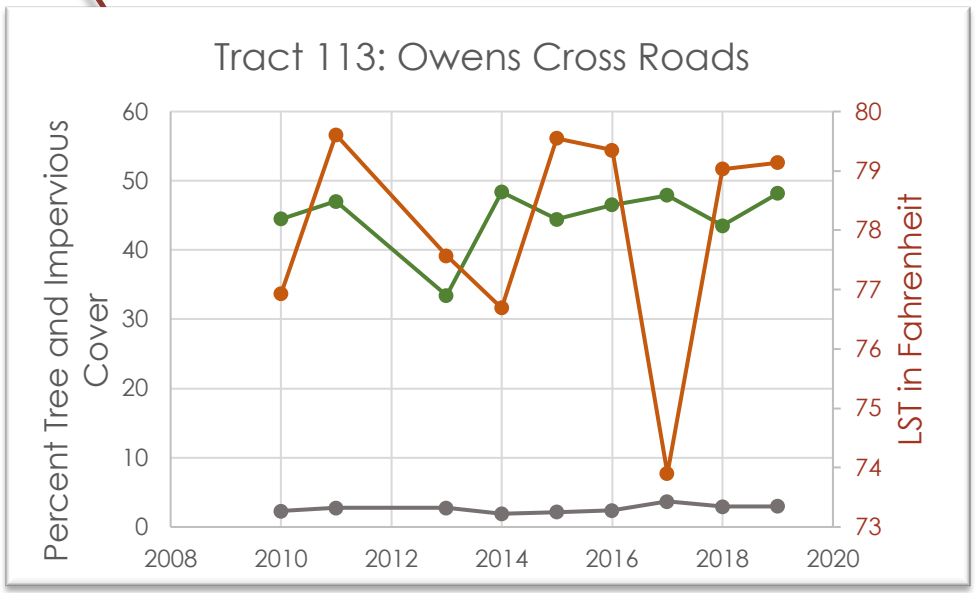
Case Study Census Tracts



All Census Tracts

Case Study Tracts



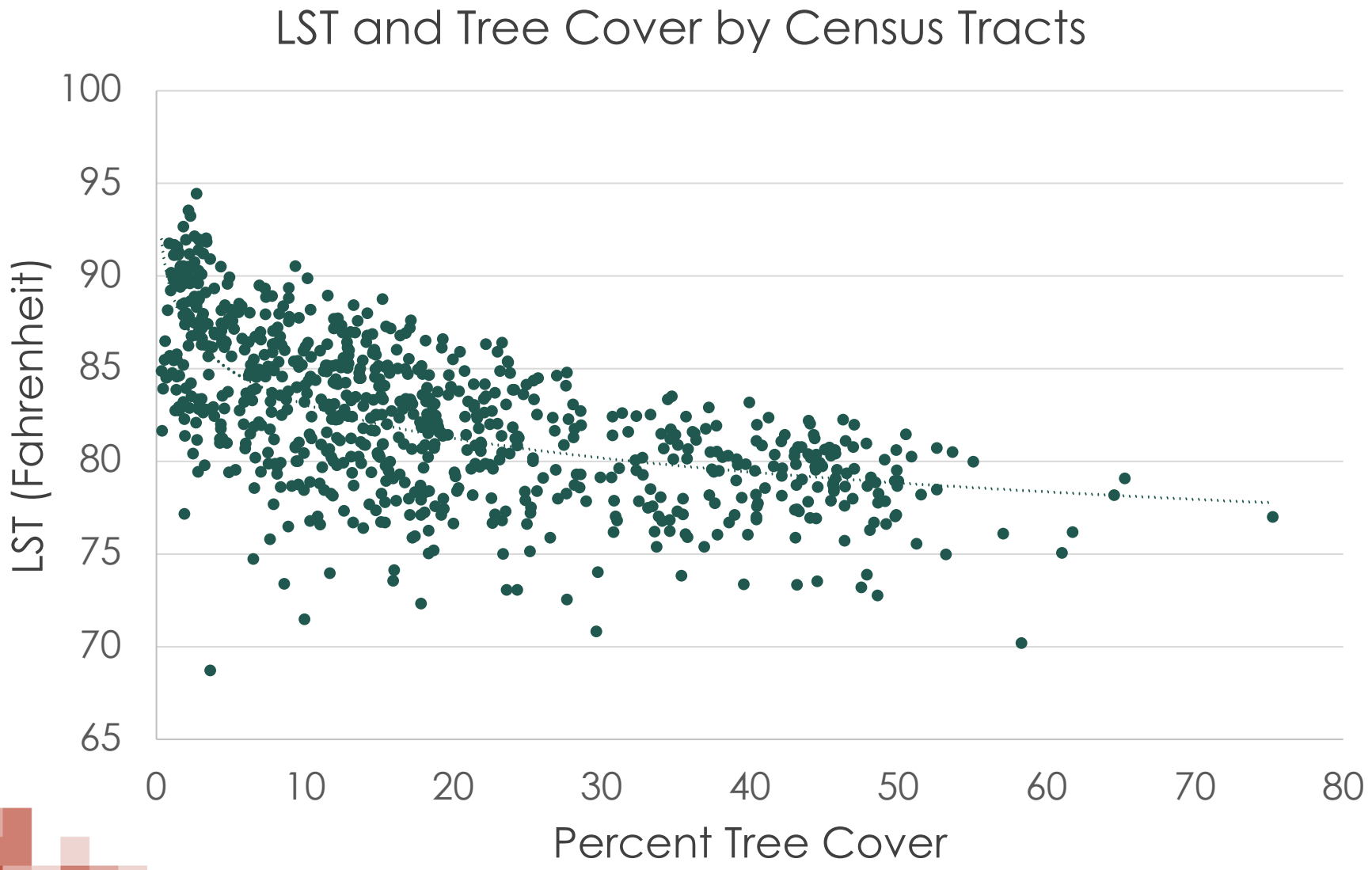


Tree Cover

Impervious Cover

LST

Results: LST and Land Cover

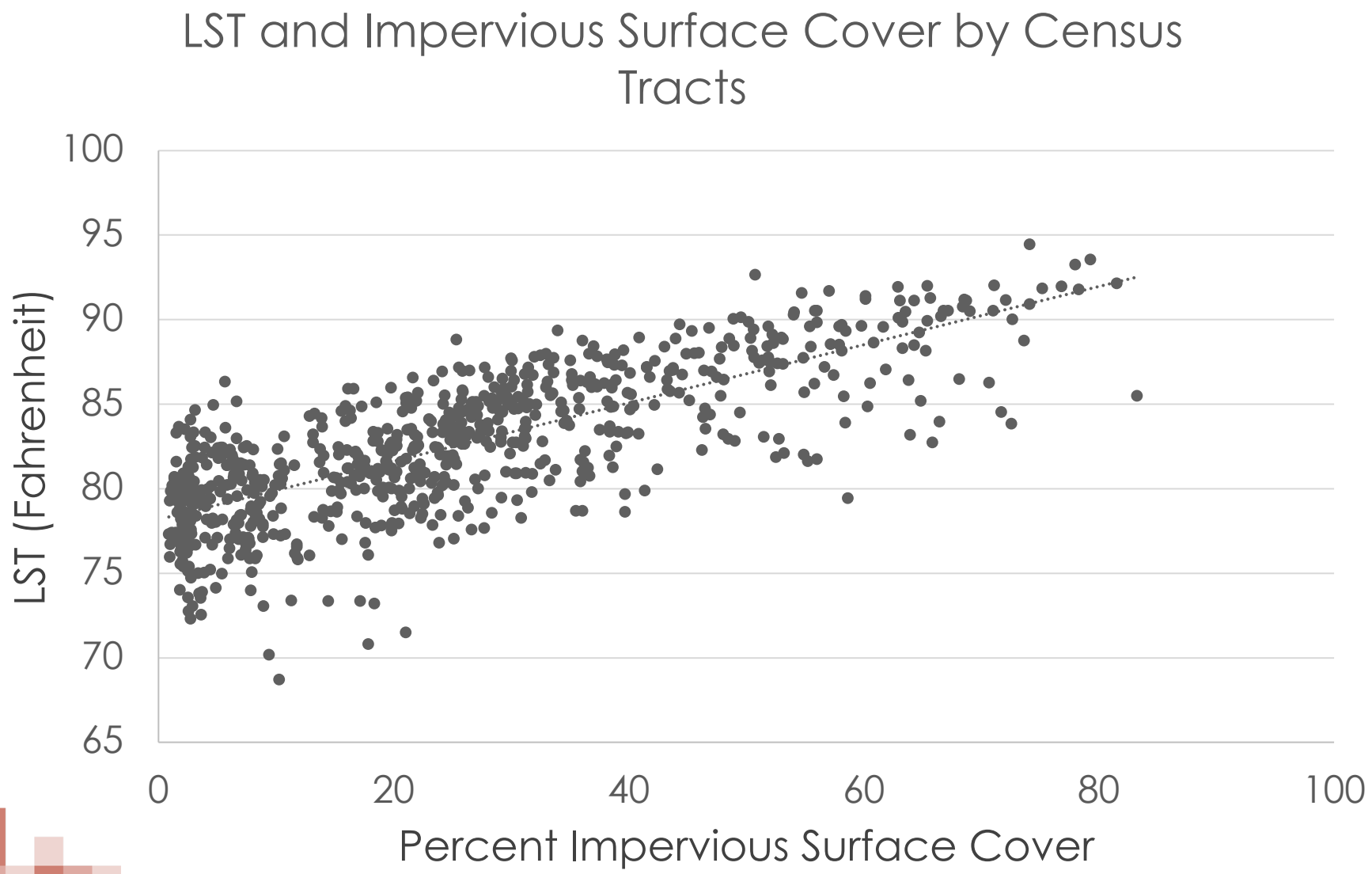


Line of Best Fit:

$y = -2.636\ln(x) + 89.148$

R^2: 0.4024

Results: LST and Land Cover

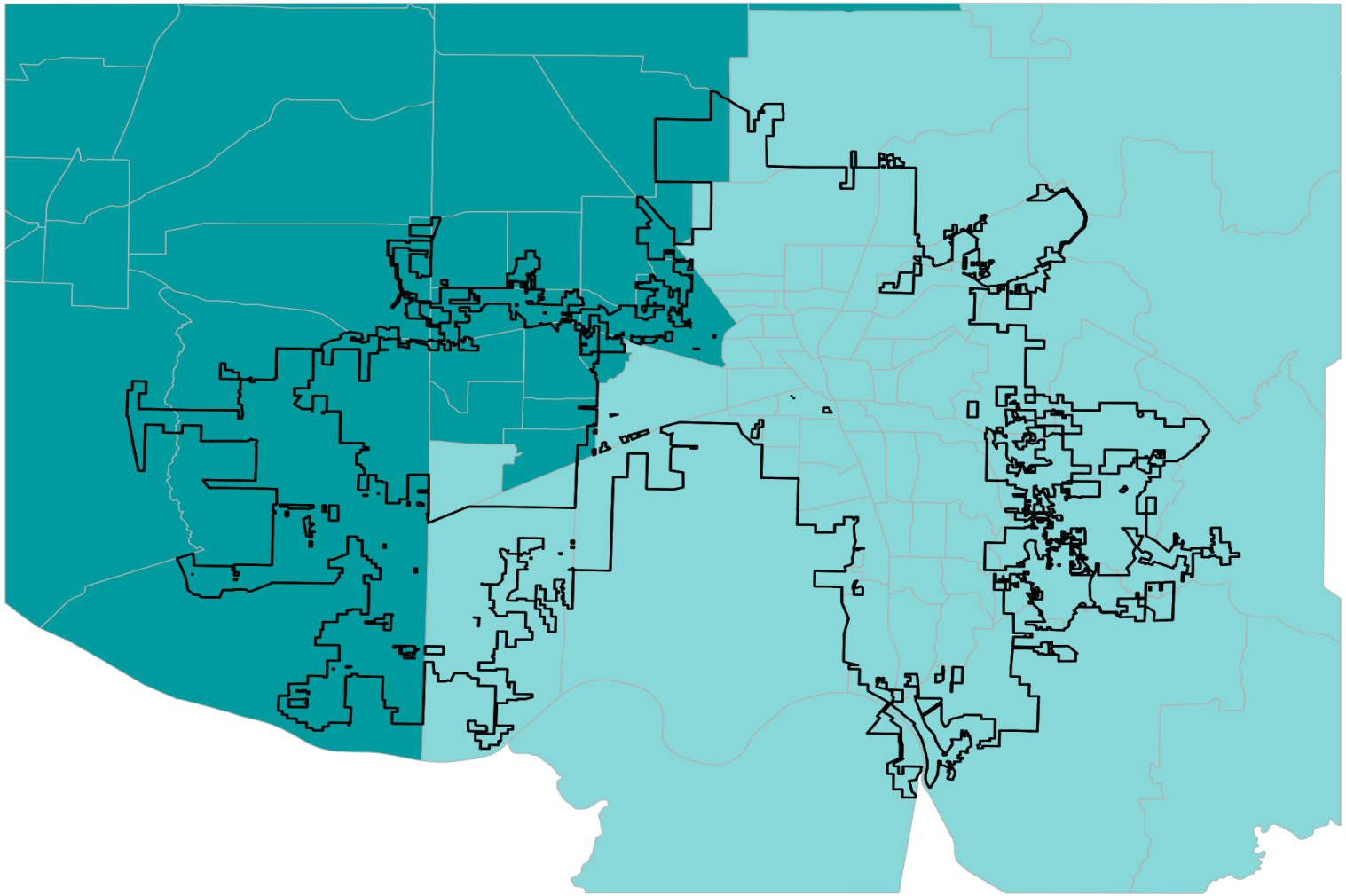


Line of Best Fit:

0.1723x + 78.18

R^2: 0.5982

Results: Bivariate Relationships Map



Bivariate Relationships

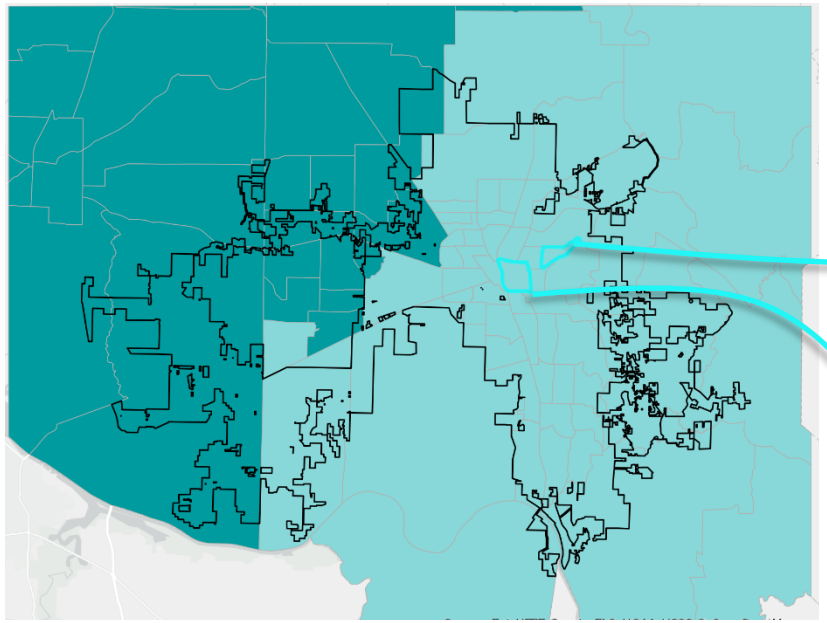
- Negative Linear
- Negative Convex
- City of Huntsville
- Census Tracts

LST decreases drastically with increased tree cover. This relationship holds throughout all areas of Huntsville.

N

0 10 20 miles

Results: Bivariate Charts



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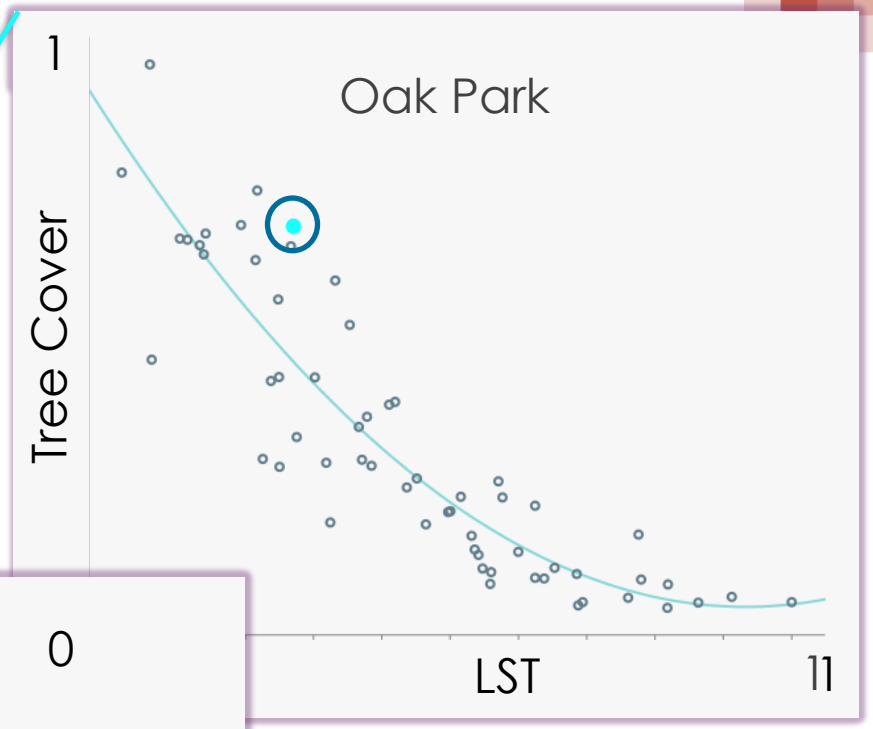
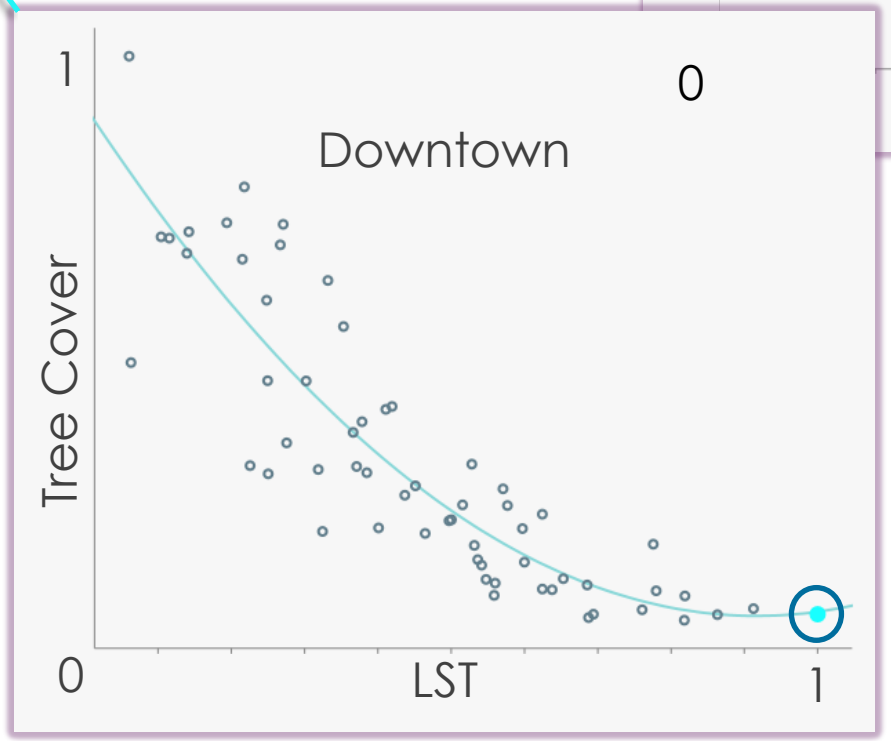
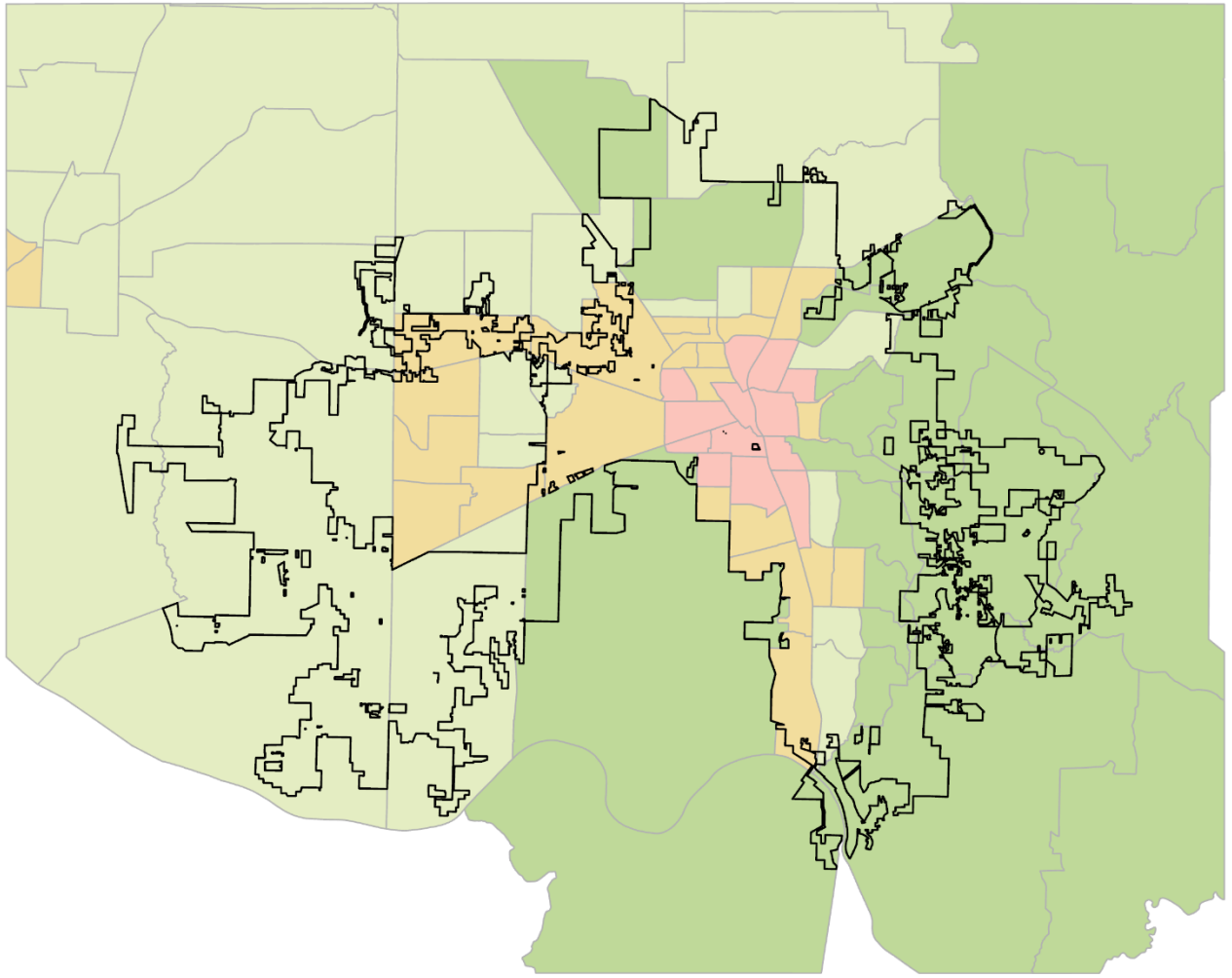




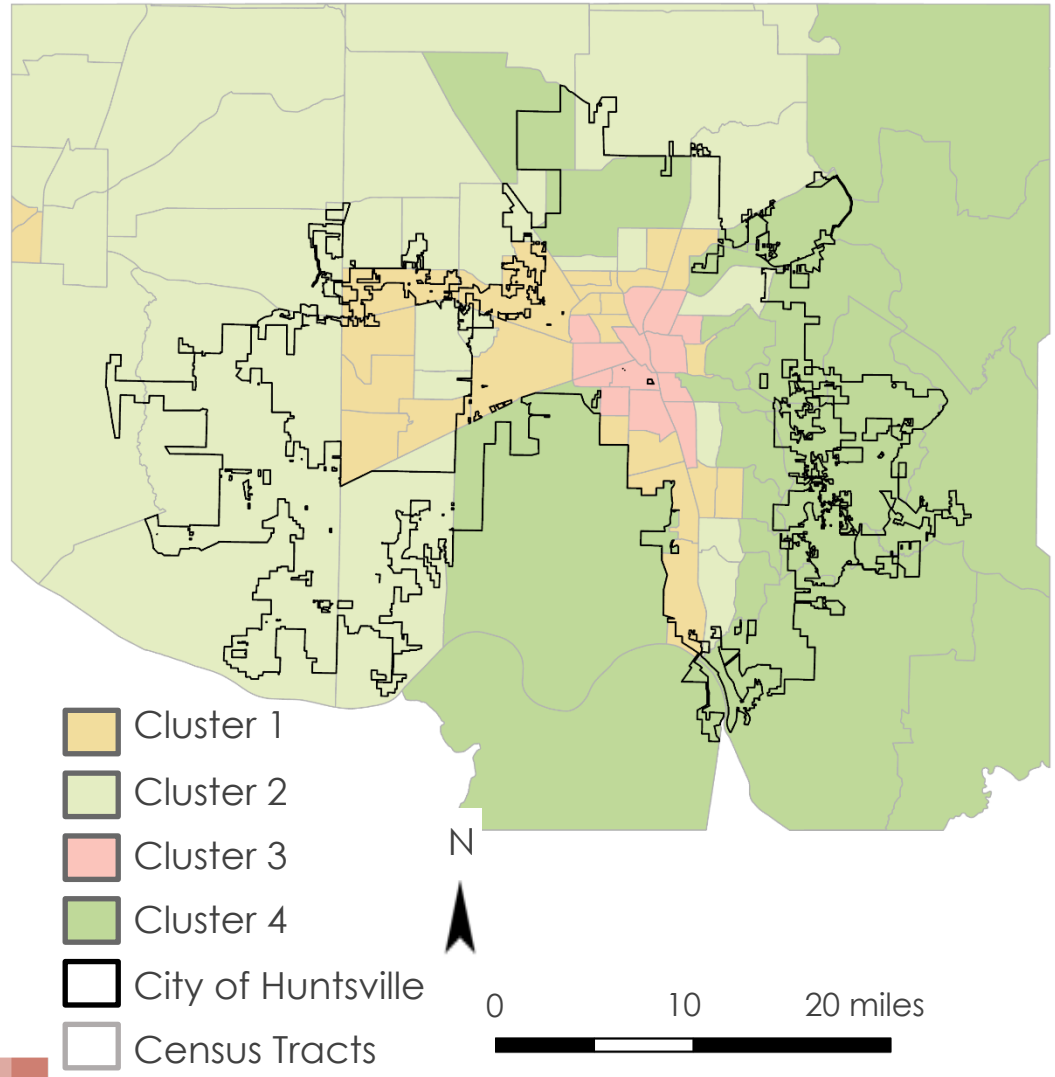
Oak Park has much lower LST because of its higher tree cover.

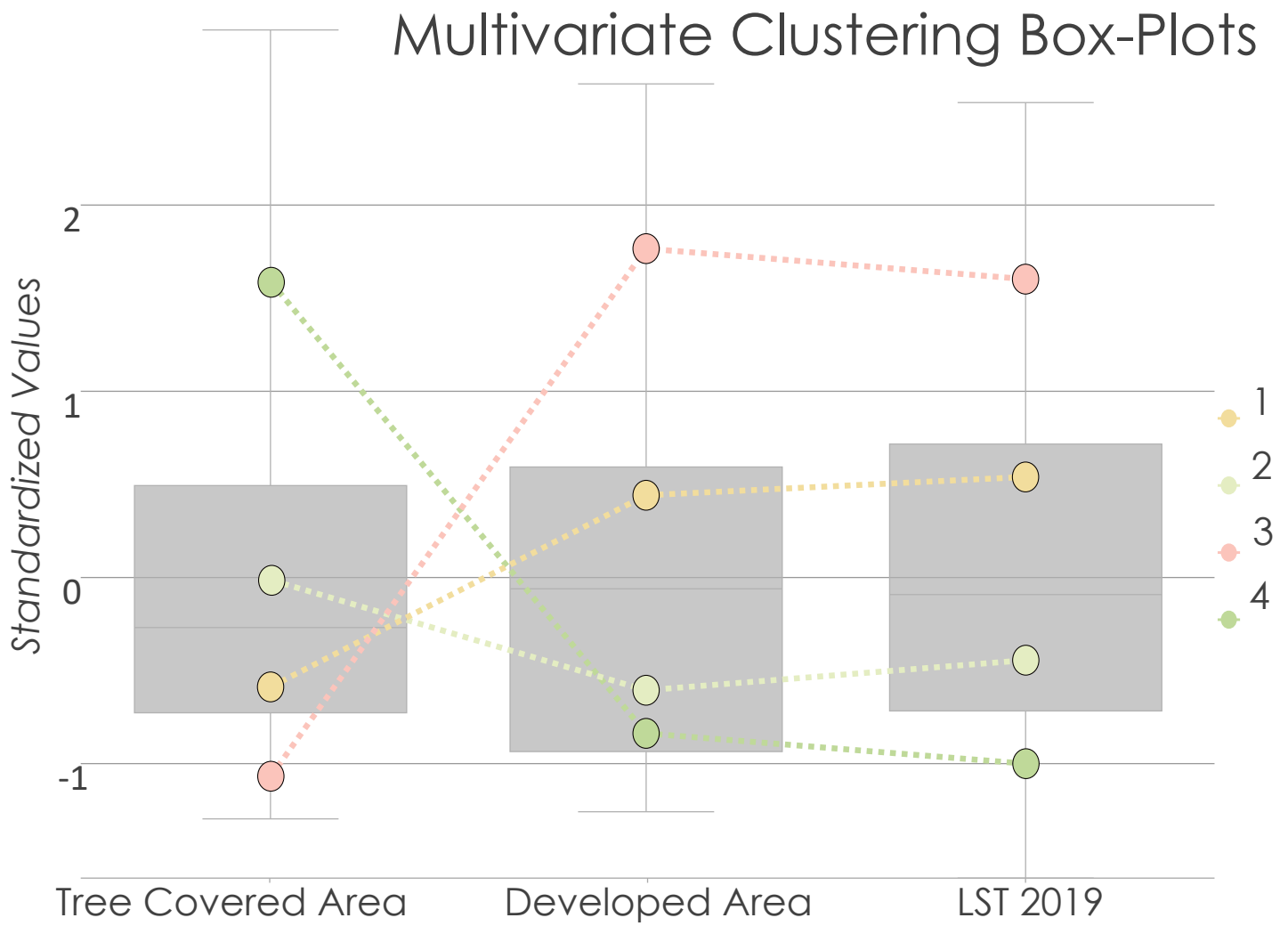
Downtown has much higher LST because of its lower tree cover.

Results: Multivariate Clustering

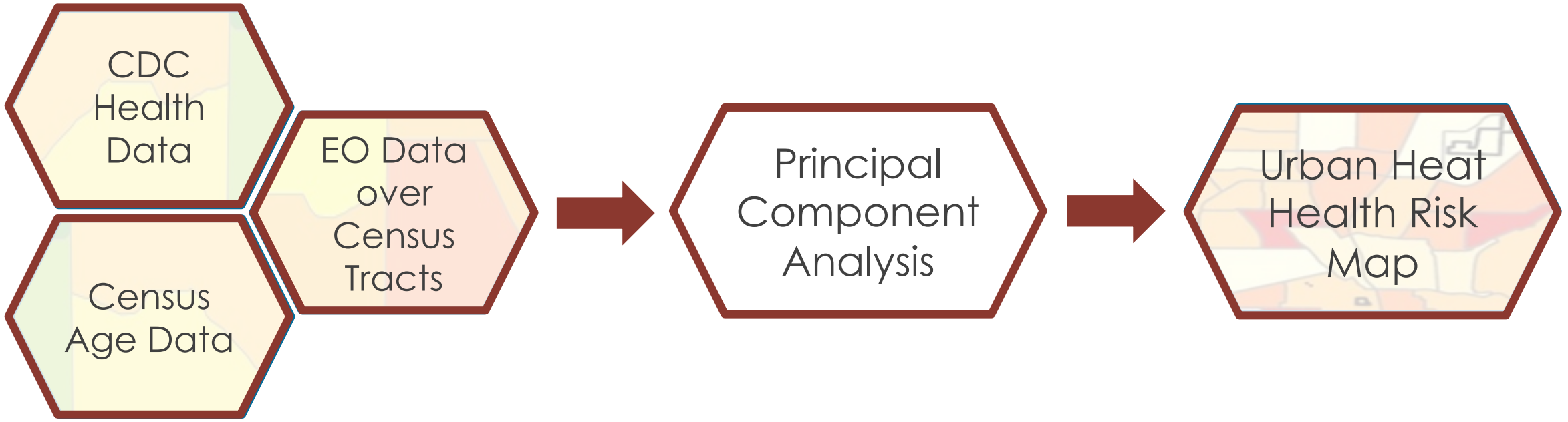


Results: Multivariate Clustering





Methodology: Heat Vulnerability

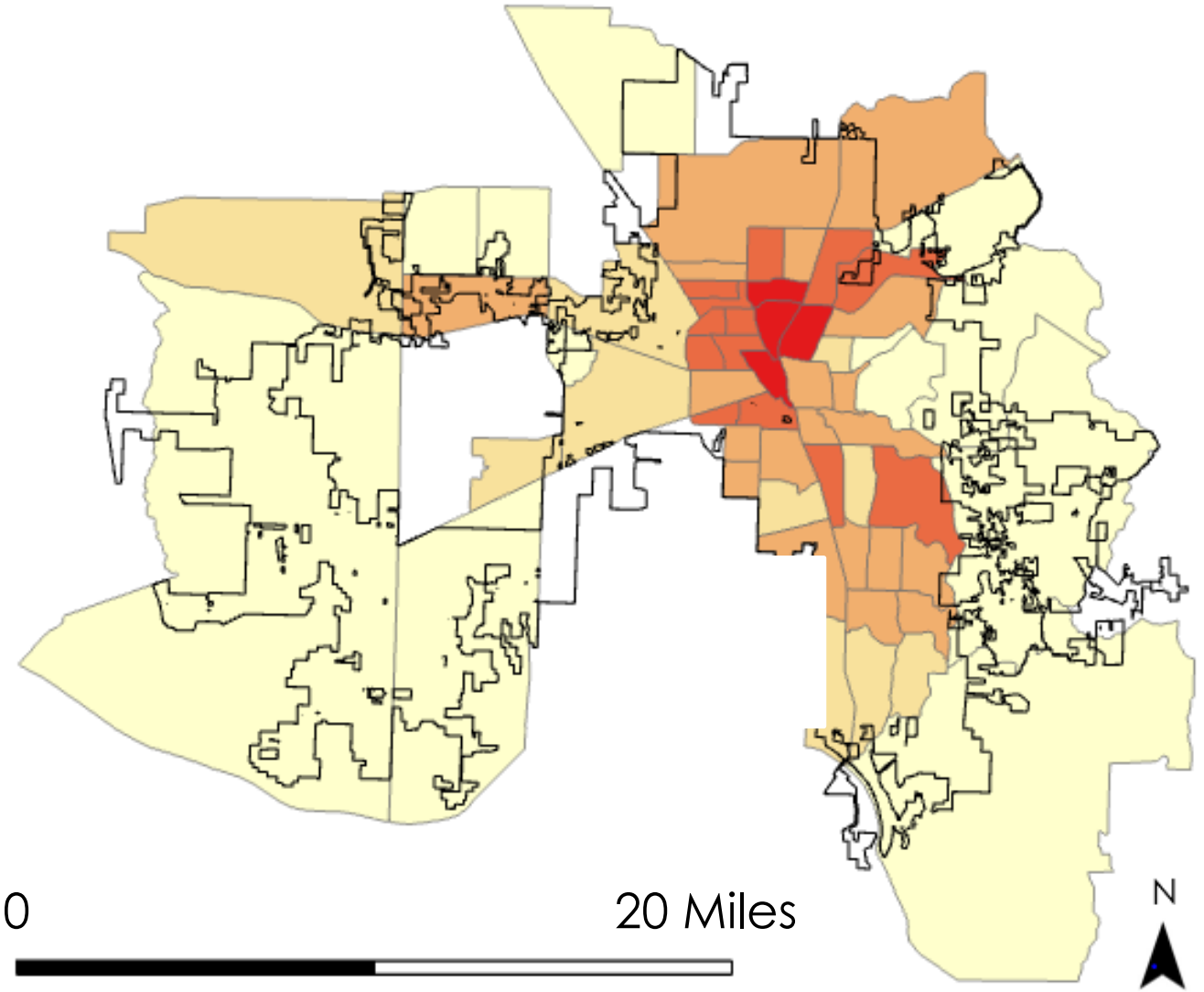


Data Acquisition and Processing

Statistical Analyses

End Product

Results: Urban Heat Health Risk Map



Overall Heat Vulnerability

Huntsville City Limits

Census Tracts

Lowest vulnerability

Highest vulnerability

No data

Conclusions

- LST has **increased** by approximately 4 °F while tree cover has increased by 3% across the city from 2010-2019.
- Urban expansion in Huntsville has **not substantially** impacted tree canopy cover from 2010-2019.
- LST has a linear **increase** in developed areas and **decreases** logarithmically in relation to tree cover.
- Highly developed areas such as **Downtown Huntsville** and the **Huntsville International Airport** exhibited the **highest** temperatures.
- From our areas of interest, **North Downtown Huntsville** had one of the **highest** Heat Vulnerability scores.

Limitations

- Through creating confusion matrices for land cover classification, the overall **accuracies** for the validated years ranged between 70%-75%.
- Cloud cover **varied** year to year and may have **reduced** some results.
- GEDI transects were **not available** for the entire study area.

Acknowledgements

- **Advisors:**
  - **Dr. Jeffery Luvall**, NASA Marshall Space Flight Center
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  - **Christine Evans**, University of Alabama in Huntsville
  - **Madison Murphy**, Optimal GEO
- **Partners:**
  - The City of Huntsville
    - **Urban and Economic Development**: Shane Davis
    - **City Council**: Francis Akridge
    - **City Planning**: Lady Kassama
    - **GIS**: Amy Kenum and Nicholas Haney
    - **Urban and Long-Range Planning**: Dennis Madsen and Ken Newberry
    - **City Engineering**: Kathy Martin and Gary Gleason
    - **Landscape Management**: Marc Byers

ArcGIS Story Map