Roots of Change

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How Planting More Trees Can Help Combat the Heat in Phoenix, AZ

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## Phoenix: The Valley of the Sun

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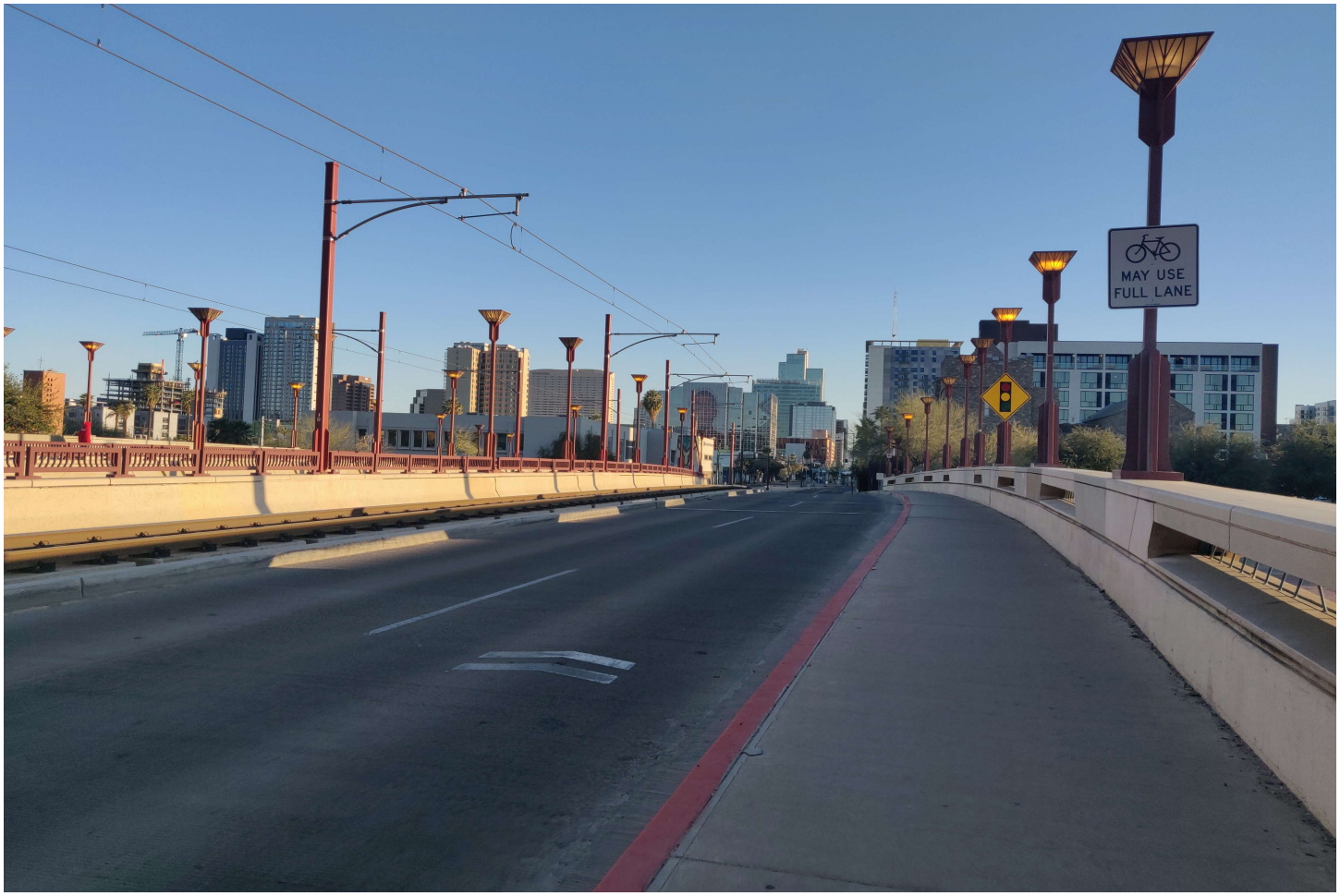
Phoenix is the 5th largest city in the United States, with a population of 1.6 million people in 2020 and growing (US Census, 2020). Rightfully nicknamed the Valley of the Sun, Phoenix is the hottest major city in the United States, with daytime summer temperatures consistently reaching upwards of 100°F. These daytime temperatures continue to climb as vegetation is removed in urban environments and replaced by impervious surfaces.




## Impervious Surfaces and Heat

Impervious surfaces like roofs, roads, and parking lots trap and release significantly more heat than plants. This is because impervious surfaces absorb sunlight and release it into the environment as heat. In a desert city like Phoenix, large amounts of impervious surfaces cause hotter day and nighttime temperatures.

## Urban Heat

As the city warms, heat-related risks and illnesses become more prevalent. There were 323 heat related deaths in Maricopa County in 2020, which is a 62.3% increase from 2019. To address these heightened risks, the City of Phoenix's Office of Heat Response and Mitigation is working on ways to cool the urban landscape.

## Urban Heat Solutions

Increasing Phoenix's tree canopy is a promising way to combat rising urban temperatures. Planting more trees can offset increasing heat by shading impervious surfaces, preventing sunlight (and the heat that comes with it) from being absorbed at the street level (Wang et al., 2016). Trees also cool the air through evapotranspiration, where the trapped water within their leaves is released as water vapor during the night, producing a cooling effect

in the surrounding air. Urban forests improve other aspects of the environment by removing certain air pollution, sequestering carbon, and improving groundwater quality (Nowak et al., 2007). These benefits make trees a great option for tackling several environmental issues at once.

## Environmental Justice


Residential street in a lower income neighborhood with less developed tree canopy.


Residential street in a wealthier neighborhood with a more developed tree canopy.

The effects of urban heat disproportionally impact communities in Phoenix which have fewer resources available to help them cope with summer temperatures (Harlan et al., 2013). Vulnerability to extreme heat has been linked to areas with high poverty and a higher proportion of nonwhite residents, both associated with a higher risk of heat-related mortality (Maier et al., 2014). Additionally, areas of high poverty and high concentration of racial and ethnic minority residents tend to have less green space coverage and higher distances to the nearest green spaces on average (Wen et al., 2013). These disparities must be addressed to solve the problem of urban heat in Phoenix. Environmental justice (EJ) focuses on creating healthy and clean environments, especially for those who have traditionally lived, worked, and played closest to the sources of pollution.

> *"Environmental Justice is the fair treatment and meaningful involvement of all people regardless of race, color, national origin, culture, education, or income..." (NASA NEPA).*

Environmental justice demands social justice, equal access to a clean and healthy environment, and an end to institutional discrimination. Incorporating an environmental justice framework within city planning and development initiatives can help inform the City of Phoenix which areas need to be prioritized when implementing heat-mitigation strategies.

## Phoenix Cooling Initiatives

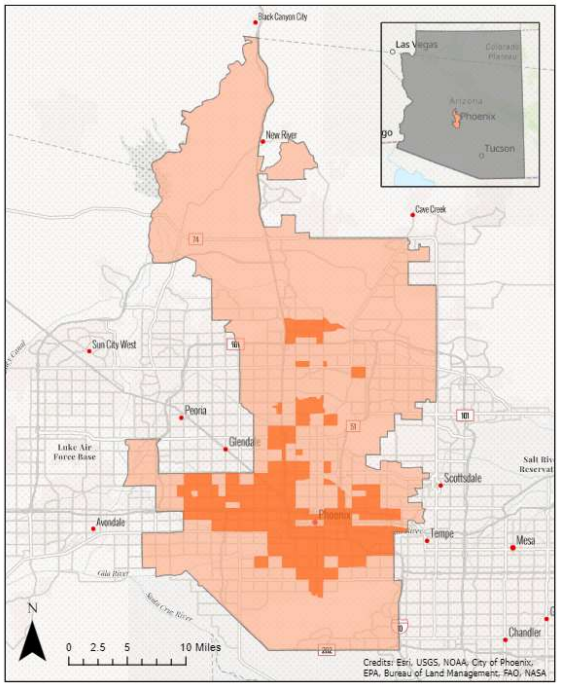



Figure 1: City of Phoenix Boundary and Qualified Census Tracts within Phoenix

To address growing concerns over urban heat, the city has proposed a Residential Tree Equity Accelerator program. The Residential Tree Equity Accelerator program seeks to mitigate urban heat by increasing shade within residential areas. To aid in the City of Phoenix's efforts to increase tree canopy coverage, the NASA DEVELOP Phoenix Climate team has created heat vulnerability, tree equity, and social vulnerability indices. These indices utilize environmental data, demographic data and NASA Earth observations. Our data was gathered over a period of 5 years, from 2015-2020 within Phoenix city boundaries (Figure 1).

## NASA DEVELOP Project Objectives

The City of Phoenix has initiated green infrastructure programs and hopes to reach a city-wide average of 25% canopy coverage in Phoenix by 2030 (City of Phoenix, 2010). To do so, the City of Phoenix Office of Heat Response and Mitigation, Office of Sustainability, and Streets Department have expanded tree planting

initiatives to residential areas deemed most vulnerable to urban heat effects.

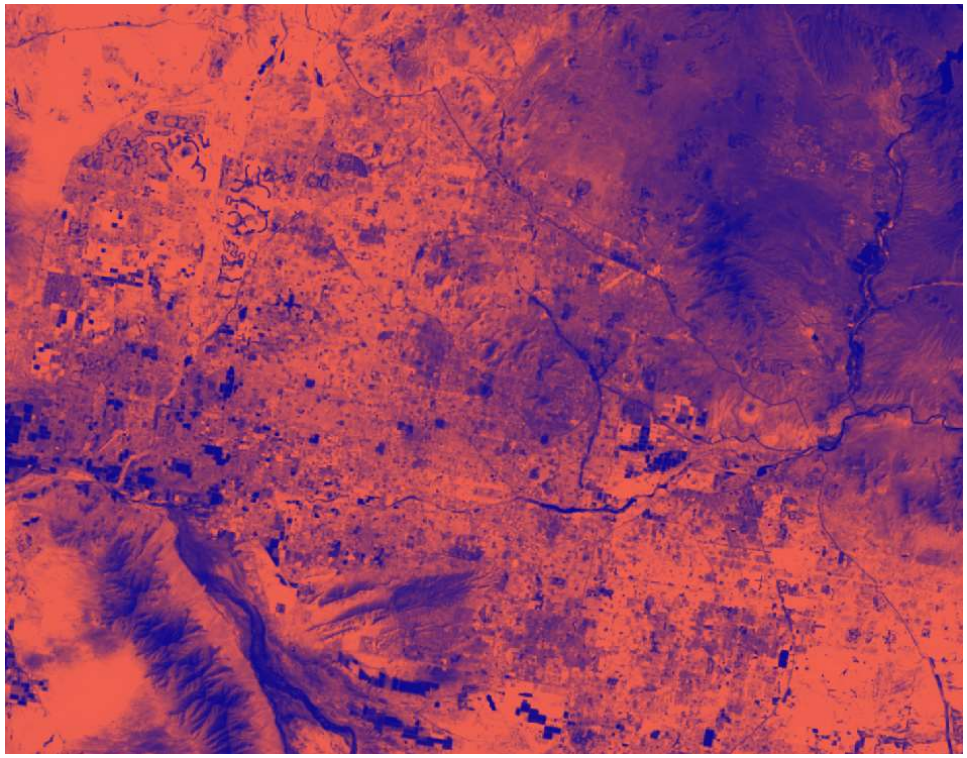
NASA DEVELOP logo

Our team created a ranking system for census block groups and qualified census tracts (QCTs) within Phoenix and selected specific households that would be ideal candidates for their residential tree planting program. This ranking system addresses current areas of environmental and shade inequity, by assessing existing tree canopy and mean radiant temperature (MRT) at the census block group scale within QCTs. The ranking system considers socioeconomic inequities and the number of households within each block group as well . The team developed public communication tools and graphics to aid in advocacy efforts to policy makers and inform residents in need of increased tree cover on their properties. The city and other partners will use the ranking system and communication tools to identify vulnerable, tree-sparse communities for tree planting in residential neighborhoods in order to create a more equitable tree canopy in Phoenix.

## NASA Earth Observations

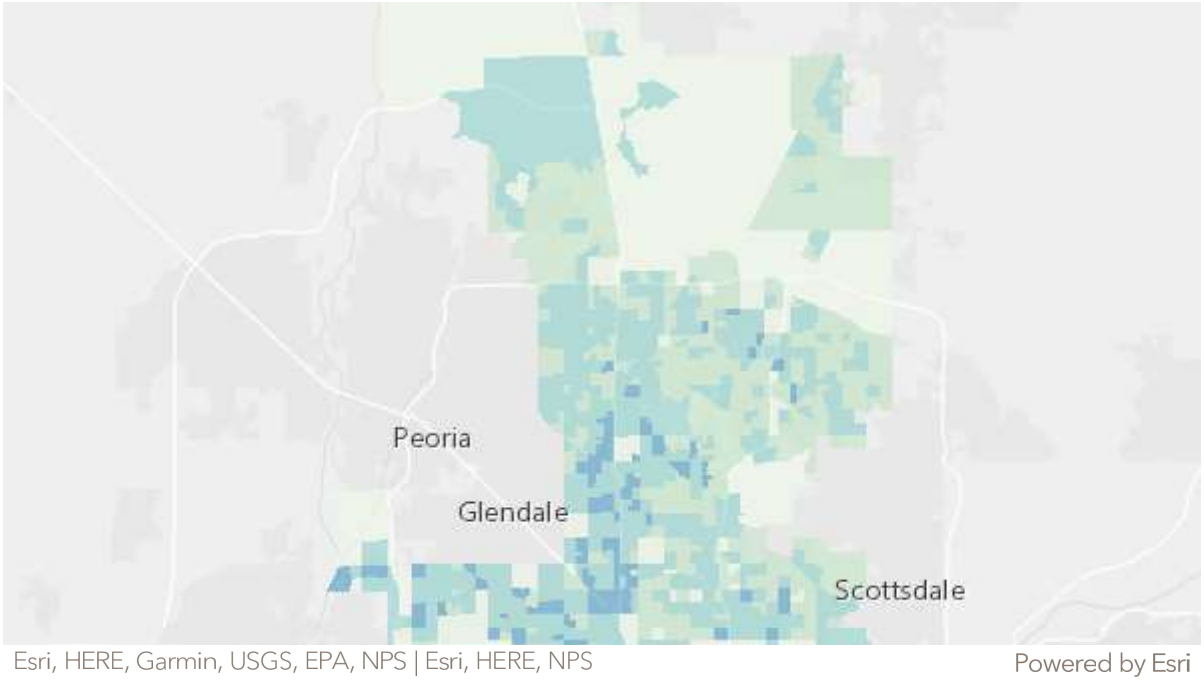
To identify areas for a Residential Tree Planting Program, our team used NASA Earth observations. Specifically, we used data from the Operational Land Imager (OLI) on Landsat 8, a satellite orbiting the

Earth. Landsat 8 orbits over Phoenix once every 16 days, taking images of the city across multiple spectrums. From Landsat 8, we created a composite land surface dataset similar to the image below. We included data from The National Land Cover Database (NLCD) as well, which also uses Landsat 8 data.



Phoenix land surface temperature (USGS)

## Social Vulnerability Index




Social Vulnerability Index: City of Phoenix

The Social Vulnerability Index (SVI) displays the ability of communities within each block group to adapt to increasing temperatures. The higher the score, the more vulnerable the population is to heat-related illnesses and risks. This score was determined by compiling socioeconomic demographics from the 2019 5-year US Census Bureau American Community Survey, listed below:

- % non-white
- % 65 and older
- % 9 and under
- % no vehicle
- % income below the poverty line

- % no high school diploma
- % living in crowded homes
- % unemployed
- Per capita income

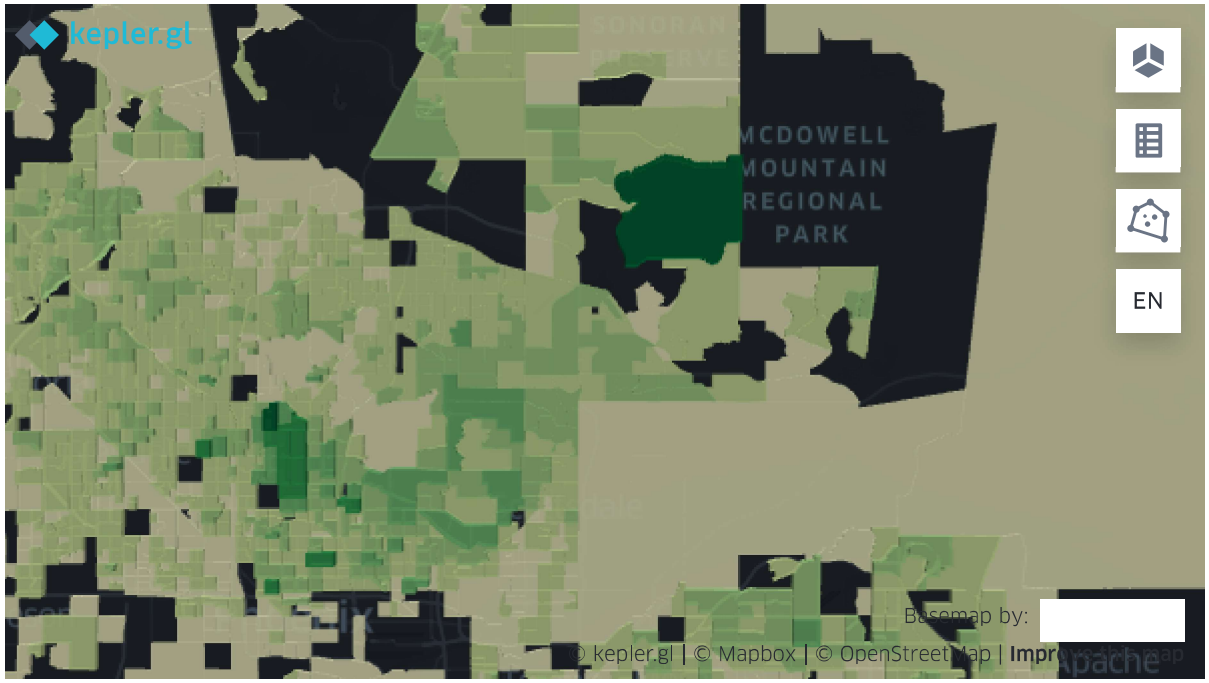
Our SVI variables and methods were informed by the Social and Heat Vulnerability Indices published by researchers at Arizona State University's Global Institute of Sustainability and Innovation and the SVI published by the US Centers for Disasese Control (CDC). Interact with the buttons below to explore these indices.

Indices by ASU Researchers

Social Vulnerability by CDC

American Community Survey

## Tree Canopy




Tree Canopy Percent Cover in Maricopa County per block group

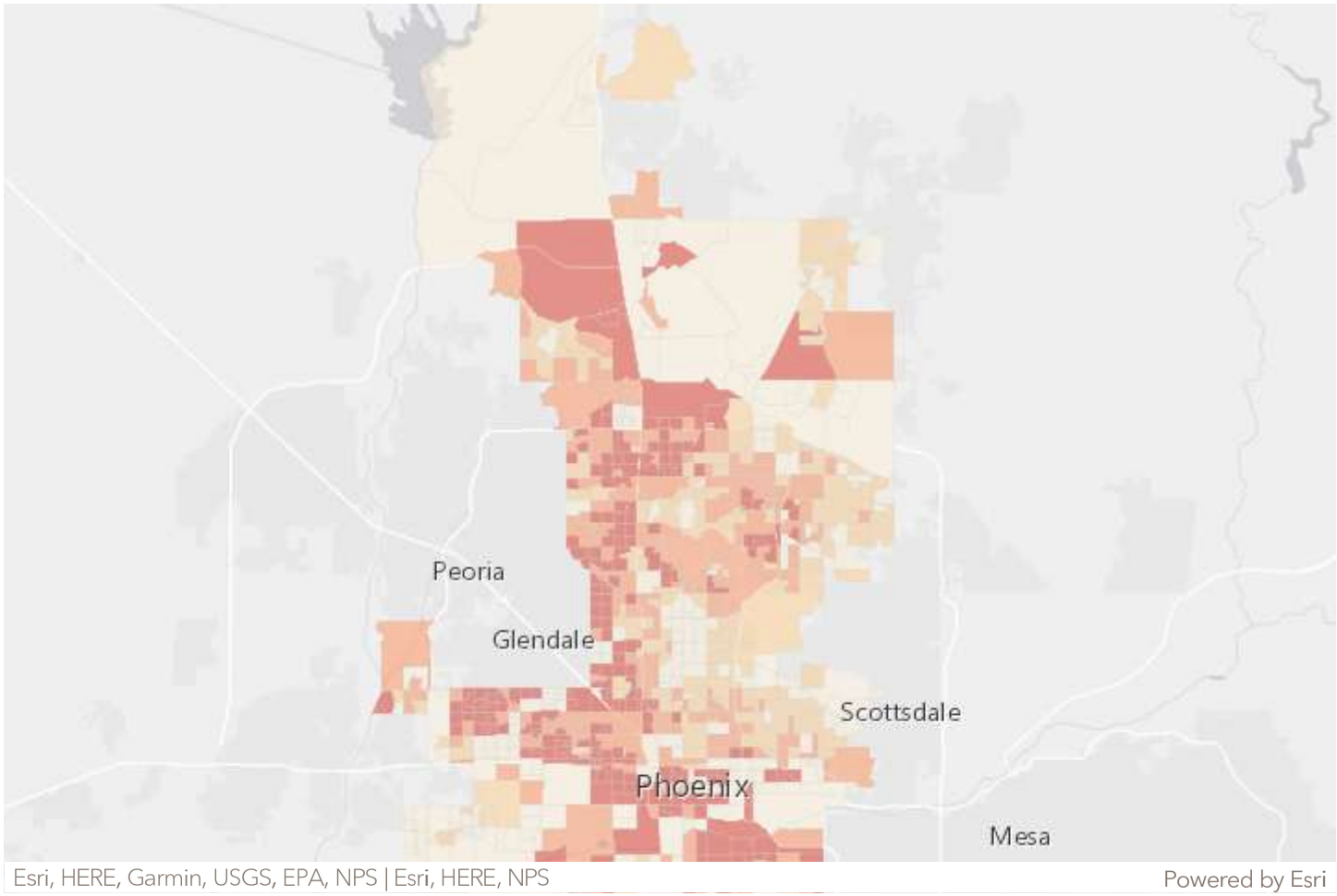
We sourced tree canopy percent cover from the American Forests Tree Equity project. The dataset also included tree canopy coverage goals that were calculated using the American Forests methodology that we opted not to use. Their method sets lower tree canopy targets for higher population density areas, but higher population density areas are often those that are most underprioritized and in need of investment. We took the opposite approach, prioritizing higher density areas, and also simply prioritizing areas with lower tree canopy instead of setting a specific tree canopy goal per block group.

### Tree Equity Score

Find your score and help create Tree Equity in cities and towns across America.

https://www.treeequityscore.org/

## Heat: LST and Impervious Surfaces

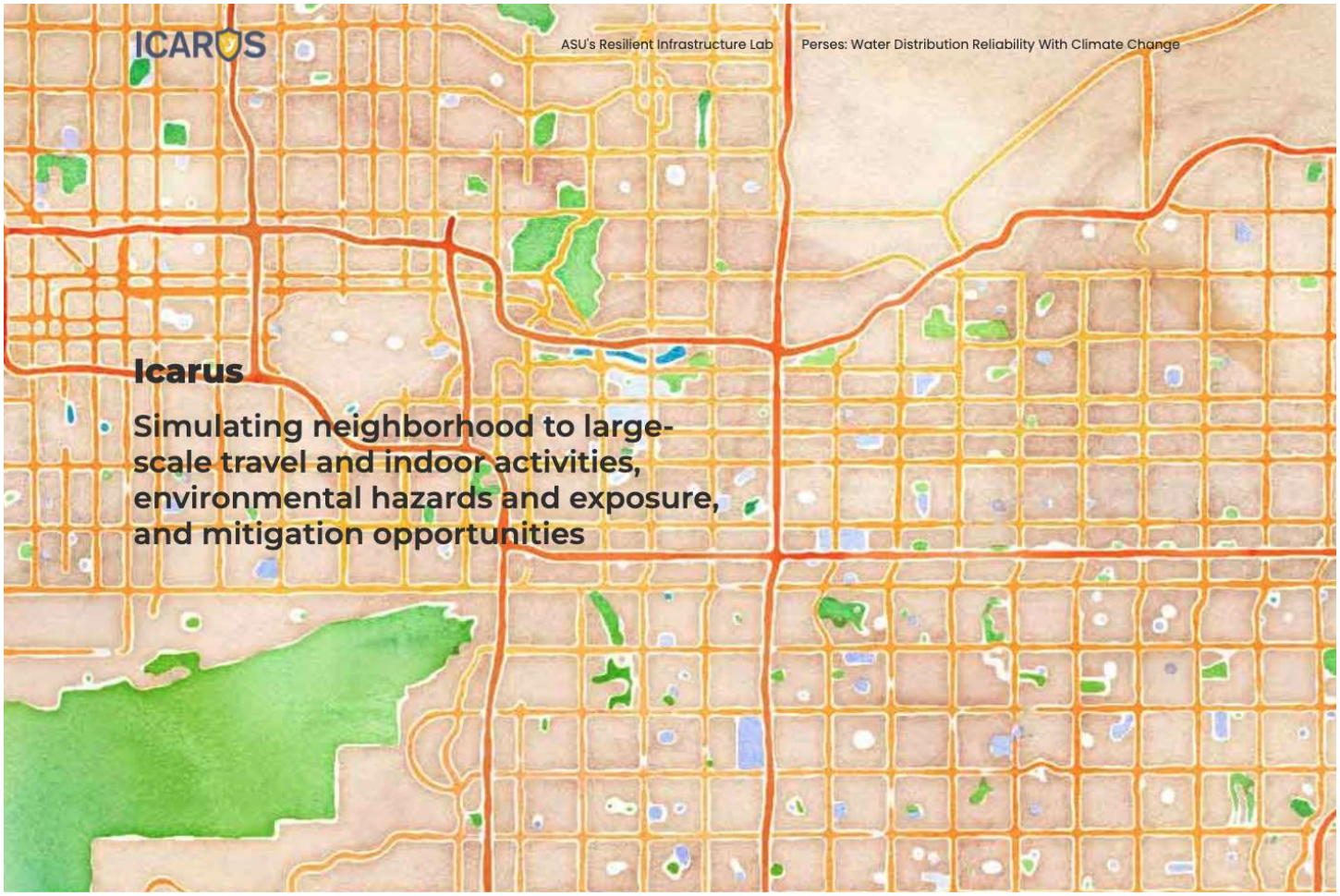


The heat exacerbation caused by impervious surfaces is best illustrated by comparing the impervious surface amounts to land surface temperatures. By toggling the different buttons below, you can see how hotter areas also have a higher presence of impermeable surfaces.

Land Surface Temperature

Impervious Surfaces

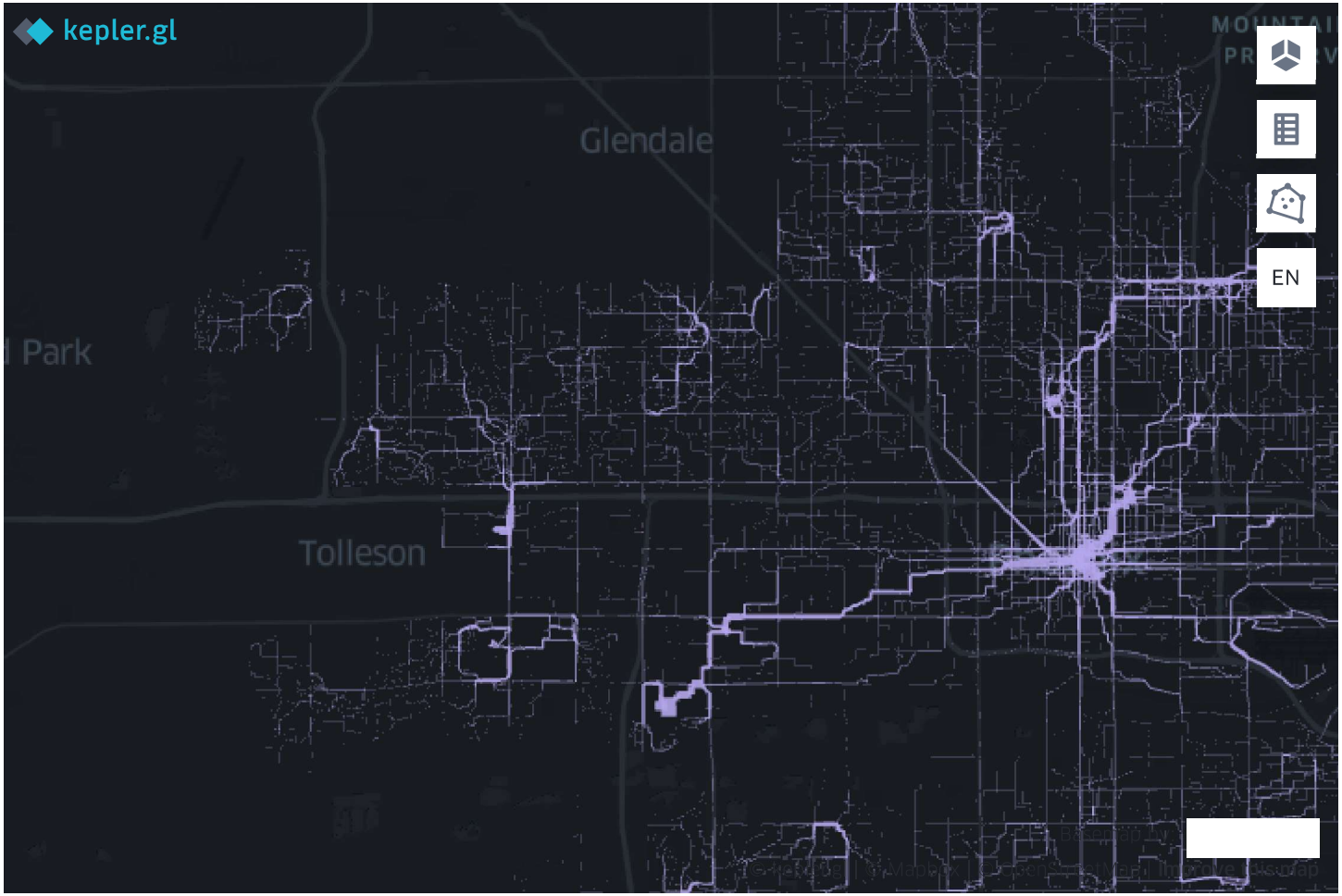
## Bike/Pedestrian Movement & Heat Exposure




In addition to measuring heat, we also wanted to understand how much heat people are exposed to.

We focused on outdoor heat exposure, using bike and pedestrian movement data from Icarus. Icarus is an activity-based model that, among other things, simulates the movement of people around Phoenix. The model was built using trips carried out by 3.8 million travelers on June 30th 2017 for 24 hours.

## Resilient Infrastructure - Icarus




We looked at trips that occurred where the biker/pedestrian was experiencing mean radiant temperatures (MRT) of over 140°F. These trips are visualized on the map in light purple. Segments that had higher traffic are drawn thicker and low traffic segments are thinner.

## Bus Ridership

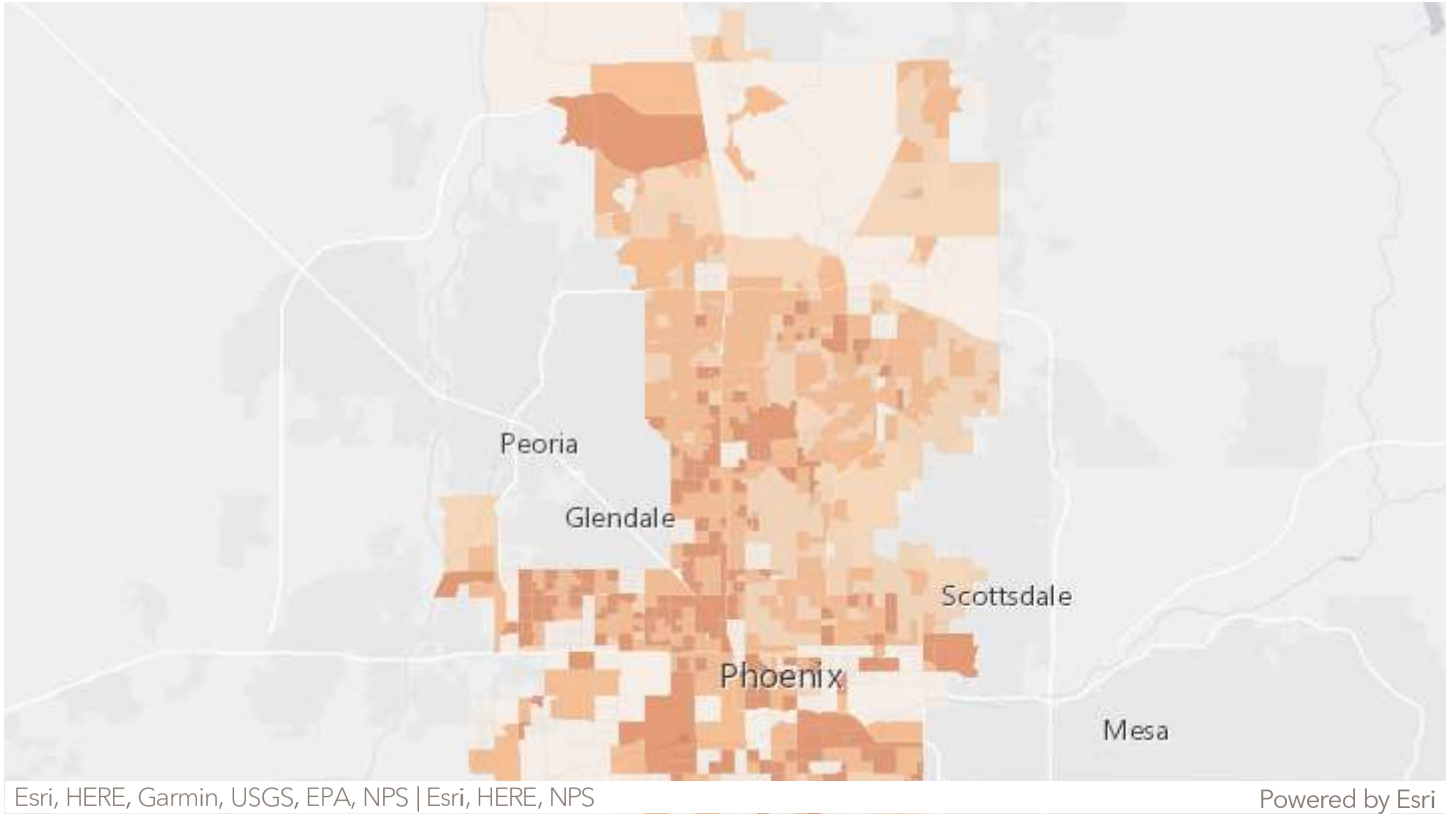
More than two-thirds of transit riders in the United States have been found to walk to their stop or station (American Public Transportation Association Who Rides Public Transportation). More time riding transit likely means more time outside walking to their stop and waiting for the bus, and increased heat exposure.


Average Weekday Bus Stop Boardings in Maricopa County

## Heat Vulnerability Index

To create the heat vulnerability index (HVI), all of the data variables are normalized on a scale from 0-1 to make them easily comparable. A weighted mean is then calculated as the final heat vulnerability score. We weigh the SVI by 9 because there are 9 variables included in it, and the Tree Canopy Index is weighted by 5 since we are most

interested in prioritizing areas with a lack of tree cover. All other variables are weighted the same. The final results are displayed on the map below.




Heat Vulnerability Index: City of Phoenix

## Parcel Selection

To assess the feasibility of tree-planting using this mode of block group selection, a sample of the top 25 block groups in the HVI were analyzed at a finer scale to identify single-family parcels with low existing tree cover and adequate available area on the property

for new trees. The 100 parcels identified by these criteria as having the highest need for more trees are identified in red below. Other parcels are shown in purple, buildings are shown in green, and trees are shown as points.


1


This block group in northern Phoenix contained 26 of the top 100 parcels in need of trees. This block group had a high social vulnerability score of 0.79, a high Land Surface Temperature of 120 degrees Fahrenheit, and 467 trees in the block group.

2


This cluster of three-block groups had 31 of the top 100 parcels in need of trees. These three block groups had an SVI score from 0.75 - 0.91, a Land Surface Temperature of 118 degrees Fahrenheit, and a range of 750 - 1,830 trees in each block group.

## Final Results

A combination of the Heat Vulnerability Index and parcel analysis can be found here. Use the web app to navigate through different data, and see which parcels are prime candidates for a residential tree planting program.

## Future of Tree Planting in Phoenix

These methods show how NASA Earth Observations and related spatial analysis can adapt principles of heat vulnerability research to aid the City of Phoenix's heat mitigation strategies. By prioritizing existing tree cover along with social variables, the City can build heat mitigation programs around areas of the most need. These rankings of census block groups give an initial priority list for the initiation of residential tree-planting programs, and are expandable based on funding and participation.

As the City initiates tree planting in these areas of priority, NASA Earth Observations similar to the ones used in this study will be a useful tool to assess the impact of added trees.

## Glossary

**ACS** – American Community Survey; conducted annually to provide frequent estimates about socioeconomic attributes of communities.

**Earth observations** – Satellites and sensors that collect information about the Earth's physical, chemical, and biological systems over space and time

**Environmental justice** – the fair treatment and meaningful involvement of all people regardless of race, color, national origin, or

income with respect to the development, implementation and enforcement of environmental laws, regulations, and policies

**Evapotranspiration** – the sum of evaporation of water from land and other surfaces and through transpiration by plants

**HVI** – Heat Vulnerability Index

**LST** – Land Surface Temperature; a measure of how hot the Earth's surface feels to the touch in a particular location

**MRT** – Mean Radiant Temperature; a measure of the average temperature of the surfaces that surround a particular point, with which it exchanges thermal radiation

**SVI** – Social Vulnerability Index

**QCT** – Qualified Census Tracts; a census tract that is eligible for the Low-Income Housing Tax Credit because at least 50% of its households have incomes below 60% of the Area Median Gross Income or because there is a poverty rate of 25% or more

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Ben Schafermeyer (2022). Land Surface Temperature, Phoenix – Google Earth Engine

Gloria Liu (2022). Icarus Dataset Introduction – Stamen Watercolor Basemap

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