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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November 24, 2020
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.
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)

**Terra**
Moderate Resolution Imaging Spectroradiometer (MODIS)

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

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

Image Credits: NASA
## Ancillary Datasets

<table>
<thead>
<tr>
<th>Data Source</th>
<th>Parameter</th>
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<tbody>
<tr>
<td>United States Census Bureau Topologically Integrated Geographic Encoding and Referencing</td>
<td>Population Data</td>
</tr>
<tr>
<td>Centers for Disease Control</td>
<td>Health Statistics</td>
</tr>
<tr>
<td>USGS National Land Cover Database</td>
<td>Land Cover Images</td>
</tr>
<tr>
<td>USDA National Agriculture Imagery Program</td>
<td>Digital Ortho-photography</td>
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</tbody>
</table>
Methodology: Overview

NASA EOs

Google Earth Engine

GEDI Tree Survey

R Studio / ArcPro

Day / Night LST

Land Cover 2010 - 2019

LST 2010 - 2019

Health Data

Principal Component Analysis

End Products

LST/ Land Cover Timeseries

Urban Heat Health Risk

UHI Identification

Tree Canopy Cover Survey

NASA’s Applied Remote Sensing Training Program
Methodology: Land Cover

- Landsat 5
- Landsat 8
- Normalized Difference Built Up Index
- Normalized Difference Vegetation Index
- National Land Cover Database
- Threshold Classification
- Supervised Classification
Results: Land Cover, 2010 to 2019

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

2010 Supervised Classification
Huntsville, AL: Downtown, Census Tract: 31
Results: Land Cover Validation

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

<table>
<thead>
<tr>
<th>2017 Reference</th>
<th>Tree</th>
<th>Non-Tree Vegetation</th>
<th>Impervious</th>
<th>Water</th>
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<td>8</td>
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<td>Non-Tree Vegetation</td>
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<tr>
<td>Water</td>
<td>5</td>
<td>1</td>
<td>0</td>
<td>5</td>
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</thead>
<tbody>
<tr>
<td>65</td>
<td>66</td>
<td>16</td>
<td>5</td>
<td>152</td>
</tr>
</tbody>
</table>

Overall accuracy ranged from 70.0% to 75.0%.
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
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

Distribution of Plant Area Index

- Mean: 3

Distribution of Tree Height (feet)

- Mean: 82

City of Huntsville Trees

GEDI – Global Ecosystem Dynamics Investigation

LST (°F)

- 106
- 70

0 0.2 miles
Methodology: Land Surface Temperature (LST)

- Landsat 5, 8
- MODIS
- ECOSTRESS
- NDVI to Emissivity
- LST (K to °F)
- Day vs Night LST Maps
- LST Calculation (K to °F)
- LST Timeseries

LST Calculation (K to °F): Converts land surface temperature from Kelvin (K) to degrees Fahrenheit (°F).
Results: LST, 2010 to 2019

2010 Land Surface Temperature
Huntsville, AL; Downtown, Census Tract: 31

LST (°F)

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

0 2 miles

0 32 miles

NASA’s Applied Remote Sensing Training Program
Results: UHI Identification

Mean LST for Summer 2019 (°F)

LST (°F)
- 63.4 – 74.1
- 74.1 – 78.0
- 78.0 – 82.0
- 82.0 – 86.0
- 86.0 – 90.0
- 90.0 – 94.0
- 94.0 – 98.1
- 98.1 – 102.2
- 102.2 – 106.2
- 106.2 – 139.9

Huntsville City Boundary
Census Tracts
Results: UHI Identification

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

Daytime vs. Nighttime:
- **Day**: 62.2 – 64.5
- **Night**: 84.3 – 87.7

Temperature Ranges:
- 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

Legend:
- Huntsville City Boundary
- Census Tracts
Results: LST Change, 2010 to 2019

Change in LST (°F)

- Yellow: +0 to 2
- Light Orange: +2 to 4
- Orange: +4 to 6
- Dark Orange: +6 to 8
- White: City of Huntsville
- Light Grey: Census Tracts

Map showing the change in LST (°F) for different Census Tracts in the City of Huntsville, with areas shaded according to the change in LST.
Results: Time Series – LST Increase

Tracts with Highest LST Increase

LST Change (2010 – 2019) °F
- + 0 to 2
- +6 to 8
- +2 to 4
- Census Tracts
- +4 to 6

LST Increase

Tree Cover
Impervious Cover
LST
Results: Time Series – Tree Loss

Tree Cover Change (2010 to 2019)

- ≤ -4%
- ≤ -2%
- ≤ 0%
- ≤ 2%
- ≤ 4%

NASA’s Applied Remote Sensing Training Program
Results: Time Series – Case Study Tracts

Case Study Census Tracts

Map of All Census Tracts and Case Study Census Tracts

Tract 9.02: Oak Park

- LST in Fahrenheit
- Percent Tree and Impervious Cover

Tract 113: Owens Cross Roads

- LST in Fahrenheit
- Percent Tree and Impervious Cover

Graphs showing LST and tree cover for both tracts over time (2008-2020).
Results: LST and Land Cover

LST and Tree Cover by Census Tracts

Line of Best Fit:

\[ y = -2.636\ln(x) + 89.148 \]

\[ R^2: 0.4024 \]
Results: LST and Land Cover

LST and Impervious Surface Cover by Census Tracts

Line of Best Fit:

\[0.1723x + 78.18\]

\[R^2: 0.5982\]
Results: Bivariate Relationships Map

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

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

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

Multivariate Clusters

- Cluster 1
- Cluster 2
- Cluster 3
- Cluster 4
- City of Huntsville
- Census Tracts

City of Huntsville and Census Tracts are marked on the map.
Results: Multivariate Clustering

Multivariate Clustering Box-Plots

Cluster 1
Cluster 2
Cluster 3
Cluster 4
City of Huntsville
Census Tracts

Cluster

Developed Area
LST 2019

Tree Covered Area

Standardized Values
Methodology: Heat Vulnerability

Data Acquisition and Processing:
- CDC Health Data
- Census Age Data
- EO Data over Census Tracts

Statistical Analyses: Principal Component Analysis

End Product: Urban Heat Health Risk Map
Results: Urban Heat Health Risk Map

Overall Heat Vulnerability:
- Huntsville City Limits
- Census Tracts
- Lowest vulnerability
- Moderate vulnerability
- High vulnerability
- Highest vulnerability
- No data

Legend:
- Huntsville City Limits
- Census Tracts
- Lowest vulnerability
- Moderate vulnerability
- High vulnerability
- Highest vulnerability
- No data

Scale:
- 0
- 20 Miles
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
  - Dr. Robert Griffin, University of Alabama in Huntsville
  - A. R. Williams, NASA DEVELOP

 DEVELOP Mentors:
  - Helen Baldwin, NASA SERVIR
  - 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
Hunting for Heat in Huntsville

Tree Canopy Loss and the Urban Heat Island Effect

Sabine Nix, Greta Paris, Thomas Quintero, and Amanda Tomlinson | July 23, 2020