



Huntsville Urban Development

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

Project Team

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Project Overview

Project Synopsis:

Huntsville is the fastest growing city in Alabama and is projected to experience a 26.5% increase in population between 2010 and 2030. The loss of trees and increasing impervious surface cover resulting from urban expansion can lead to an enhanced urban heat island (UHI) effect, posing health risks to vulnerable populations. In partnership with the City of Huntsville, the team utilized NASA Earth observations to spatially demonstrate the relationship between tree canopy cover and land surface temperature. Understanding this relationship may aid decision makers in mitigating the impacts of the urban heat island effect.

Abstract:

Huntsville, Alabama's population has grown by approximately 11% since 2010, due in part to the city's advancing engineering industry. Rapid urban growth negatively impacts the environment by decreasing tree canopy cover and increasing impervious surface cover, which can intensify the urban heat island effect. To examine the impacts of this urban growth on the environment, the team partnered with the City of Huntsville to utilize Landsat 5 Thematic Mapper (TM), Landsat 8 Operational Land Imager (OLI) and Thermal Infrared Sensor (TIRS), Terra Moderate Resolution Imaging Spectroradiometer (MODIS) and the International Space Station's Global Ecosystems Dynamic Investigation (GEDI) and ECOSystem Spaceborne Thermal Radiometer Experiment on Space Station (ECOSTRESS). The team utilized these Earth observations in combination with ancillary datasets to create a suite of end products to assist in mitigating the effects of extreme heat

due to urban expansion and tree canopy loss. Annual land surface temperature (LST) was calculated and land cover classes were derived through supervised and threshold classification methods to distinguish trees, other vegetation types, impervious surfaces, and water. From 2010 to 2019, LST increased approximately 4 °F for all census tracts within the city and the total amount of tree cover increased by approximately 3%. The findings will aid the city in future decision-making processes by indicating areas that would benefit from increased green infrastructure.

Key Terms:

Landsat, GEDI, urban heat island, urban expansion, remote sensing, NDVI, NDBI, urban forest

National Application Area Addressed: Urban Development

Study Location: Huntsville, AL

Study Period: June 2010 to June 2020

Community Concerns:

- The rapid urban expansion of Huntsville could lead to a loss of tree canopy, as 20 million hectares of forest are projected to be lost in the United States to population growth and associated urban expansion by 2040.
- Tree canopy loss could result in an enhanced UHI effect.
- The UHI effect can lead to health issues for those over the age of 65 and those with existing medical conditions such as asthma, diabetes, or COPD.

Project Objectives:

- Quantify the impact of Huntsville’s urban expansion on tree canopy cover, impervious surfaces, and LST
- Assess the relationship between factors of social vulnerability, tree canopy cover, expansion of impervious surfaces, and land surface temperature
- Provide tree canopy and health vulnerability analysis to allow end users to incorporate this information into future decision-making

Partner Overview

Partner Organization:

Organization	POC	Partner Type	Boundary Org?
City of Huntsville	Shane Davis, Director-Urban and Economic Development; Amy Kenum Interim Manager-Geographic Information Systems Office; Nicholas Haney, Geographic Information Systems Office; Marc Byers, Arborist-Landscape Management; Kathy Martin, City Engineering; Gary Gleason, City Engineering; Dennis Madsen, Manager-Urban and Long-Range Planning; Ken Newberry, Urban and Long-Range Planning; Frances Akridge, City	End User	No

	Council; Lady Kassama, City Planning		
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Decision-Making Practices & Policies:

The team partnered with several departments within the City of Huntsville, including long-range and urban planning, landscape management, city planning, and Geographic Information Systems (GIS). The Huntsville City Council, comprised of five members, is also involved in decision making by managing cost/benefit analyses and other business topics. These groups will work together in allocating \$2 million annually to areas of interest to ensure that these areas receive necessary landscaping services. These include development inspections, site plan review, tree trimming, planting, maintenance, beautification, design standards, flood mitigation, identifying areas for sustainable green space, parks and recreation enhancements, and bonding requirements for commercial project management. The city uses GIS but does not currently have the capacity to utilize remote sensing data products.

Earth Observations & End Products Overview

Earth Observations:

Platform & Sensor	Parameters	Use
Landsat 5 TM	Normalized Difference Vegetation Index (NDVI), Normalized Difference Built-up Index (NDBI) LST	Landsat 5 TM images were used to calculate NDVI and NDBI in the Huntsville area from 2010 to 2011 at a 30 x 30-meter resolution. The thermal bands from this sensor were utilized to observe LST from 2010 to 2013.
Landsat 8 OLI	NDVI, NDBI	Landsat 8 OLI images were used to calculate NDVI and NDBI in the Huntsville area from 2013 to 2019 at a 30 x 30-meter resolution.
Landsat 8 TIRS	LST	Landsat 8 TIRS images were used to detect LST in the Huntsville area at a 100 x 100-meter resolution from 2013 to 2019.
ISS GEDI	Ecosystem LiDAR	GEDI datasets were used to determine plant area index and height within the study area.
ISS ECOSTRESS	LST	ECOSTRESS datasets were utilized to observe LST within the study area at 70-meter resolution during the daytime for June 2020.
Terra MODIS	LST	Terra MODIS images were used to observe LST at 1,000-meter resolution during the night for June 2020 in Huntsville.

Ancillary Datasets:

- USGS National Land Cover Database - 30 x 30-meter images for classification of land cover
- USDA National Agriculture Imagery Program - Digital ortho-photography of the Huntsville area
- US Census Bureau Topologically Integrated Geographic Encoding and Referencing /Line Shapefiles - US Census Bureau population and socioeconomic data for Madison, Morgan, and Limestone Counties, AL
- Centers for Disease Control (CDC) 500 Cities Project - Health statistics for the City of Huntsville

Software & Scripting:

- Google Earth Engine Application Programming Interface - Data acquisition and manipulation, image processing, and tool development
- Esri ArcGIS Map 10.5 - Raster manipulation, map generation, and image classification development
- Esri ArcGIS Pro 2.5 - Raster manipulation, map generation, and image classification development
- R 4.0.0 and RStudio 1.3.959 - Retrieving US Census population data and CDC health data, calculating heat vulnerability index

End Products:

End Products	Earth Observations Used	Partner Benefit & Use	Software Release Category
<p>Land Cover /Land Surface Temperature Time-Series Analysis</p>	<p>Landsat 5 TM Landsat 8 OLI Landsat 8 TIRS</p>	<p>This product aided partners in observing changes in tree canopy cover and impervious surface cover in comparison to changes in LST. It provided insight into which areas have experienced the greatest changes in tree canopy cover and impervious surface cover and how that has impacted LST.</p>	<p>I</p>
<p>Urban Heat Island Identification Maps</p>	<p>Landsat 8 TIRS ISS ECOSTRESS Terra MODIS</p>	<p>These maps gave our partners the ability to identify areas displaying the UHI effect throughout the city. Daytime and nighttime LST were compared for a single summer day in 2020 to examine UHI effect during the day and at night throughout the city. A more in</p>	<p>N/A</p>

		depth look at average LST for summer months in 2019 was also presented in this product. The team identified high priority census tracts throughout the city with these maps as well.	
Urban Heat Health Risk Map	Landsat 8 OLI Landsat 8 TIRS	This map provided partners with information regarding what census tracts are most vulnerable to heat-related illnesses by factors of age over 65, obesity, diabetes, COPD, and asthma. The team utilized these factors in combination with environmental factors, LST, NDVI, and NDBI, to calculate a Heat Vulnerability Index which was displayed on a map. This map helped to identify census tracts that are most at risk of heat-related illnesses as a result of the UHI effect.	I
Tree Canopy Cover Survey Map	ISS GEDI	The tree cover survey gave our partners the ability to examine the height and density of tree canopy throughout the city. The team examined tree canopy cover in relation to LST in specific areas of interest, and calculated plant area index to determine the shading potential of trees in these areas.	I
Hunting for Heat in Huntsville: Tree Canopy Loss and the Urban Heat Island Effect	N/A	The StoryMap provided an overall summary of how urban tree canopy change and increased impervious surface cover has impacted LST and UHI effect throughout the city. It helped to visualize the different factors that contribute to urban heat while providing more localized information in well-known areas of the city.	N/A

Product Benefit to End User:

These products will aid the City of Huntsville in targeting specific areas for green infrastructure development in order to mitigate the UHI effect. These products will also serve as visual tools to facilitate communication between citizens and the city to improve public awareness of tree conservation. The city GIS department currently does not use remotely sensed data, and a comparative land-based study would be cost prohibitive.

Project Continuation Plan:

This project is planned to conduct a second term that focuses on mapping flood risk as well as stormwater runoff in relation to urban expansion. The team will expand on the green infrastructure analysis from this work to better aid the partners in their decision-making processes. This project provided products relating to tree canopy and urban heat while the second term will focus on flood risk analysis and stormwater mapping. The final handoff will include extra tutorials and educational materials will be provided that encompass both projects.

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