**Tempe Urban Development**

*Utilizing NASA Earth Observations to Assess Thermal Landscapes and Prioritize Greening Initiatives in Tempe, Arizona*

**VPS Title:** Trees in Tempe, AZ: Prioritizing Greening Initiatives

**Project Team**

***Project Team*:**

Hannah Bonestroo (Project Lead), hkbonestroo@gmail.com

Roger Alvarez

Taylor Quinn

Elizabeth Swanson

***Advisors & Mentors*:**

Dr. David Hondula (Arizona State University)

Dr. Ariane Middel (Arizona State University)

**Project Overview**

***Project Synopsis*:** This project used NASA Earth observations to aid the City of Tempe in an effort to improve the thermal environment of its parks and green spaces through the implementation of tree canopy cover and reduction of impervious spaces. Landsat derived land surface temperature (LST) and *in situ* measurements of air temperature and LST, along with data on vegetation cover, secondary shading, and land cover will give the City of Tempe a better understanding of steps needed to implement its Urban Forestry Master Plan and achieve its goal of becoming a 20-minute city with 25% tree canopy cover by 2040.

***Abstract*:**

Located in the northern Sonoran Desert, Tempe, Arizona, regularly experiences extreme heat, with summer daily maximum temperatures reaching over 37°C. The rapid urbanization of the region in the last 50 years has caused a steady increase in the mean daily air temperature due to the urban heat island (UHI) effect. Recognizing that urban forestry has been documented to mitigate the effects of UHIs through the processes of evapotranspiration and shading, the City of Tempe created an Urban Forestry Master Plan (UFMP) in 2017 in an effort to improve the thermal environment of its parks and green spaces. In partnership with the City of Tempe and the Arizona State University (ASU) Urban Climate Research Center (UCRC), the fall 2018 Tempe Urban Development DEVELOP team used Landsat 5 Thematic Mapper (TM) and Landsat 8 Operational Land Imager (OLI) and Thermal Infrared Sensor (TIRS) satellite imagery to identify changes in the normalized difference vegetation index (NDVI) and land surface temperature (LST) from 1998 to 2018. Combined with United States Geological Survey (USGS) lidar tree point data and Central Arizona-Phoenix Long-Term Ecological Research (CAP LTER) Land Cover Classification data using National Agriculture Imagery Program (NAIP) imagery, the team examined the correlation between tree clustering, land cover, and LST in city parks. The City of Tempe can use these results to inform residents and developers about how investment in deliberate urban forestry improves the city’s thermal environment and helps mitigate extreme heat.

**Keywords:**

Outdoor thermal comfort, urban forestry, remote sensing, Landsat, urban heat island, land surface temperature, normalized difference vegetation index

***National Application Area Addressed:*** Urban Development

***Study Location:*** Tempe, AZ

***Study Period:*** June1998 – August 2018

***Community Concern:***

* As the mean daily air temperature in Tempe continues to increase annually due to the UHI effect and Earth’s warming climate, maintaining the health of Tempe’s urban forest is essential in heat mitigation and achieving the goal of becoming a 20-minute walkable city. The City of Tempe defined this goal in the UFMP as supporting development and land use where residents can comfortably walk or bike to urban hubs and major amenities within 20 minutes of their homes.
* Storm damage and lack of informed care practices, including under- and overwatering, have led to the reduction of overall tree coverage in Tempe since 2010. No concrete plan for the replacement of lost trees is in place.
* The city, homeowners associations, and commercial centers are all responsible for tree care. Currently, there is a lack of information available regarding proper tree care and planting best practices, as well as a misunderstanding between the groups for who is responsible for consistent tree care.

***Project Objectives:***

* Provide the City of Tempe with data that can be used to support the Urban Forestry Master Plan
* Create a set of thematic maps showing NDVI and LST change in Tempe from 1998 through 2018
* Determine if city investments in trees in Svob and Rio Salado/Tempe Beach Parks have improved the parks’ thermal environments
* Investigate the effects that tree clustering and land cover have on the thermal environment
* Establish the effects different types of shade and ground cover have on the thermal environment
* Create a brochure incorporating project results to educate local residents and developers about the science behind the positive benefits of deliberate urban forestry

**Partner Overview**

***Partner Organizations:***

|  |  |  |  |
| --- | --- | --- | --- |
| **Organization** | **POC (Name, Position/Title)** | **Partner Type** | **Boundary Org?** |
| **City of Tempe** | Bonnie Richardson, Architect and Urban Planner; Braden Kay, City Sustainability Manager | End User | No |
| **Arizona State University, Urban Climate Research Center** | Dr. David Sailor, UCRC Director | Collaborator | No |

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

In 2017, the City of Tempe released an UFMP with the goal of showing how crucial its urban forest is to its public health infrastructure. Much of the supporting data for the UFMP, including a review of the current state of Tempe’s urban forest, was prepared in collaboration with the Walton Sustainability Solutions Initiatives at ASU. Besides the analyses in the UFMP, the City of Tempe only has access to regularly updated information about trees on public lands. The City of Tempe currently lacks updated spatiotemporal data on tree canopy on both public and private lands.

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

The City of Tempe will be able to use the outcomes of this project to supplement its UFMP and identify strategies to improve the thermal environment of its parks and green spaces. The provided data and analyses using NASA Earth observations will enable the City of Tempe to assess current canopy cover trends and determine the steps needed to reach its goal of 25% tree cover by 2040. The City of Tempe will be able to use the satellite-derived LST data alongside *in situ* LST measurements to show areas where city investments in tree planting have helped mitigate heat as well as identify areas for future investment. All analyses conducted will provide evidence of the impact of the city’s most recent urban forestry initiatives.

**Earth Observations & End Products Overview**

***Earth Observations:***

|  |  |  |
| --- | --- | --- |
| **Platform & Sensor** | **Parameter(s)** | **Use** |
| **Landsat 5 TM** | NDVI, LST | NDVI and LST assessments of Tempe were used between 1998 and 2018 to assess trends in vegetation coverage and overall LST. |
| **Landsat 8 OLI** | NDVI | NDVI assessments of Tempe were used between 1998 and 2018 to assess trends in vegetation coverage. |
| **Landsat 8 TIRS** | LST | LST assessments of Tempe between 1998 and 2018 were used to assess impact of the recent city investments in tree planting. |

***Ancillary Datasets:***

USGS 3D Elevation Program (3DEP) Lidar data – tree point data provided by partners at the ASU UCRC

 (data have not been released to the public by the USGS) for use in regression analysis comparing tree density, land cover, and LST

CAP LTER Land Cover Classification using 2010 NAIP Imagery – land cover classification data for use in regression analysis comparing tree density, land cover, and LST

NASA DEVELOP and ASU Urban Climate Research Center *in situ* meteorological measurements – air temperature, relative humidity, and surface temperature for use in informative brochure

***Software & Scripting:***

Esri ArcMap – map generation

Esri ArcGIS Pro – map generation

QGIS – map generation

Google Earth Engine API – raster data processing

R – data manipulation and analysis

Microsoft Excel – data manipulation

***End Products:***

|  |  |  |  |
| --- | --- | --- | --- |
| **End Products** | **Earth Observations Used**  | **Partner Benefit & Use** | **Software Release Category** |
| **NDVI Time Series** | Landsat 5 TMLandsat 8 OLI | This will allow the partners to identify how vegetation coverage has changed from 1998 to 2018. | I |
| **LST Time Series** | Landsat 5 TMLandsat 8 OLILandsat 8 TIRS  | These dataset and maps analyzed the change in LST from 1998 to 2018. This will allow the City of Tempe to understand trends in LST compared with trends in vegetation coverage in the city. | I |
| **Regression Analysis Comparing Tree Density, Land Cover, and LST** | Landsat 5 TMLandsat 8 OLILandsat 8 TIRS  | This assessment will provide the partners with data and maps that explore the correlation between tree density, land cover, and LST. The City of Tempe can use the results to identify heat mitigation strategies. | I |
| **Educational Brochure**  | N/A | This brochure can be used by the City of Tempe to educate residents, business owners, and developers about the importance of deliberate urban forestry. It will highlight the resulting LST and air temperature from different shade types and land cover.  | N/A |

**Project Handoff Package**

**Transition Plan:**

The team presented their results and end products to partners and other interested parties at Arizona State University. The processed datasets, end products, and supporting documentation were sent to partners through NASA Large File Transfer (LFT).

**Team POC:** Hannah Bonestroo, hkbonestroo@gmail.com

**Partner POC**: Bonnie Richardson, bonnie\_richardson@tempe.gov

**Handoff Package:**

* NDVI Time Series maps
* LST Time Series maps
* Additional processed data associated with maps
* Tables and data from the Regression Analysis Comparing Tree Density, Land Cover, and LST
* Educational Brochure
* Technical Paper
* Poster
* Project Video

**References:**

Baker, L. A., Brazel, A. J., Selover, N., Martin, C., McIntyre, N., Steiner, F. R., . . . Musacchio, L. (2002).

 Urbanization and warming of Phoenix (Arizona, USA): Impacts, feedbacks and mitigation. *Urban Ecosystems, 6*, 183-203. https://doi.org/10.1023/A:1026101528700

Buyantuyev, A., & Wu, J. (2009). Urban heat islands and landscape heterogeneity: Linking spatiotemporal variations in surface temperatures to land-cover and socioeconomic patterns. *Landscape Ecology, 25*(1), 17-33. doi:10.1007/s10980-009-9402-4

City of Tempe, Arizona. (2017). *City of Tempe Urban Forestry Master Plan*. Retrieved from City of Tempe Website: https://www.tempe.gov/city-hall/community-services/parks/urban-forest

Harlan, S. L., Brazel, A. J., Prashad, L., Stefanov, W. L., & Larsen, L. (2006). Neighborhood microclimates and vulnerability to heat stress. *Social Science & Medicine, 63*(11), 2847-2863. doi:10.1016/j.socscimed.2006.07.030

Harlan, S. L., Declet-Barreto, J. H., Stefanov, W. L., & Petitti, D. B. (2013). Neighborhood effects on heat deaths: Social and environmental predictors of vulnerability in Maricopa County, Arizona. *Environmental Health Perspectives, 121*(2), 197-204. doi:10.1289/ehp.110465

Middel, A., Selover, N., Hagen, B., & Chhetri, N. (2016). Impact of shade on outdoor thermal comfort—a seasonal field study in Tempe, Arizona. *International Journal of Biometeorology, 60*(12), 1849-1861. doi:10.1007/s00484-016-1172-5