**Texas Water Resources**

*Analyzing Drought-related Impacts on Urban Tree Inventory Conditions and Recovery in Texas*

**VPS Title:** When in Drought, Scout it Out: Assessing Drought-Related Canopy Mortality in Texas

**Project Team**

***Project Team:***

Anna Stamatogiannakis (Project Lead)

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***Advisors & Mentors:***

Dr. Jessica Matthews (North Carolina Institute for Climate Studies, North Carolina State University)

Joe Spruce (Science Systems & Applications, Inc.)

**Project Overview**

***Project Synopsis:*** Urban forests provide a myriad of ecosystem services such as pollution reduction, carbon sequestration, and more, but prolonged drought events can interfere with those services and inflict significant damage to tree inventories. To gain more insight on the effects of the historic 2011 Texas drought, the NASA DEVELOP team partnered with the Texas A&M Forest Service (TFS) and used satellite imagery paired with high-resolution aerial imagery to derive relationships between vegetation characteristics and Urban Tree Canopy (UTC) mortality. Team research efforts focused on utilizing vegetation indices to analyze UTC mortality over time and interpret patterns of post-drought recovery.

***Abstract:***

In 2011, Texas experienced a severe drought that caused substantial economic and environmental losses. The Texas A&M Forest Service (TFS) estimated that 300 million trees succumbed to the severe drought conditions, with urban areas, in particular, losing about 5.6 million shade trees. For these estimations, the TFS uses resource-intensive *in situ* data collection methods. Studies have shown that ground-based inventories of the Urban Tree Canopy (UTC) can be augmented with remote sensing data. To explore this, the TFS Sustainable Forestry Department and the US Forest Service Southern Research Station partnered with NASA DEVELOP. For this project, our team aimed to assess pre- and post-drought canopy mortality in Austin and Houston. We implemented an unsupervised classification technique on National Agriculture Imagery Program (NAIP) high-resolution aerial imagery to determine the existence of UTC. Then, using the Normalized Difference Vegetation Index (NDVI) derived from Landsat 5 Thematic Mapper (TM), Landsat 7 Enhanced Thematic Mapper Plus (ETM+), and Landsat 8 Operational Land Imager (OLI) data, we analyzed the relationship between NDVI anomalies and canopy mortality. Additionally, we utilized the Standardized Precipitation-Evapotranspiration Index (SPEI) derived from the National Oceanic and Atmospheric Administration’s nClimGrid dataset to give a broader context of climatic variables surrounding canopy loss. Ultimately, our results will be used by the TFS to identify areas that are likely to experience higher instances of UTC mortality and to monitor trends in recovery.

**Keywords:**

Normalized Difference Vegetation Index (NDVI), remote sensing, Landsat, urban tree mortality, drought, urban trees, unsupervised classification

***National Application Area Addressed:*** Water Resources

***Study Location:*** Austin, TX, and Houston, TX

***Study Period:*** May 2010 to May 2016

***Community Concern:***

* Urban trees provide immeasurable ecosystem services such as improving air, soil, and water quality, reducing carbon emissions, and increasing biodiversity.
* Urban trees are linked to improved quality of life in the urban environment through increased thermal comfort, air quality, aesthetic appearance, and noise abatement.
* Urban forests are economically important - for every 100 million trees in the US, over $2 billion is saved in energy costs.
* Standing dead trees pose both safety concerns and an economic burden to the public.
* *In situ* data collection of tree inventory data is expensive and time-consuming.

***Project Objectives:***

* Employ NASA Earth observations (EO) and National Oceanic and Atmospheric Administration (NOAA) drought indices to monitor drought impacts
* Analyze the response of the UTC in Austin and Houston to drought using unsupervised classification methods
* Investigate the relationship between NDVI anomalies and canopy mortality

**Partner Overview**

***Partner Organizations:***

|  |  |  |  |
| --- | --- | --- | --- |
| **Organization** | **POC (Name, Position/Title)** | **Partner Type** | **Boundary Org?** |
| **Texas A&M Forest Service, Sustainable Forestry Department** | Rebekah Zehnder, Geospatial Analyst; Burl Carraway, Sustainable Forestry Department Head | End User | No |
| **United States Department of Agriculture Forest Service, Southern Research Station Threat Assessment Center** | Lazarus Pomara, Ecologist | Collaborator | Yes |

***Decision-Making Practices & Policies:***

Currently, the TFS utilizes Forest Inventory and Analysis (FIA) data and other field-based surveys for urban forestry management purposes. These bottom-up assessments are extremely useful in characterizing forest structure and function, but their labor-intensive and costly nature can result in infrequent inventories. Therefore, resource managers are exploring the feasibility of EO and other remotely sensed data to help describe and monitor tree canopies. These alternative methods are particularly useful following extreme weather events, such as the 2011 drought, when disaster management strategies need to be quickly developed.

***Project Benefit to End User:***

The results from this project will allow the TFS to measure UTC mortality and recovery trends following the 2011 Texas drought. Our model will enable urban forest managers to identify areas of significant UTC mortality from Landsat data, which helps inform management practices and single out locations in need of further assessment. Additionally, this project will serve as a top-down assessment utilizing remote sensing, GIS, and aerial photo interpretation to describe the status of vegetative health in Austin and Houston. Paired with *in situ* data, EO can be employed to present a holistic view of urban forest structure and health.

**Earth Observations & End Products Overview**

***Earth Observations:***

|  |  |  |
| --- | --- | --- |
| **Platform & Sensor** | **Parameter** | **Use** |
| **Landsat 5 TM** | NDVI | Landsat 5 Thematic Mapper (TM) data were used in the computation of a 30-year NDVI historical norm, as well as to calculate NDVI anomalies for Austin and Houston in the year 2010. |
| **Landsat 7 ETM+** | NDVI | Landsat 7 Enhanced Thematic Mapper Plus (ETM+) data were used in the computation of a 30-year NDVI historical norm, as well as to calculate NDVI anomalies for Austin and Houston in the year 2012. |
| **Landsat 8 OLI** | NDVI | Landsat 8 Operational Land Imager (OLI) data were used in the computation of a 30-year NDVI historical norm, as well as to calculate NDVI anomalies for Austin and Houston in the year 2016. |

***Ancillary Datasets:***

* United States Department of Agriculture (USDA) National Agriculture Imagery Program (NAIP) – High resolution aerial imagery used in the identification of UTC
* NOAA Standardized Precipitation-Evapotranspiration Index (SPEI) – A multiscalar drought index derived from NOAA’s nClimGrid dataset that can be used for determining the onset, duration, and magnitude of drought conditions

***Software & Scripting:***

* Google Earth Engine API – Gather and process Landsat data for historical norm calculation
* R – Derive regression coefficients and model estimated canopy mortality using NDVI
* Esri ArcMap 10.6.1 – Unsupervised (Urban Tree Canopy) classification and map generation
* Esri ArcGIS Online – Story map creation and hosting

***End Products:***

|  |  |  |  |
| --- | --- | --- | --- |
| **End Products** | **Earth Observations Used**  | **Partner Benefit & Use** | **Software Release Category** |
| **Canopy Mortality Change Maps** | N/A | This visualization used NAIP imagery to help the partners better understand the direct impacts of the drought on canopy mortality. Maps showing canopy cover in Austin and Houston pre- and post-drought emphasize the areas that were most affected. The partners can use their available *in situ* data to identify tree species in those areas and determine on a broad scale if certain species were more affected than others. | I |
| **Canopy Mortality Model** | Landsat 5 TM, Landsat 7 ETM+, and Landsat 8 OLI | This model can be used to estimate canopy mortality from Landsat-derived NDVI anomalies. This will be useful for understanding the impacts of past and future drought events and for highlighting priority areas for management efforts. | IV |
| **User’s Guide** | N/A | This guide serves as a reproducible methodology for the partners to follow. All steps are clearly laid out in order for the partners to recreate our analysis. | N/A |
| **ESRI Story Map** | N/A | The story map incorporates maps, legends, text, photos, and video and provided functionality such as swipe and pop-ups, which will be useful for members of the community to explore the impacts of the drought. | N/A |

**Project Handoff Package**

*Transition Plan:* During the week of April 1, 2019, our team had a teleconference with the partners to provide technical explanations of project methodology and results. All deliverables prepared by our team were made available to the partners at the end of the term in a shared Google Drive folder. We also provided a link to our story map, which incorporates the project video.

*Software Release Plan:* The Canopy Mortality Model utilizes code falling under software release category IV. Thus, the code had to go through NASA’s software release process. Our team communicated with the partners regarding the software release timeline, and Anna Stamatogiannakis served as the point of contact after the completion of the term. After the code was successfully passed through the release process, the partners electronically received the functional form of the code along with a README document detailing steps and procedures for implementation and updates.

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**Software Release POC**: Anna Stamatogiannakis, annastamatog@gmail.com

**Partner POC**: Rebekah Zehnder, rzehnder@tfs.tamu.edu

**Handoff Package:**

* Poster
* Presentation
* Technical Paper
* Project Video
* Canopy Mortality Change Maps
* User’s Guide
* ESRI story map

**References:**

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