Neighborhood-level Heat Exposure: A Comparison of IETs and Ecological Variables Used to Create Heat Vulnerability Indexes

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Introduction

Heat vulnerability has become an increasingly popular subject of study among many researchers in the twenty-first century. In recent years, researchers as well as the media have shed light on the potential hazards of urbanization and climate change and their association with increased temperatures. Recent studies have indicated certain populations that may be more susceptible to heat-related illness and mortality through the creation of a heat vulnerability index (e.g. Harlan et al., 2006; Reid et al., 2009). Heat vulnerability indexes have been created and measured in numerous ways, including: occurrence of vegetation calculated through the Normalized Difference Vegetation Index (NDVI), average household incomes, average age, ethnic/racial backgrounds, prevalence of air conditioning, percent elderly/living alone, prevalence of diabetes, etc . (Harlan et al., 2006; Harlan et al., 2013; Reid et al., 2009). The measure of heat has been measured in many ways.. Harlan et al. (2013) noted that outdoor ambient temperature, which is usually measured 2m above ground, has the potential to significantly vary from land surface temperature. Land surface temperature is a measure of the thermal inertia of land surface characteristics by means of remote sensing, while outdoor ambient air temperature measures the thermal inertia of the surface atmospheric components (Johnson et al., 2009).

One way to better understand the temperatures people actually experience as they go about their daily lives is to acquire Individually Experienced Temperatures (IETs) from residents of a given neighborhood. Using IETs is a way to most closely record temperature variations for residents, especially as they move in and out of different settings and microclimates. The present study created implications on each neighborhood's vulnerability to heat from multiple two-dimensional analyses by comparing mean IETs (daytime, nighttime, and total) with select variables incorporated in studies by Harlan et al. (2006) and Harlan et al. (2013), including estimated land surface temperature (hereafter surface temperature), outdoor ambient temperature (hereafter air temperature), prevalence of vegetation, and impact of urbanization.

Methods

The present study focused on five neighborhoods within the greater Phoenix, Arizona that provide contrasts in urban geography and form, socioeconomics, demographics, and vegetative cover. The five neighborhoods are as follows: Coffelt (public housing), Encanto-Palmcroft (historic preservation), Garfield (gentrification center), Power Ranch (master planned community), and Thunderhill (large suburban cul-de-sac).

The ecological variables commonly used in depicting heat vulnerability indexes were found for each neighborhood through satellite imagery. These include NDVIs, percentage Urban, and average land surface temperature (LST). In place of LST, at-satellite brightness temperature (TB) was calculated utilizing the following ModelBuilder flow in geographic information systems software, ArcMap.

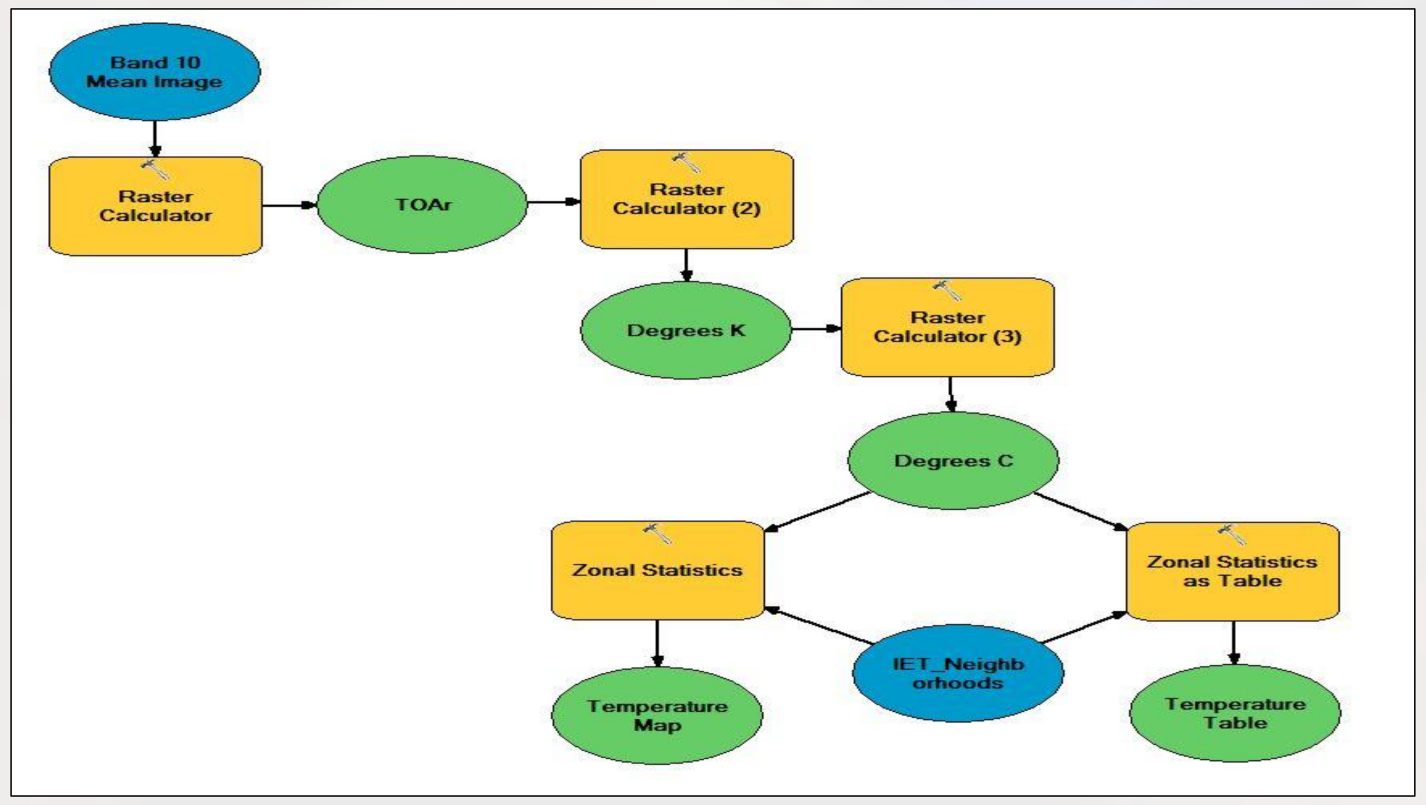

Figure 1. ArcMap ModelBuilder converting satellite imagery into brightness temperature.

Results

The ecological variables were applied to IET values, the mean IETs were shown for each neighborhood. CO, which is located close to the heart of the Phoenix urban landscape, had consistently high mean IETs when compared to the other neighborhoods as a whole. TH had consistently low mean IETs when compared to the other neighborhoods as a whole.

Vegetation cover, as measured through a NDVI, varied for each neighborhood. Higher NDVI values are equated with higher prevalence of vegetation, while lower NDVI values are equated with lower prevalence of vegetation. EP was shown to have the highest vegetation cover while GF and CO were nearly tied for having the least amount of vegetation cover.

Areas consisting of more urbanization have typically displayed higher surface temperatures (Johnson et al., 2009). Despite an overall high percentage, the study's neighborhoods had a high variability of urbanization. GF was associated with the highest percentage of urbanization being the only neighborhood to have a value over 90%, while PR had the lowest percentage of urbanization, being over 10% less than EP, the second least urbanized neighborhood.

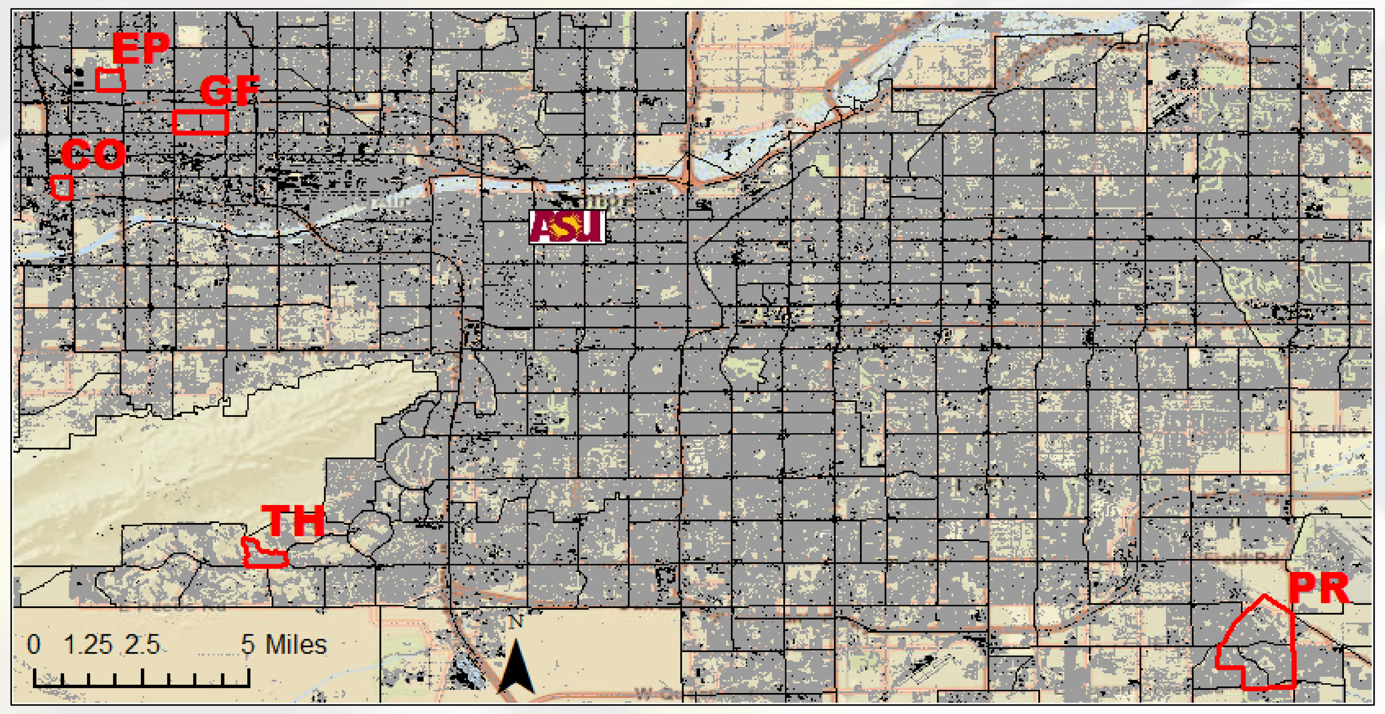

Figure 2. Prevalence of urbanization (gray) or asphalt (black) in Phoenix metro.

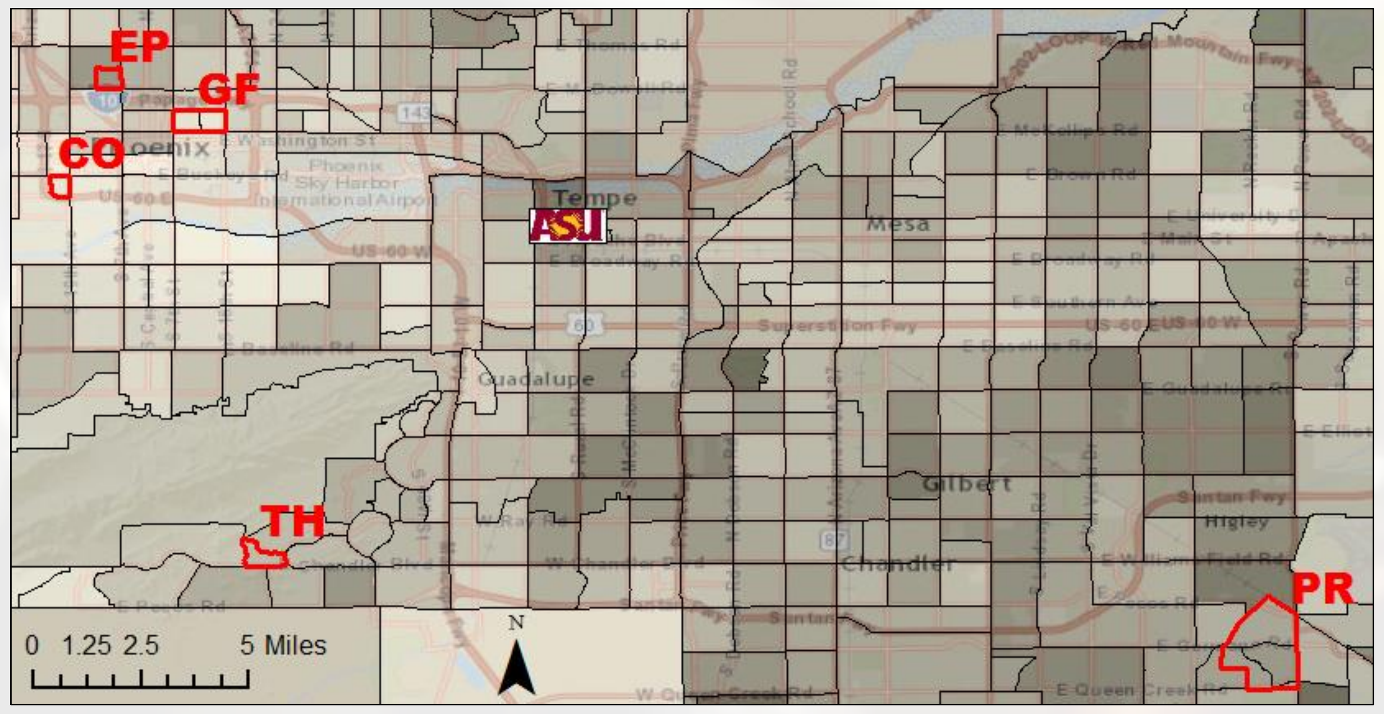

Figure 3. Average TB values per census tract; darker shades imply lower temperatures

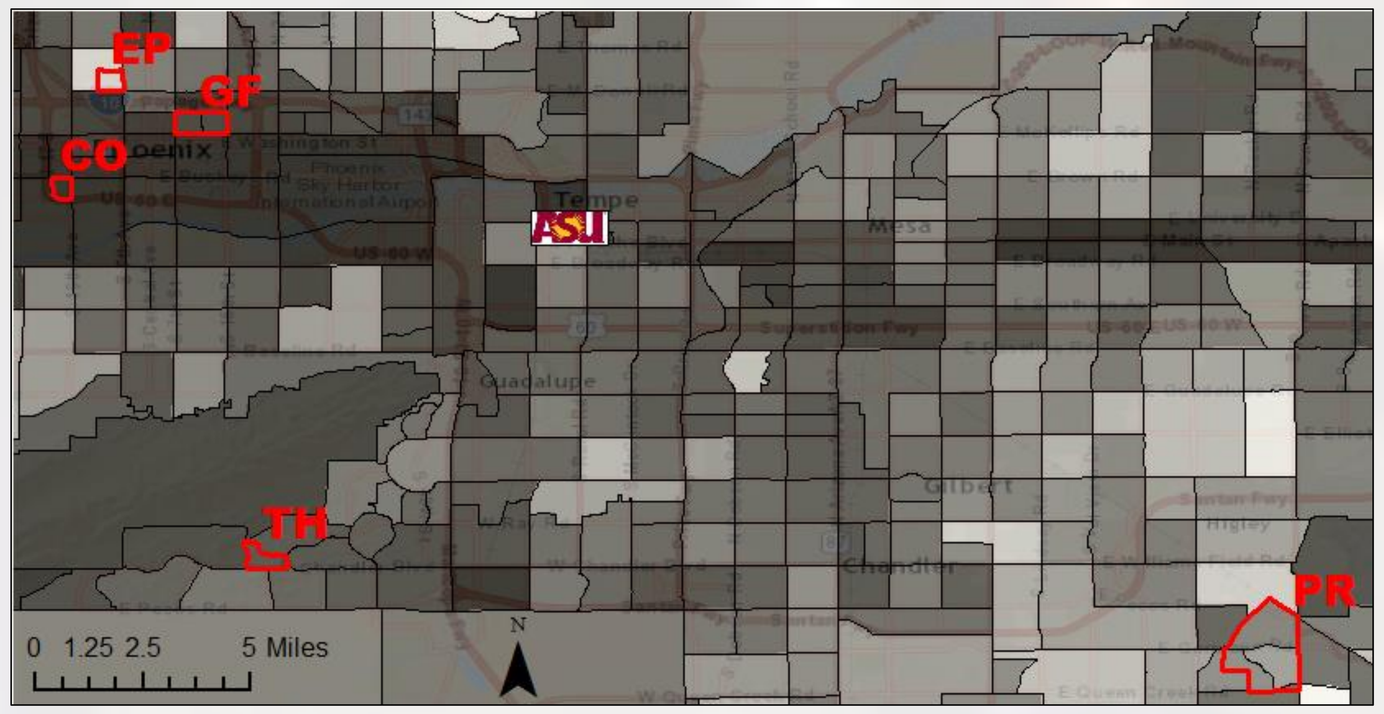

Figure 4. Average NDVI values per census tract; lighter shades imply more vegetation.

Discussion & Future Directions

The land surface temperatures, as estimated by TB, and vegetation had a very visible relationship for neighborhoods within the Phoenix metropolitan area. Also, the values from both the TB and the NDVI display an inverse correlation.

While nearly all of the neighborhoods had a fairly high percentage of urbanization, the range between GF (the highest) and PR (the lowest) was over 20 percent. PR, which is the only neighborhood located outside of Phoenix, had a much lower percentage of urbanization. PR tended to have a larger amount of land cover associated with cultivated vegetation mixed in with the urban and asphalt classifications. As the newest neighborhood as well as the neighborhood associated with master planning, PR's neighborhood layout consisted of more parks and greenery throughout the large space.

Although TBs and NDVI values had a fairly strong correlation for each neighborhood, they did not necessarily follow the trends of IETs. Despite TBs, NDVI values, and IETs agreeing on the overall high heat vulnerability of CO and the overall low heat vulnerability for EP, IETs differed greatly when it came to PR. Regardless of its above average vegetation, below average TB, and greatly below average percentage of urbanization, PR recorded total mean IETs above the neighborhood average. TH, which had the lowest mean IETs, also differed from the other indicators of heat vulnerability with lower than average vegetation cover and higher percentage of urbanization.

Overall, IETs cannot be determined by just ecologically-based heat vulnerability factors alone. While CO and EP IETs aligned with heat vulnerability implications made by TBs and NDVI values, the other three neighborhood IETs were not as strictly adherent. Past studies on heat vulnerability take into account multiple demographic details of each neighborhood when determining heat vulnerability (Harlan et al., 2006; Harlan et al., 2013; Reid et al., 2009). Future works involving IETs should include statistical representations and demographic rankings in order to assess non-ecologically based factors for heat vulnerability.

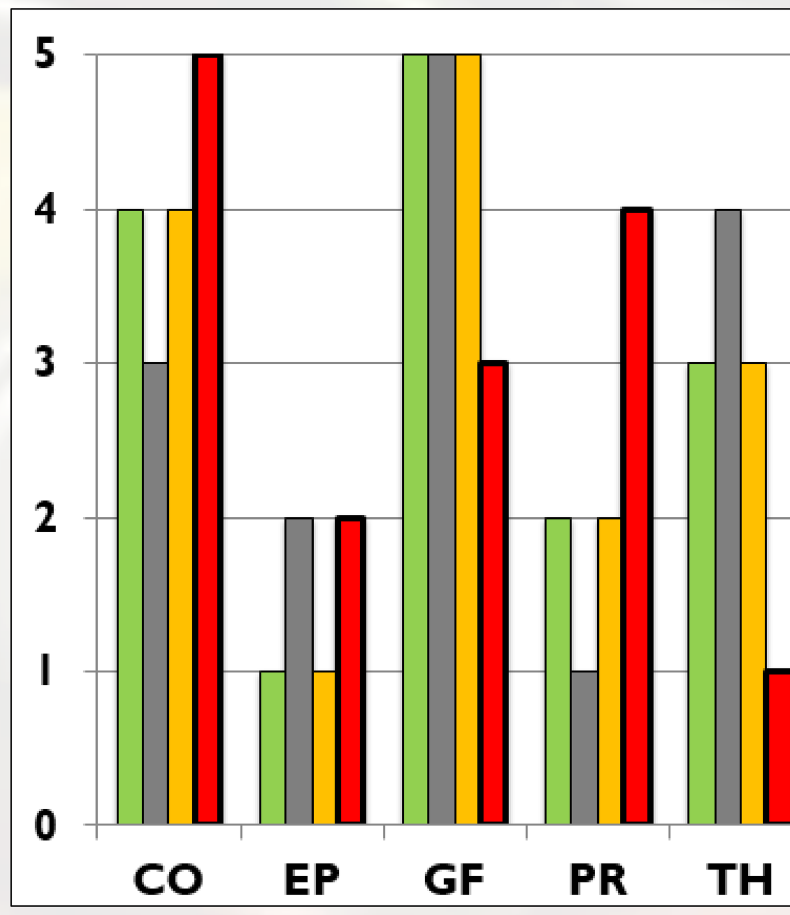

Figure 5. Ranked ecological variables and IETs for each neighborhood (1 = least vulnerable to heat)

Bibliography

Harlan et al., 2006; Harlan et al., 2013; Jenerette et al., 2007; Johnson et al, 2009; Reid et al., 2009

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