Promoting Equitable Climate Resilience in King County:
Mapping Communities Vulnerable to Extreme Heat

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King County Department of Natural Resources and Parks Project Goal

“This effort seeks to design, build, populate, and launch an online mapping product that guides pro-equity human health climate preparedness actions of public, civic, and private actors.”

Recommended Course of Action

From the outset, this data analysis and web application has been developed with future implementation potential in mind. Representatives from King County DNRP, Public Health outreach programs, the Puget Sound Clean Air Agency have all expressed interest and intent in contributing to additions that will further identify communities of concern. While the investment of time and resources is not a small one, we understand that the stakeholders already recognize the value of creating sophisticated identification tools that can pinpoint vulnerable communities on a fine scale. The more detailed the collated information, the more efficient and precise the prevention and intervention strategies will be, ultimately saving the public, private, and civic sectors involved time and money. This project provides a prototype that serves as motivating example of what is possible. We recommend using this prototype as a starting point from which products can be further developed to meet the evolving needs of decision-makers, stakeholders, and communities in King County.

1. Introduction

Geographic information systems are designed to examine a problem, a community, an event, a place, from all angles - investigating the interplay of social, ecological, and economic influences for best possible outcomes. Never is this form of study more powerful than with the impacts of climate change. King County is located in northwestern Washington State, hugging the coastline of Puget Sound and bordered in the east by the rugged Cascade Range. The county spans 2,131 square miles and is home to a vast watershed, protected forests and contains a rich and diverse population. But even this vibrant geography has begun to feel the effects of the globally changing climate. Many organizations - private, public, and civic - are working together to understand the particular risks this county faces, identify the most vulnerable locations and populations, and formulate useful prevention and intervention strategies.

King County Department of Natural Resources and partnering agencies--King County Department of Public Health, and the Puget Sound Clean Air Agency--hope to increase their collaboration in preparing King County for the impacts of climate change and extreme weather events. With a goal of increasing resiliency and equity among King County communities, this team was tasked with creating a tool that will assist in ensuring that the most vulnerable communities are able to withstand and adequately respond to extreme climate events. We have designed and built an online mapping resource for King County that can be shared and contributed to by multiple agencies, departments, and community organizations all working toward this common goal of increasing resilience to climate change. We created a working prototype using 'extreme heat events' as a functioning example for identifying populations and geographies most vulnerable to such an event and others like it.

In the effort to shore up resilience of the social organism as a whole, policy-makers are recognizing that social vulnerability must be acknowledged and addressed as environmental hazards become more common. Social vulnerability is defined here as a given population's ability to prepare for, respond to, and recover from climate change impacts (Cutter 2009). High sensitivity among part of the population will affect the health of the entire, interconnected social-ecological-economic system. A study by the Pacific Institute in California has recognized this concept and used it as a guiding principle for the state's own preparedness strategies:

> *"Understanding vulnerability factors and the populations that exhibit these vulnerabilities is critical for crafting effective climate change adaptation policies and disaster response strategies. This is also important to achieving climate justice, which is the concept that no group of people should disproportionately bear the burden of climate impacts or the costs of mitigation and adaptation. (Cooley 2012)."*

King County has already devoted significant resources to examining its climate change risks and forming a Strategic Climate Action Plan (SCAP, 2015) with climate justice as a goal. Until now, shared resources only exist in the form of static maps which can be challenging to analyze, become quickly outdated, and are difficult to compare with new information. An online platform is designed to host multiple layers of data that can be turned on or off, overlaid with one another, and compared in a variety of ways. Zooming options allow viewers to focus in on smaller census tracts that often get lost in a static map, and those interested in the particularities of the data will be able to open attribute tables and 'look under the hood'. Users will have many of the functionality options of ArcMap, but in a user-friendly online forum. These features will allow participating agencies to better coordinate prevention and relief measures for vulnerable areas with precision and efficiency.

1.1 Scope

This paper and accompanying web application examine geographic locations in King County that may be particularly impacted by the extreme heat events that the state of Washington has, and will continue to experience, as a result of globally rising temperatures. The Center of Disease Control defines heat events as unusually high temperatures for an extended period of time, impacting human health.

As mentioned above, King County Department of Natural Resources and Parks (KC-DNRP) initiated this project, alongside King County Public Health and Puget Sound Clean Air Agency, with the goal of sharing information about vulnerable locations amongst their organizations and others to improve response strategies.

With guidance from KC-DNRP, we examined three categories of variables known to play a role in extreme heat impacts:

1. certain demographics known to be socially vulnerable,
2. health conditions known to worsen with heat,
3. and environmental characteristics that contribute to a neighborhood's experience of high temperatures.

Table 1.1 Social-Ecological-Systems Table

Social Ecological Systems Table: Challenges for Heat Resilience Equity			
Scale	**Social**	**Ecological**	**Economic**
Above: Washington	Economic realities throughout the state create clusters of vulnerable demographics	Statewide heat waves could create water shortages and crop failure	Shifts in climate could influence leading industries' productivity
Focal: King County	Demographic markers of high risk/low resiliency: low income, high percentages of non-white population, low English proficiency, seniors, poor health	Lack of vegetation and tree cover within urban areas can create residential heat islands	Heat waves could create transit slowdowns, productivity decline, taxing of medical resources

Below: At Risk Neighborhoods	Social isolation and distance from resources make neighborhoods more vulnerable		Challenges keeping normal routines/work schedules during heat could increase further vulnerability

Working with the King County GIS department and Public Health, we gathered data to explore the relationships between these variables and collated their values in a visually meaningful web application (See Table 1.2 Data Table in Appendix A for a full data list). The web application includes the following layers and features:

Table 1.2: Layers/Features included in Web AppBuilder: 'Climate Vulnerability-King County'

Layer/Feature	Type	Description
Demographics Index	(Tiled Map/Feature Service)	Includes income, race, english proficiency, age
Health Conditions Index: Hospitalizations	(Tiled Map/Feature Service)	Includes asthma, diabetes, heart disease
Health Conditions Index: Hospitalizations Focal Scale	(Tiled Map/Feature Service)	Includes asthma, diabetes, heart disease for a focal area
Health Conditions Index: Prevalence	(Tiled Map/Feature Service)	Includes asthma, diabetes, heart disease
Environmental Index	(Tiled Map/Feature Service)	Includes impervious surface, building characteristics, NDVI
Impervious Surface	(Tiled Map/Feature Service)	Impervious Surface Data for King County
Building Characteristics Index	(Tiled Map/Feature Service)	Vulnerable building characteristics
Heat Vulnerability Index	(Tiled Map/Feature Service)	Includes all variables
On/Off	Option	Layers can be turned on and off

Transparency	Option	Layers are set at a transparency level that allows for comparison with other layers
‘Swipe’	Widget	Enhances the comparison between layers by allowing users to swipe layers over one another
‘Add Data’	Widget	Allows users to add content
‘Select’	Widget	Allows users to select features

Out of Scope

- Air quality is an important factor in climate related health impacts, and in the case of extreme heat pollution often increases and contributes to respiratory suffering. Our limited timeframe, however, did not allow us to include air quality measures in our analysis, or to explore in detail their relationship to heat and health.

- Many demographic factors could be considered when defining a region’s social vulnerability to heat. Since King County has already investigated this topic deeply, we chose to work with the top three elements it has concluded to be most significant and not explore further variables, other than age.

- King County project sponsors expressed a desire for the web application to include capability to recalculate analyses based on configurable weighting options. This development falls outside our range of experience and the timeframe to learn how to incorporate it as an online feature. We produced several static maps in the meantime, showcasing variable differences when weights are applied. Please note these maps use natural breaks (jenks), and should not be used for decision-making. They are a visual example only. See Appendix A.

- King County also requested the option to zoom into a focal scale, and recalculate the analyses to just include data from a selected area. Again, we chose to not develop this for the online application due to time and resource constraints, and supplied a static map with an example recalculated focal scale to represent the potential differences. See Appendix A.

1.2 Deliverables

- Geodatabase
- Report Documentation
- SES Table
- Static Maps
- Data Table
- Web AppBuilder Online Application
- Tile and feature layers published to the King County ArcGIS Online account

2. Design and Methods

2.1 Design Methodology

This project method is based on the social vulnerability index design developed for the Pacific Institute's examination of climate change impact distribution on the socially vulnerable populations of California (Cooley 2012). Their method allowed them to combine 19 indicators into a single index, collating their values into one final score. Our own design differs from theirs in two ways: 1) we have chosen different and fewer variables to focus on the impact of extreme heat, 2) we have created modular indexes according to indicator type to allow for nimble comparison and analysis, in addition to a full index containing all variables at the census tract level. We use ArcGIS Desktop to collate and analyze our collected data, and then publish finished layers to King County Organizational ArcGIS Online account for display in Web AppBuilder. As mentioned above, each index can be turned on or off, or be overlaid on top of one another to emphasize the relationships between variables and hone in on particularly high risk census tracts.

We chose the following variables that indicate geographic vulnerability to extreme heat:

Table 2.1: Climate Vulnerability Variables

Extreme Heat Vulnerability - Index Variables				
Category	Variable	Reference Source	Geography	Description
Demographics	Equity and Social Justice Demographics (ESJ)	King County ESJ, 2015	Census tracts 2010	"Combines three demographic characteristics into one category. English proficiency, people of color, and household income are scored and combined into a equal weighted score."
	Age - 65 and over (seniors)	Basu and Ostro, 2008	Census tracts 2010	Percentage of the population that is age 65 years and over.
Health				
Hospitalizations	Asthma	Lin, 2009	Zipcode to census tract	Hospitalizations in 2012-2014, Asthma (zipcode converted to census tract)
	Diabetes	Schwartz, 2005	Zipcode to census tract	Hospitalizations in 2012-2014, Diabetes (zipcode converted to census tract)
	Heart Disease	Madrigano, 2013	Zipcode to census tract	Hospitalizations in 2012-2014, Heart Disease (zipcode converted to census tract)
Prevalence	Asthma	Lin, 2009	HRA	Condition Prevalence in 2009-2013, Asthma (HRA)
	Diabetes	Schwartz, 2005	HRA	Condition Prevalence in 2009-2013, Diabetes (HRA)
	Heart Disease	Madrigano, 2013	HRA	Condition Prevalence in 2009-2013, Heart Disease (HRA)
Environment	Building Characteristics	Kilbourne et al. 1982	Census tracts	Age of structure, condition, number of levels, occupancy
	Normalized Difference Vegetation Index (NDVI)	Shonkoff et al 2009	Raster to census tract	Percentage of vegetation per area
	Impervious Surface Data	Shonkoff et al 2009	Raster to census tract	Prevalence of impervious surfaces (pavement)

2.2 Data Sources and Processing

2.2.1 Demographics

Our first index - demographics - builds on work already completed by King County defining the variables for their own social vulnerability index (SVI). GIS analysts Harkeerat Kang and Mary Ulrich created a SVI layer for King County and included 1) low income, 2) people of color, and 3) low English speaking proficiency as three primary identifiers of high-risk populations. This data was shared with us as a map package and we were given permission to use these variables to calculate a demographics index.

Knowing age to be a significant factor in mortality rates during heat events (Basu and Ostro 2008), we chose to include percentages of the population 65 and over as an additional demographic variable. A map service published by Esri contributor 'AtlasPublisher' and available through ArcGIS Online titled 'US Census 65 and Older Population' supplied the necessary data according to 2010 census tracts. The layer included percentages for the entire country so we selected polygons according to King County and exported the selected feature attribute table to a csv file. We added this data into the final heat vulnerability index (discussed in more details in Section 3 - Index Methodology).

2.2.3 Health Outcomes

When considering factors that contribute to social vulnerability, many health conditions could cause an individual to be considered high risk to environmental impacts. Given our 8-week timeframe, we limited our scope to include three conditions known to be exacerbated by and possibly life threatening during heat events: asthma, diabetes, and heart disease.

In a 2009 study in New York, high heat was found to be a direct link to increased hospitalizations for those suffering from respiratory disorders (Lin 2009). Air quality often decreases when the temperatures are at their highest, pollution and wildfire smoke (Reid 2016) can combine into a deadly inhalant cocktail that can trigger asthmatic attacks. Those living with diabetes as a pre-existing condition and taking related medications can be more susceptible to extreme heat and those suffering from cardiovascular diseases are found to have a higher rate of heart attacks during heat waves (Madrigano 2013). ''Cardiovascular' or 'heart disease' are terms that cover a wide array of conditions. After consulting with a representative from Public Health, we chose "coronary atherosclerosis and other heart disease" to serve as our proxy.

In addition to the documented relationship between these conditions and temperatures, we knew they are common enough to guarantee a certain amount of available data for analysis. We found, however, that even with the common existence of these conditions the data contained a number of limitations requiring us to make certain assumptions and choices to complete our index.

King County Public Health first provided us with data from the Behavioral Risk Factor Surveillance System showing the prevalence of each condition among adults, according to ‘Health Reporting Area’. The most recent data available was in rolling averages for years 2009-2013 in PDF format, which we converted to tables. While useful, we also wanted to include the rate of hospitalizations for each of these conditions. Public Health provided this data for all ages for years 2012-2014 in a table format, but according to zipcode. This presented a dilemma of geographic boundary and scale that we solved by creating two health indices:

- a ‘Prevalence Index’ in HRA boundaries to showcase the prevalence of conditions throughout the county,
- and a ‘Hospitalizations Index’ in zipcodes converted to census tracts using a Housing and Urban Development crosswalk file.

Updated in 2011, HRA boundaries are designed to coincide with city boundaries as much as possible, grouping related neighborhoods together with borders lining up with census blocks. They cover a fairly large area, and for the purposes of identifying communities at risk to formulate intervention strategies we wanted to see data on a finer scale. This motivated us to convert the hospitalization data from zipcode (also large areas) to census tract, which would allow us to mesh health information with other variables (demographics, environmental) and see the results. In doing this, we also found that we could overlay the index with HRA boundaries over the index with census tract boundaries and see slivers of tracts emerge at a higher risk rate. In short, the two indices provided information together that would not have been seen otherwise (discussed further in the ‘Results’ section).

Housing and Urban Development provides ‘crosswalk’ files for public download, updated every quarter, to allow analysts to convert data from zipcode to census tract and vice versa. In most cases, several census tracts fall more or less within the boundaries of a given zipcode but the borders do not fully synchronize. The zipcode-to-tract crosswalk file allows for a rough conversion, and in our case made it possible to apply the hospitalization rates for each King County zipcode to the census tracts that more or less corresponded.

We used the file created in the 4th quarter of 2014, in order to most closely match the timing of the hospitalization data. We found, of course, that in many cases census tracts fell in more than one zipcode boundary. This means that more than one hospitalization rate could potentially apply to a single census tract. To simplify for the purposes of this study, we allowed ArcGIS to select the first zipcode the tract appeared in during the table join to shapefile, and then hide the rest. We sampled a number of tracts for logical accuracy, and found the results to be consistent with the raw preconversion data. We have also provided an ArcMap document and static map that shows the hospitalization data according to zipcode, without the census tract conversion (see Appendix A). This allows a view of the raw data for comparison.

Data Limitations and Assumptions:

- Prevalence data is measured in HRAs, averaged for years 2009-2013 (most recent available), and only measures adults.
- Prevalence data in many cases was calculated with a small sample size, according to the original documentation and users are cautioned to interpret with care. We have proceeded with the values as they are.
- Hospitalization data is measured in zipcodes converted to census tracts, averaged for years 2012-2014 (most recent available), and measures all ages.
- Hospitalization data contains suppressed values whenever the ‘count’ sample is less than 5, and the ‘population’ is less than 50, for confidentiality purposes. Given these parameters, we have chosen to represent these values as ‘zero’.
- Zip-to-tract conversion via crosswalk file is meant for rough-scale analysis and not for fine detail. Policy-makers should keep in mind that rates attributed to certain tracts may have originally included other values as well.

2.2.4 Environmental Data

The objective of developing the environmental variables was to assess how certain built and natural living conditions factor into the impact of extreme heat event in King County, WA. These variables consist of a combination of living conditions and surrounding environmental conditions, (refer back to Table 2.1). These conditions, when combined with ‘intrinsic’ vulnerabilities, such as age class, medical condition, or other vulnerable demography, contribute to the overall impact of heat related illnesses and deaths experienced during extreme heat events. We chose the following three variables:

- Building characteristics
- Impervious surface data
- Normalized Difference Vegetation Index (NDVI)

Building attributes that could indicate a greater vulnerability to extreme heat events were used as substitutes.

- Building age: the older the structure the less energy efficient the dwelling is likely to be.
- Building condition: scored by the King County Assessor’s Office
- Building grade: low scores may indicate buildings that are less likely to offer protection from extreme heat events.

Data Limitations:

- We were not able to access data indicating households with air conditioning.
- Total number of rooms in a residence were not accounted for. Instead, the total living area is considered. Likewise, census tract area attempts to account for population density (smaller tracts likely having higher density).
- We were not able to access tree canopy data for King County. We used a Normalized Difference Vegetation Index paired with impervious surface data to act as a proxy. We strongly recommend incorporating tree canopy data when it becomes available.

Data

All data used to construct the index came from King County (See Table 2.4 at the end of Section 2). Three types of data were used, raster, vector and table. Raster data was used to assess both the impervious and NDVI percentage per area. Two vector datasets were used, ‘parcel_address’ is the basis of the building attribute polygon layer. Census tract polygons were used to define the Index area. Tables from the King County Assessor’s Office containing building attribute data were joined to ‘parcel_address’.

Scale

The focal scale for the ‘Environmental Index’ is King County census tract. Though the building/impervious data has the detail to be analysed at a block or even parcel level, we limited our scale to the tract level to match the NDVI and other indices (demographics, health). We have created an index at the parcel level as well, for informational purposes. This will be not be incorporated into the web application, but provided as an ArcMap document and static map (See Appendix A).

Data Processing

ArcGIS 10.3.1 was used for the project. The majority of the data was processed in ArcMap and ArcCatalog and final products were published to Web AppBuilder. Data processes were fairly straightforward, consisting of a few data conversions, joins, overlays and statistical calculations.

The primary processing objective, again, was to produce a common score for environmental variables that could be incorporated into a larger index at the census tract level. Additionally, as mentioned, we have produced an environmental index at the parcel level. This parcel level index can be used to aggregate the environmental conditions of any geography in King County, and further expanded upon as appropriate data is available to reflect additional environmental factors that are currently beyond the scope of this project.

Building Attribute Tables

Residential building attribute data was provided in several .csv tables from the King County Assessor's Office. The original tables consisted of several columns of data containing attributes such as location, type, height and square footage, and a range of scores for total of 509,435 records.
Rather than geocode the addresses, the tables were spatially joined to the feature class 'parcel_address' with the field 'PIN'. The 'PIN' field is not present in any of the tables from the Assessor's office and needed to be aggregated from the 'Major" and 'Minor' fields. The tables were opened in Microsoft excel and the 'PIN' number was reconstituted from the 'Major' and 'Minor' columns. Before the 'Major' and 'Minor' columns could be combined the fields needed to be converted to text with six "000000" and four "0000" digits respectively in order to maintain the required 10 digit length. This was done using the equation '=TEXT(A1,"0000")', the "000….." can be set to any length. The columns were then combined using the equation '=(A1&""&B2)' to finalize the 'PIN', (see Table 2.2). This process was done for all of the listed tables except "Lookup". The building attribute tables were then spatially joined to 'parcel_adress' using the 'PIN' field. The 'Identity' tool was used to sum the building attributes to the 'tracts10_shore' feature class. The output table was then joined to the 'tracts10_shore'.

Table 2.2 Address Geospatial Location Conversion

Excel Value	Major	Minor
Original number	1	1
=Text(A1,"000…..")	000001	0001
=(A1&""&B2) 'PIN'	0000010001	

Raster Data

In order to measure what is essentially a 'heat island' effect, we obtained two raster datasets: NDVI at 30m resolution, and impervious surface data at 1m resolution.

Impervious Surface Conversion:
The impervious surface data contained cells with a wide range of values corresponding to the jurisdiction responsible for the data. These values are not appropriate for the analysis and were converted to 1 or 0, presence or absence, using the 'Raster Calculator', "Con("%ImperviousLandCover (2)%">0,1)" .

NDVI Conversion:
Because of its coarse resolution, the NDVI raster was only processed to the tract level and several preprocessing steps occurred before the data could be analyzed.
The NDVI data arrived as a range of values that required examination to determine the threshold for what is considered ‘vegetation’ and what is not. To make the determination, the NDVI layer was displayed on top of the Esri Photo Imagery Basemap, then scaled so that the cells could visually be delineated as vegetation or no vegetation. We used the ArcMap Identify tool to select cells within the raster that appeared to be the edge of vegetated areas. We examined those cell values, and found that they fell within a few hundredths of the mean cell values. Based on the observation, the ‘Reclassify’ tool was then used to change all values in the raster that were less than the mean to 0 and greater than the mean to 1, thus providing a presence or absence value for the raster.

The ‘Zonal Statistics as Table’ tool was used to assess the area of both impervious and NDVI rasters. The tool allowed for the use of non-raster zonal inputs, unfortunately however the tool failed consistently when attempted. To avoid continued error and failures, we converted ‘tract10_shore’ and ‘parcel_address’ feature classes to rasters using the ‘Feature to Raster’ tool. The NDVI output table was then joined to ‘tract10_shore’ and the impervious output table was joined to both the ‘tract10_shore’ and the ‘parcel_address’ feature classes.

Statistical Analysis

New fields were added to ‘tract10_shore’ and the ‘parcel_address’ feature classes (see Table 2.3. Values from joined tables were used to populate new fields for “SUM” using field calculator. Z-scores were calculated for ‘tracts10_shore’ using the methods in section 3.4, below.

Table 2.3: Fields Added

NDVI	TRACTS10_SHORE	NDVI_SUM	NDVI_PCT	NDVI_Z	IMP_SUM	IMP_PCT	IMP_Z	TRC_AREA_Z	BLD_AGE_Sum	BLD_AGE_Z
Bldng	TRACTS10_SHORE	BLD_Ht_Sum	BLD_Ht_Z	BLD_Grd_Sum	BLD_Grd_Z	BLD_Con_Sum	BLD_Con_Z	BLD_LvgAr_Sum	BLD_LvgAr_Z	BLD_Ht_Sum
Bldng Index	PARCEL_ADDRESS	BLD_HT	BLD_GRD	BLD_CON	BLD_LVGA	IMP_SUM	IMP_PCT	PARCEL_NDX		

Table 2.4: Environmental Index Data

Name	Purpose	Description	Source
TRACTS10_SHORE	Provide polygon border for Index analysis.	'2010 Census Tracts for King County - Conflated to Parcels - Major Waterbodies Erased'	King Co. http://www5.kingcounty.gov/sdc/Metadata.aspx?Layer=tracts10_shore
PARCEL_ADDRESS	Provide address locations for building attribute data. Provide polygon area for parcel attribute analysis.	'GIS based source of address, property, and owner information to the King County integrated permitting system. This layer was designed to meet the specific needs of the Permit Integration implementation team.'	http://www5.kingcounty.gov/sdc/Metadata.aspx?Layer=parcel_address
Apartment Complex (.ZIP)	Building attributes for apartment complexes	CSV file containing building attributes related to apartment complexes.	http://info.kingcounty.gov/assessor/DataDownload/default.aspx
Condo Complex and Units (.ZIP)	Building attributes for condominiums.	CSV file containing building attributes for condominiums.	http://info.kingcounty.gov/assessor/DataDownload/default.aspx
Residential Building (.ZIP)	Building attributes for residences.	CSV file containing building attributes for residential properties.	http://info.kingcounty.gov/assessor/DataDownload/default.aspx
Lookup (.ZIP)	Key to building attributes	CSV Lookup file contains one record for each possible value in a specific look up table.	http://info.kingcounty.gov/assessor/DataDownload/default.aspx
Lndcov_imp_2009	Impervious surface data, 1M	Raster tiles covering King Co. delineating impervious surfaces.	Provided on USB drive.
KC_NDVI_20160727.tif	NDVI coverage, 30M	Raster coverage of NDVI for King Co.	ftp://ftpgreen.kingcounty.gov/transfer/Rauscher

2.3. Index Methodology

The Use of Z-Scores

Our goal with each dataset we received was to create a common scoring system that would allow variables with a variety of unit measurements (rate, percent, area, etc) to be compared meaningfully alongside one another. Each variable contained unit measurements and calculations unique to itself when first obtained. Hospital utilization for diabetes was calculated as a rate in its original table format using the count and population by zipcode (see Figure 3.1).

King County resident hospitalizations for diabetes with complications

Note: Numerators of <5 and denominators of <50 are suppressed for confidentiality

Rate: Per 100,000 person-years
Age: All ages 1+ (grouped)
Race/ethnicity: All (combined)
Gender: All (combined)
Years: 2010–2014 (3-year rolling averages)

Data Source: Comprehensive Hospitalization Abstract Reporting System, Washington State Department of Health
Prepared by: Public Health-Seattle & King County; Assessment, Policy Development & Evaluation Unit; 07/2016.

Counts				**Population**					**Rate**	**Lower CI**	**Upper CI**		**Ra**
	2010-2012	**2011-2013**	**2012-2014**		**2010-2012**	**2011-2013**	**2012-2014**		**2010-2012**	**2010-2012**	**2010-2012**		**20**
98001	**111**	**99**	**107**	**98001**	**94,341**	**95,157**	**96,371**	**98001**	**=IF(OR(B17="*",G17="*"),"*",B17/G17*100000)**				
1-14	*	*	*	1-14	18,157	18,295	18,482	1-14	*	*	*		*
15-24	16	9	*	15-24	13,432	13,332	13,420	15-24	119.1	68.1	193.4		
25-44	16	17	28	25-44	24,438	24,483	24,666	25-44	65.5	37.4	106.3		
45-64	49	46	49	45-64	29,200	29,466	29,692	45-64	167.8	124.1	221.9		
65+	29	25	22	65+	9,114	9,581	10,111	65+	318.2	213.1	457.0		

Figure 3.1 – Hospitalization Rate for Diabetes, King County – Zipcode 98001

Similarly, impervious surface data was first calculated as a percent of total area. In order to combine variables that all contain different units, the values for each variable were transformed and standardized using z-scores (Cooley 2012). Calculating z-scores for each variable produces a range of values that has a mean of zero. The resultant z-scores are either positive (greater than zero) or negative (less than zero). The formula for z-score calculation is z-score = (observed value - mean) / standard deviation:

$$Z = \frac{X-\mu}{\sigma}$$

μ = mean
σ= standard deviation

The following steps were used to calculate z-scores for each variable:

1. Calculate the standard deviation for the range of values
2. Calculate the mean for the range of values
3. Calculate the z-score for each value using the equation:
   z-score = (value - mean)/(standard deviation)
4. Check for cardinality to make sure that the sign of the z-score (positive or negative) correctly corresponds to how that variable influences vulnerability. For example, higher diabetes rates increase vulnerability so it is important to make sure that, in this case, higher rates of diabetes have higher z-scores, and that these higher z-scores indicate higher vulnerability. Conversely, lower z-scores should correspond to lower vulnerability.

The following steps were used to calculate combined indexes:

1. Once z-scores have been calculated for each variable, these variables can be combined into a single index since the units have been standardized through the z-score transformation. The z-scores for all of the variables were then averaged to produce one mean z-score for each record across the multiple variables.

2. While the index represents a range of mean z-scores, to make the representation and display of the z-score index more intuitive to the viewer, the ranges of z-scores were re-categorized into five categories and given more intuitive labels that indicate vulnerability such as “Lowest”, “Low”, “Moderate”, “High” and “Highest”. The categories for the ranges were derived using equal intervals, which allows for consistent comparison across the data compilations.

2.3.1 Demographics Index and Age Methodology

The Equality and Social Justice demographic data procured from King County’s Harkeerat Kang included a number of subcategories nested within the three variables needed for our purposes: income, race, English proficiency. We created a copy of the original shapefile, and deleted fields we would not use.
We calculated a demographics index, first by calculating z-scores within the new shapefile. We added new fields for each variable, used the equation above to generate z-scores for all three and then summed them for each census tract. We then averaged by dividing by the number of variables in the index (3). The general field calculator expression used was:

([asthma z-scores] + [diabetes z-scores] + [heart disease z-scores]) / (3)

The mean z-scores across all variables were then displayed on the map as a representation of the locations of vulnerable demographics according to the ESJ definition. The range of z-scores were categorized into five categories using equal intervals and labeled “Very Low”, “Low”, “Moderate”, “High” and “Very High”.

Age data showing the percentage of the population 65 and over according to census tract was extracted from an ESRI ArcGIS Online map service into a .csv table format. We chose to use the age information to create a standalone variable and not join it with the ESJ Demographic Index. Cooley tells us: “Perhaps the most widely identified risk factor for heat related illness and death is age. Those 65 years and older are particularly vulnerable”. Given the importance placed on this variable, we decided it should be given equal weight in the final index as the other demographic index, health, and environmental (See Figure 3.3) Z-scores were generated after joining the table with the other indices to create the overall Heat Vulnerability Index (see Section 3.5).

2.3.2 Health Prevalence Index Methodology

The prevalence of each health condition—diabetes, heart disease, and asthma—obtained from the Behavioral Risk Factor Surveillance System was measured by percent of the population in each Health Reporting Areas (HRA) that experienced that condition. With permission, we downloaded the PDF tables accessible to the public and converted them into editable excel tables. We transformed the percentages of the population experiencing each condition into z-scores to standardize the range of values. This z-score calculations were performed in Excel.

To calculate an overall health index for prevalence of health conditions, the z-score values for each condition were then summed for each HRA and then averaged by dividing by the number of variables in the index (3). This was accomplished by first importing the Excel z-score data into ArcMap and joining it to the HRA boundary shapefile. Once joined, a new field was added in the attribute table to calculate the mean z-score across all three variables. The general field calculator expression used was:

([asthma z-scores] + [diabetes z-scores] + [heart disease z-scores]) / (3)

The mean z-scores across all variables were then displayed on the map as a representation of an overall prevalence index for diabetes, heart disease and asthma by HRA boundary. The ranges of z-scores were categorized into five categories using equal intervals and labeled by “Very Low”, “Low”, “Moderate”, “High” and “Very High”.

Higher z-scores indicate areas that have a higher prevalence of the health conditions and are therefore more vulnerable to heat.

2.3.2.1 Health Condition Prevalence—Weighted Examples

Three weighted health indexes were calculated as simple examples of a weighting scheme. These examples are meant to show the difference in results when weights are applied to the z-score values. Each weighted index was created from the health condition prevalence by HRA data. The same calculation for z-scores was performed, however, in each case, one of the variables was chosen to be “twice as important” as the other. In order to calculate this, the z-score for the variable that was chosen to be twice as important was multiplied by two in the equation. The following equation was used to calculate a weighted index that weights diabetes twice as important as asthma and heart disease:

([asthma z-scores] + ([diabetes z-scores] **** 2****) + [heart disease z-scores]) / (3)*

The same equation was used to calculate weighted indices for asthma and heart disease weighted results. The results were then displayed side-by-side to show how introducing a weighting scheme to the indices can change the overall z-score results. Again note, each are displayed using natural breaks (jenks) unlike the other indices, and should not be used for decision-making or analysis.

2.3.3 Hospitalization Index Methodology

Hospital utilization data from King County Public Health, as described above, was measured in rate of hospitalizations for the population according to zipcode. All three of the health conditions contained null values in certain zipcodes, when confidentiality commitments required Public Health to suppress the results. These values were assigned a proxy of zero. While this introduced a major simplifying assumption, these null records had to be given a value in order that z-scores could be calculated without errors. For each health condition, the rates of hospitalization were then transformed into z-scores to standardize the range of values. This z-score calculations were performed in Excel for each health condition.

2.3.3.1 Hospital Utilization by Zip Code

The hospitalization data obtained from Public Health contained a level of detail we chose not to represent in our analysis (age bands, multiple year spans, confidence levels), so we extracted our chosen values into a new table: zipcode, total counts for all ages, population, and rate for the years 2012-2014.

To calculate an overall health index for hospital utilization rates by zipcode, the z-score values were calculated for each condition,summed for each census tract, and then averaged by dividing by the number of variables in the index (3). The z-scores were calculated in Excel, and then imported into ArcMap and joined to the census tract boundary shapefile (tracts10_shore). Once joined, a new field was added in the attribute table to calculate the mean z-score across all three variables. The general field calculator expression used was:

([asthma z-scores] + [diabetes z-scores] + [heart disease z-scores]) / (3)

The mean z-scores across all variables were then displayed on the map as a representation of an overall hospital utilization index for diabetes, heart disease and asthma by zip codes. The range of z-scores were categorized into five categories using equal intervals and labeled by “Very Low”, “Low”, “Moderate”, “High” and “Very High”.

2.3.3.2 Hospital Utilization by Census Tract

To create an index for hospitalization by census tract we first, as discussed above, downloaded the 4th Quarter-2014 crosswalk table from Housing and Urban Development and then matched, in excel, each rate value with its corresponding zipcode and census tract. Since multiple census tracts fall within a zipcode boundary, a rate value was often repeated multiple times for each tract associated with that zipcode (see Figure 3.2).

ZIP	TRACT	Asth_Rate	Dia_Rate	HD_Rate
98001	53033029902	65.4	111	74.7
98001	53033030401	65.4	111	74.7
98001	53033030404	65.4	111	74.7
98001	53033029801	65.4	111	74.7
98001	53033030501	65.4	111	74.7
98001	53033030902	65.4	111	74.7
98001	53033029901	65.4	111	74.7
98001	53033030901	65.4	111	74.7
98001	53033030801	65.4	111	74.7
98001	53033029802	65.4	111	74.7

Figure 3.2 – Zip-to-Tract Rate Application, King County, Wa – Zipcode 98001

Calculating an overall health index for hospital utilization rates by census tract followed the same method applied to the zipcode index outlined above. Z-score values were calculated for each condition,summed for each census tract, and averaged by dividing by the number of variables in the index (3). The z-scores were calculated in Excel, imported into ArcMap and joined to the census tract boundary shapefile (tracts10_shores). A new field was added in the attribute table to calculate the three mean z-scores. The general field calculator expression used was:

([asthma z-scores] + [diabetes z-scores] + [heart disease z-scores]) / (3)

The mean z-scores across all variables were then displayed on the map as a representation of an overall hospital utilization index for diabetes, heart disease and asthma by census tracts. The range of z-scores were categorized into five categories using equal intervals and labeled by “Very Low”, “Low”, “Moderate”, “High” and “Very High”.

2.3.3.3 Hospital Utilization by Census Tract for Focal Area

A focal scale example was created to show changes in the index value when z-scores were calculated at a smaller, more geographically concentrated focal scale. A group of 39 census tracts in the Auburn-Kent area of King County were selected as a focal scale. Z-scores were calculated for the smaller group of selected tracts.

The method discussed above for the complete Hospitalization Index by census tract was repeated at the focal scale level, only utilizing the 39 census tracts in the z-score analysis. This adjusted the mean z-score and the range accordingly to show high and low values relative to that selected area. The range of z-scores were categorized into five categories using equal intervals and labeled by “Very Low”, “Low”, “Moderate”, “High” and “Very High”.

2.3.4 Environmental Index Methodology

The environmental index was constructed at the census tract focal scale. The scores for each vulnerability factor was summed to the census tract polygons using the “Identity” tool for vector data and the “Zonal Statistics as Table” tool for raster data sets. The summed values were then used to calculate z-scores for each census tract using the same methods described previously. The index was calculated using field calculator, and z-scores were corrected for cardinality.

([%Impervious Z] + [%NDVI Z] + [Building Height Z] + ([Building Condition Z] + [Building Grade Z] + [Building Age Z] + [Tract Area Z] + [Living Area Z])*-1) / 8

The mean z-scores across all variables were then displayed on the map as a representation of the overall state of current environmental conditions. The range of z-scores were categorized into five categories using equal intervals and labeled by “Very Low”, “Low”, “Moderate”, “High” and “Very High”.

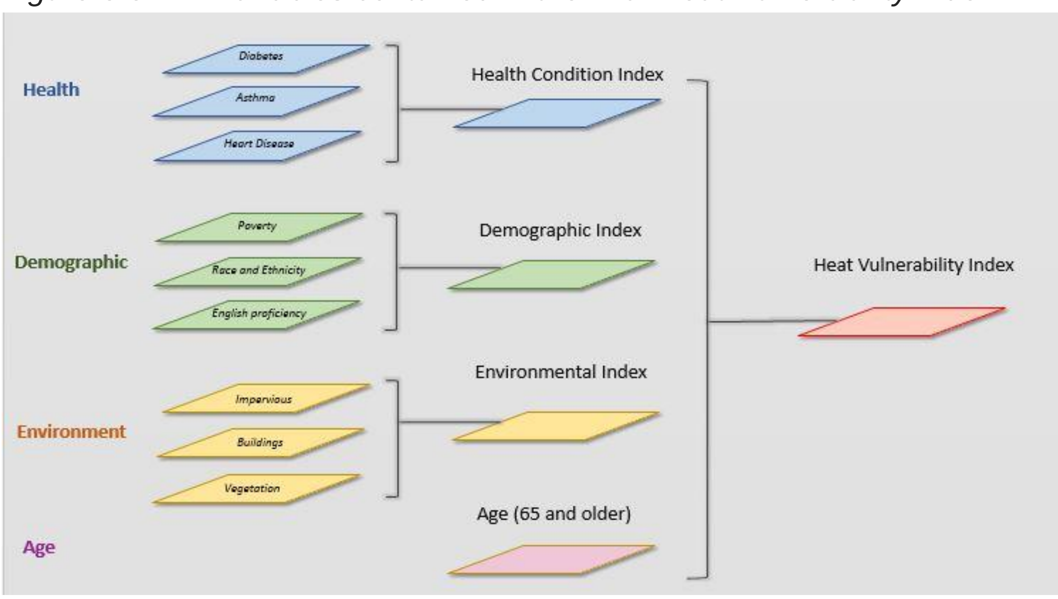
2.3.5 Final Heat Vulnerability Index

The final heat vulnerability index was constructed at the census tract focal scale. This overall composite index was created by adding together the demographic index, health conditions (hospitalizations) index, environmental conditions index, and age (population over 65). The z-scores from each of these indices were summed and then averaged to find the overall average z-score for each census tract. The index was calculated using the field calculator expression:

([Health Condition Index z-scores] + [Demographic Index z-scores] + [Environmental Index z-scores] + ([Age Over 65 z-scores]) / (4)

The mean z-scores across all variables were then displayed on the map as a representation of the overall heat vulnerability for each census tract. The range of z-scores were categorized into five categories using quintiles and labeled by “Very Low”, “Low”, “Moderate”, “High” and “Very High”.

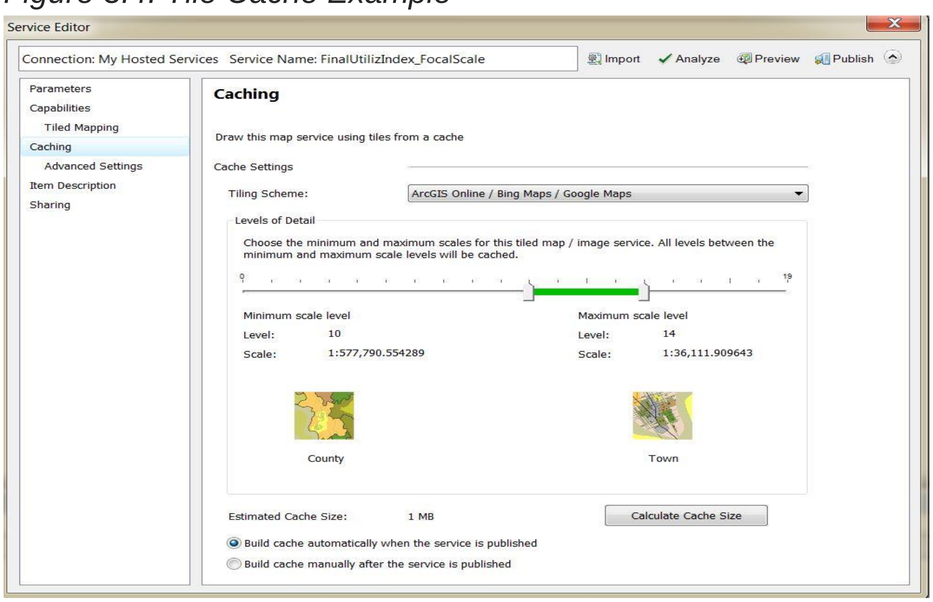
Figure 3.3 - All variables contained in the final Heat Vulnerability Index



2.3.5 Web AppBuilder Construction

King County created ArcGis Online accounts for us within their Organization and granted us publishing permissions. A Group titled ‘UW Sustainability Management’ with sharing and editing privileges was created for us by a system administrator.
To publish our indices to our Group, we signed into King County ArcGIS Online in ArcMap, and ‘shared’ each layer as a service. We chose to publish as tiled map caches with feature access to allow users to be able to access attribute data.
We adjusted the scale to show ‘counties’ as the maximum cache needed, and ‘towns’ as the minimum cache (see Figure 3.4). This adjusted the file to a much smaller size, which costs fewer online credits and makes for a more wieldy published product.
We shared the published layers from our content to the Group, and created a ‘Web Map’. We chose to display tile layers (instead of feature layers), again, to make the user experience more friendly. The tile layers load faster, and do not require the same credit usage as displaying feature layers. Those with a King County ArcGIS Online account can access the feature layers stored in the Group for analysis of the attribute tables and update capabilities. Once the tile layers were added to the Web Map and certain edits were completed (popup configuration, map notes, etc), we shared the Web Map selecting the option to ‘create a Web App using Web AppBuilder’. This drew our layers into AppBuilder where we were able to make final visual choices, and add effective widgets for data comparison.

Figure 3.4: Tile Cache Example



4. Results

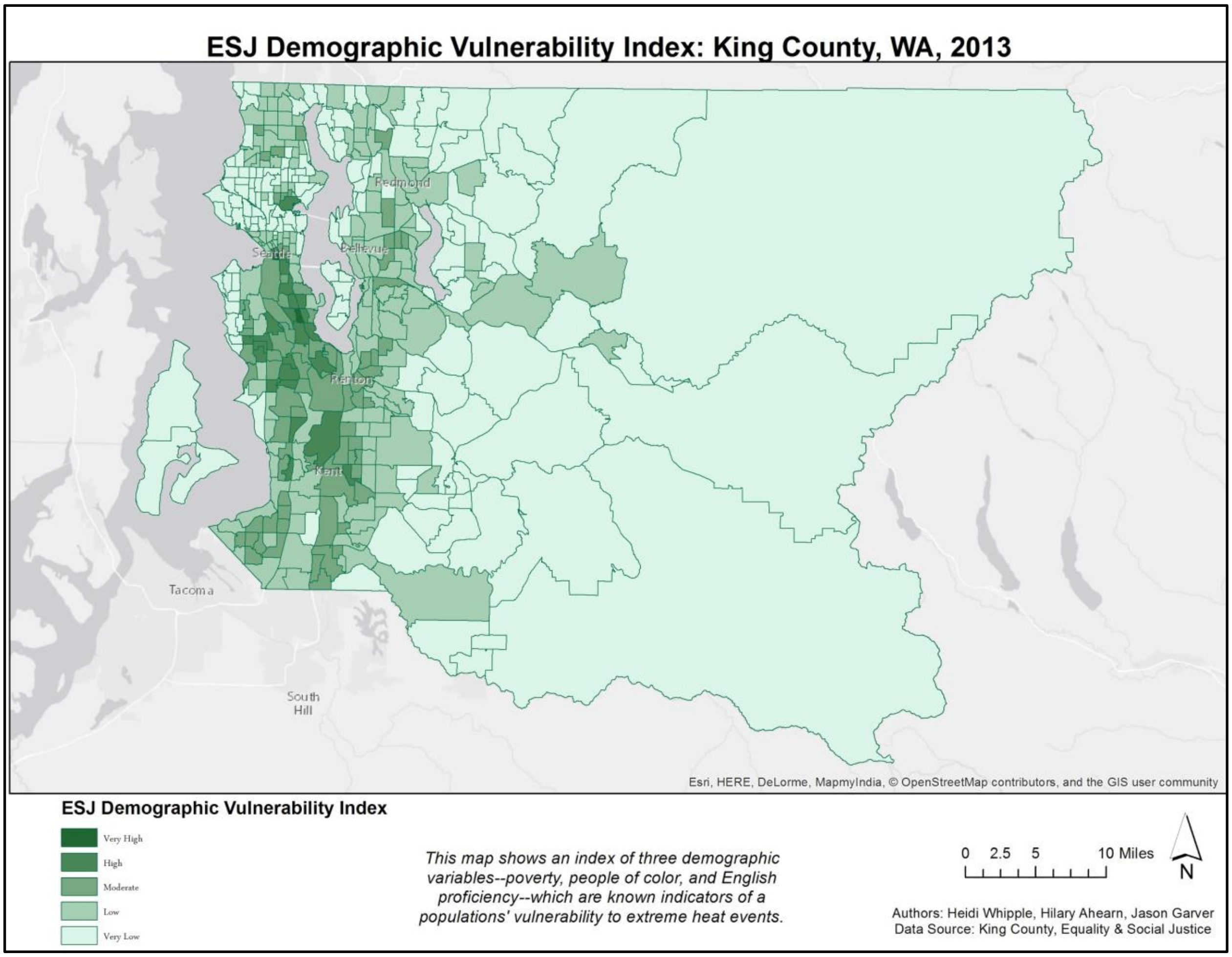
Though the online application generated by Web AppBuilder gives viewers the clearest view for analysis and comparison, we have also generated static maps to illustrate the areas of concern that emerged from the various combinations of variables.

First, see the ‘ESJ Demographic Index in Figure 4.1 below. Some of the darkest (most vulnerable) values appear along the I-5 corridor, centering in the Tukwila area, and especially near King County International Airport. The area has little relief from impervious surface, and the area has high percentages in all three categories: income, race, English proficiency. The darkest census tract, or the one with highest vulnerability score has the following values:

Table 4.1: ESJ Demographic Index for Tract 53033011001

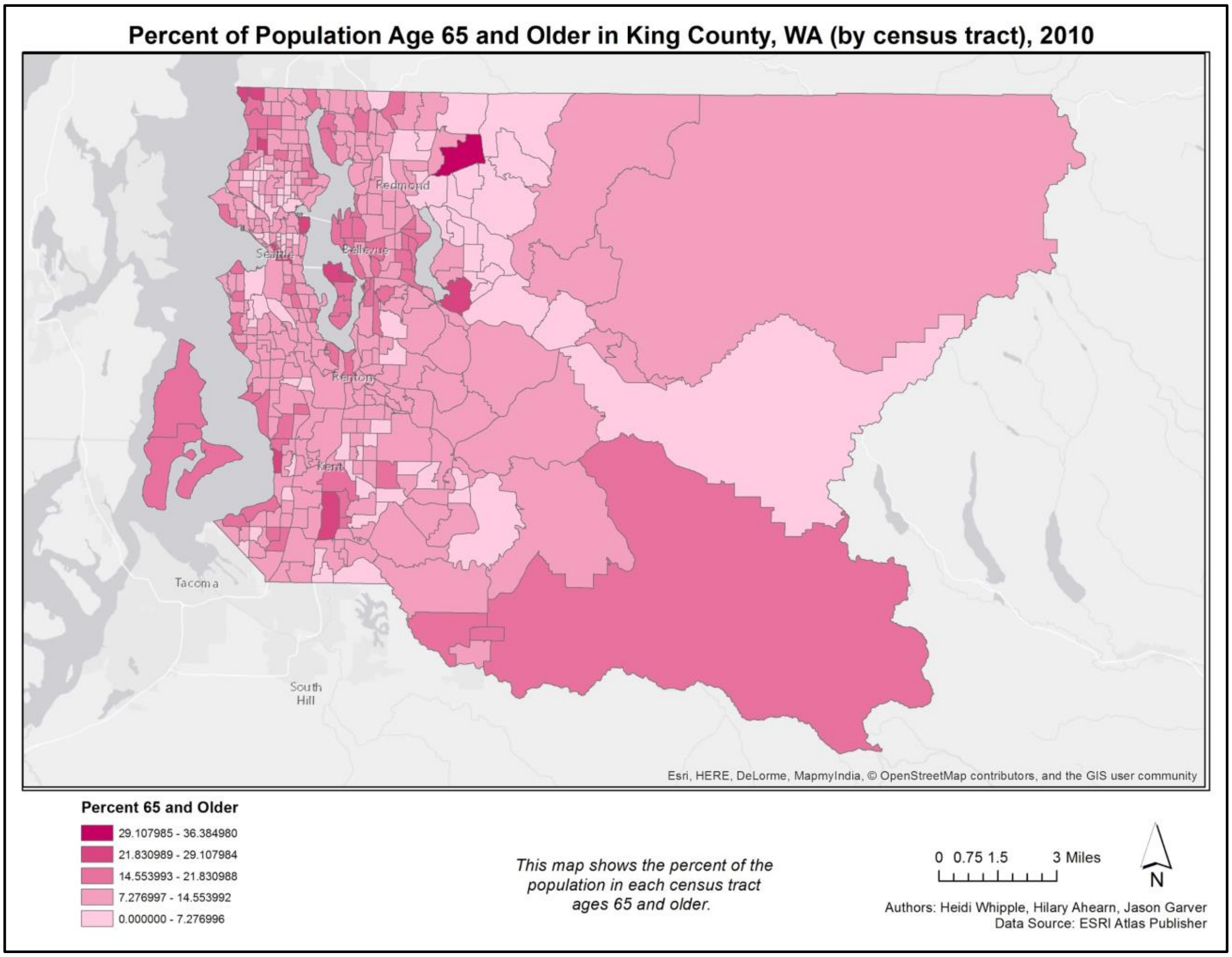
Variable	Tract 53033011001
Percent Low Income	62%
Percent of Non-White	87%
Percent Low English Proficiency	41%

Figure 4.1: ESJ Demographic Vulnerability Index



Next, in Figure 4.2, see the single most vulnerable population, those of 65 years of age and older, distributed by percentage according to census tract across the county. A surprising tract jumps out and should be taken note of, as it affects the overall index score. The single darkest tract in the northern center of the county has a very high percentage of seniors to the population, but in examining the area we found that a large portion of the region is taken up by a golf course and nestled next to what appears to be a wealthy, gated community. The population is spread out, and a lower total number than the surrounding tracts. The demographic risk numbers for this tract are quite low as well, which supports the assessment that this tract may not be as much a cause for concern as it might appear.

Figure 4.2: Percent of Population Age 65 and Older

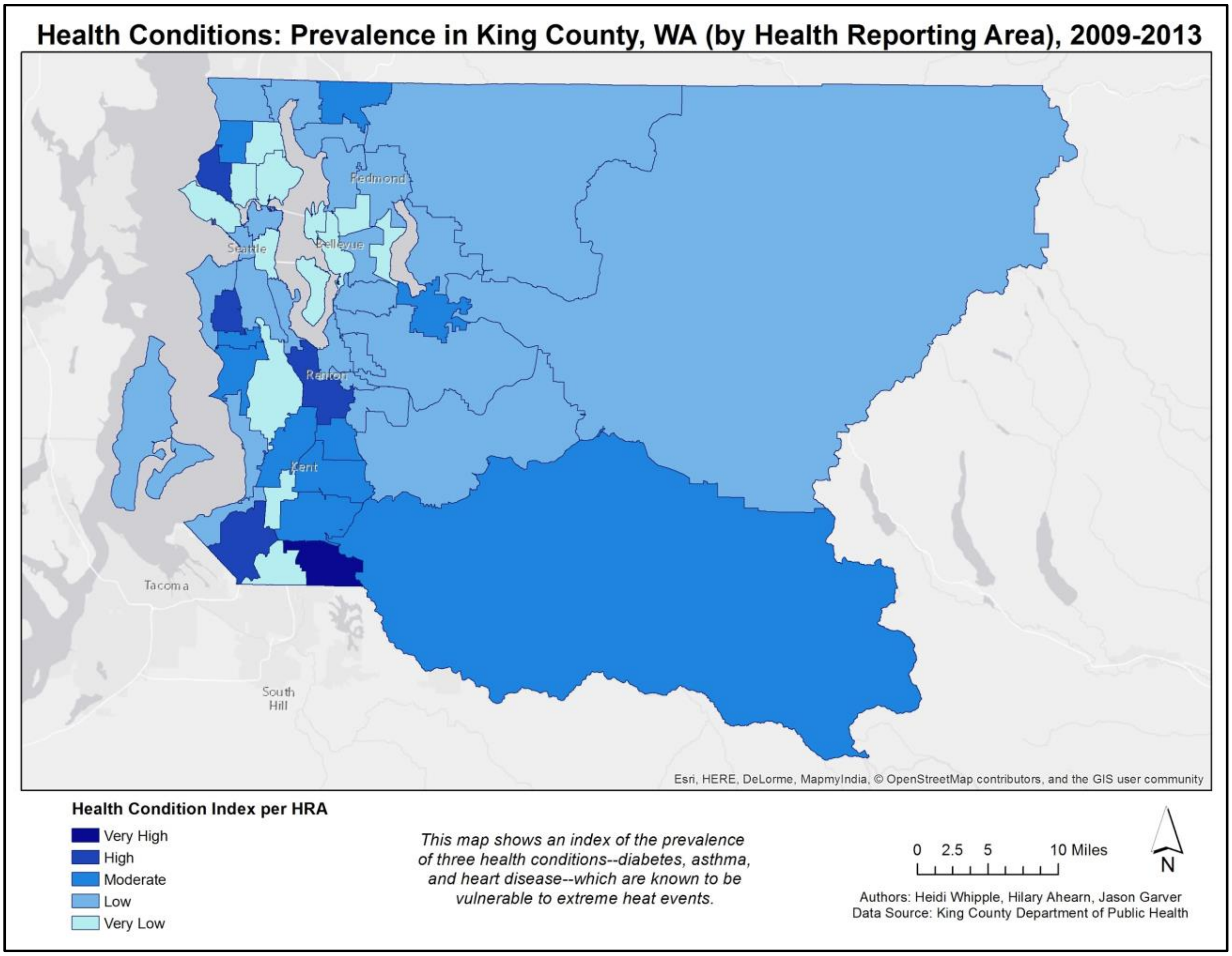


Moving into health conditions, Figure 4.3 illustrates asthma, diabetes, and heart disease prevalence as distributed throughout Health Reporting Area. The HRA with the highest risk value appears at the southwest edge of the map: Auburn-South. The percentages of these health conditions for this tract are listed below in the Table 4.2. Mercer Island, in contrast, exhibits very low values and therefore can be considered low concern. Somewhat surprisingly, the SeaTac/Tukwila HRA also does not appear to have high percentages of pre-existing health risks in its population.

Table 4.2: Health Conditions for HRA Auburn-South

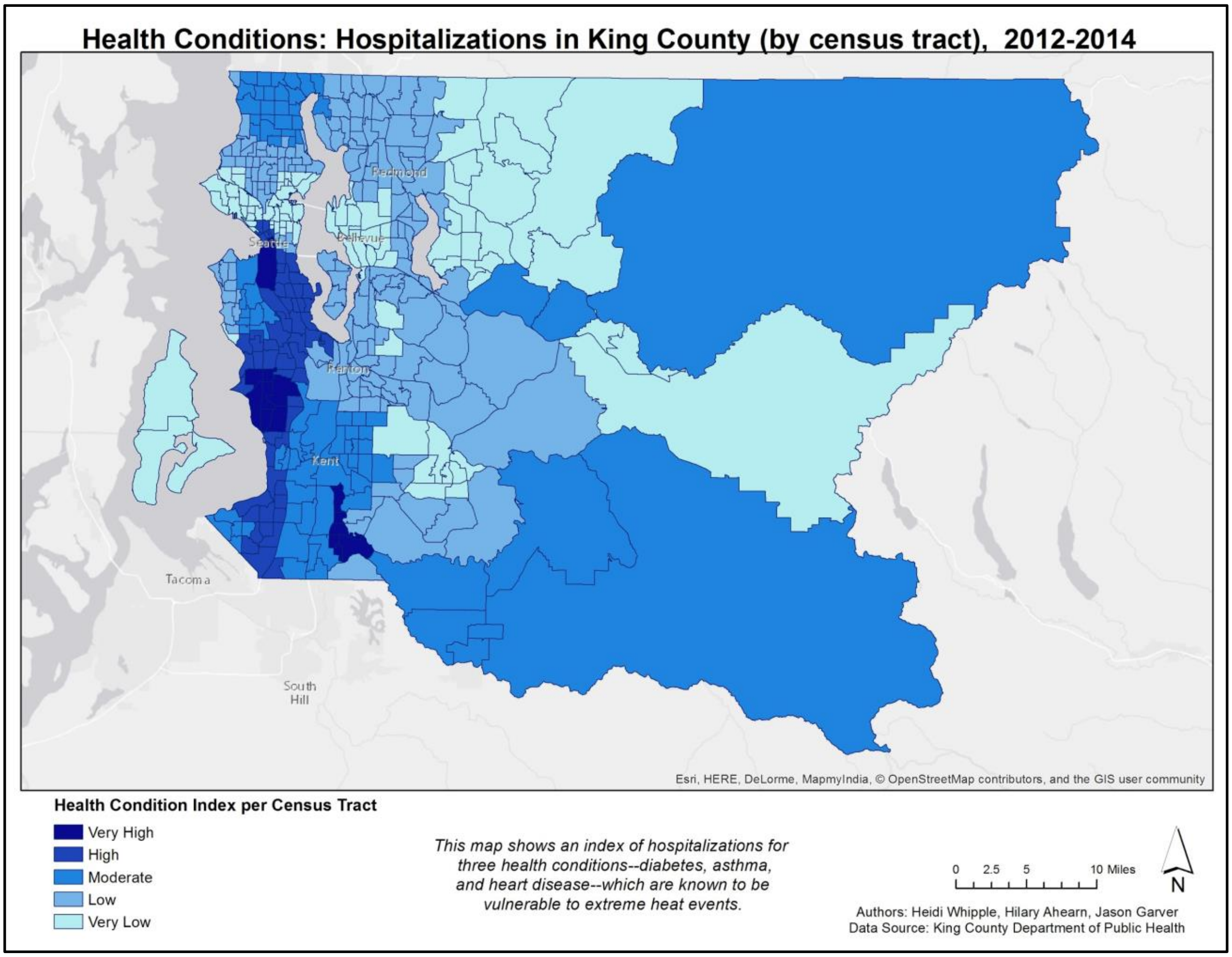
Variable	HRA: Auburn-South
Asthma Percentage	17%
Diabetes Percentage	24%
Heart Disease Percentage	3%

Figure 4.3: Health Conditions Prevalence Index



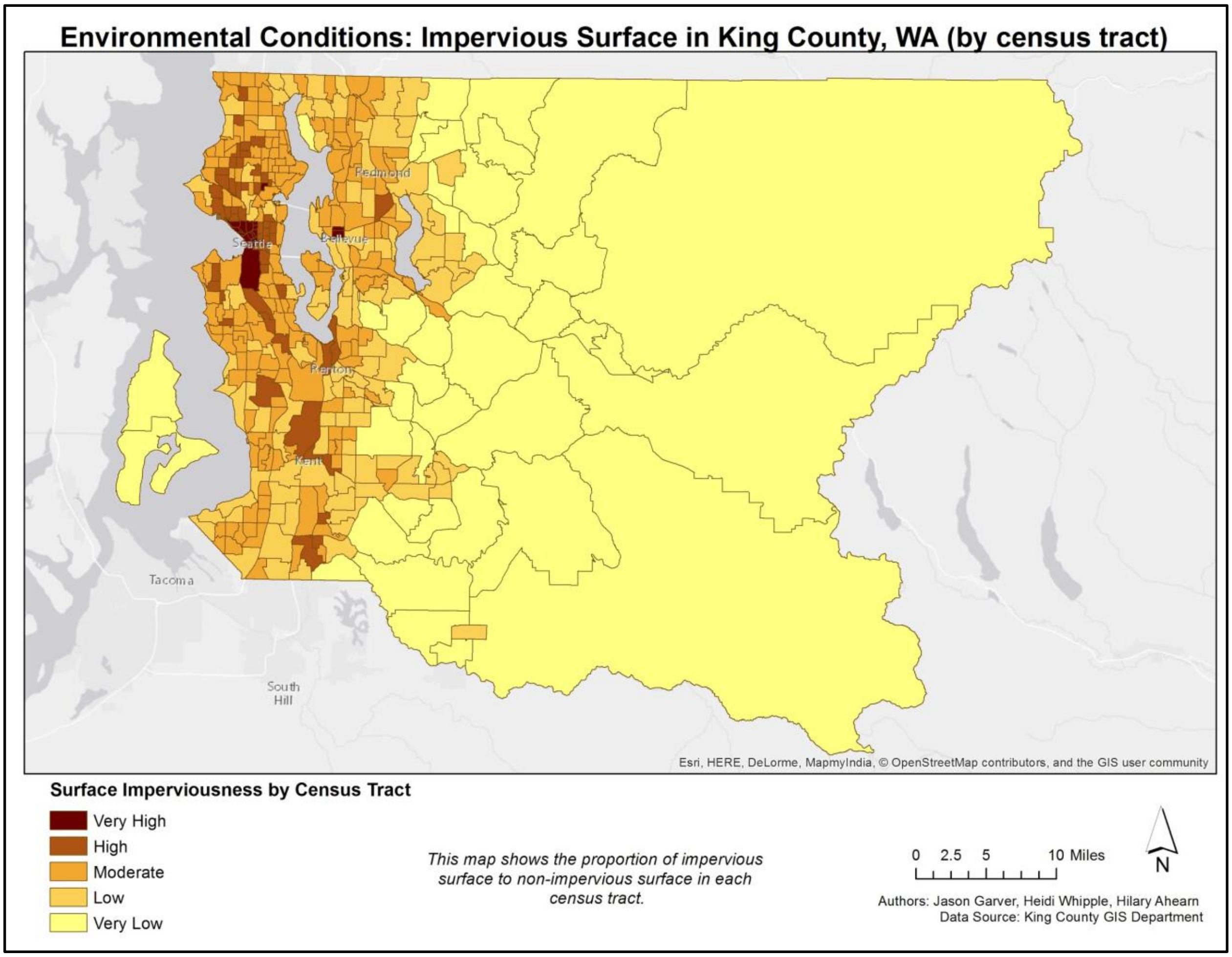
Following the health conditions prevalence display, hospitalizations for these same conditions converted from zipcode to census tract can be seen below in Figure 4.4. One of the first tracts to jump out can be seen on the middle west edge of the map - the Industrial District. While there is no value for heart disease for this tract, the asthma and diabetes rates are extremely high. The second cluster of high-scoring tracts, below the first, falls in the White Center/SeaTac area, and the third covers the city of Auburn.

Figure 4.4: Health Conditions Hospitalizations by Census Tract Index



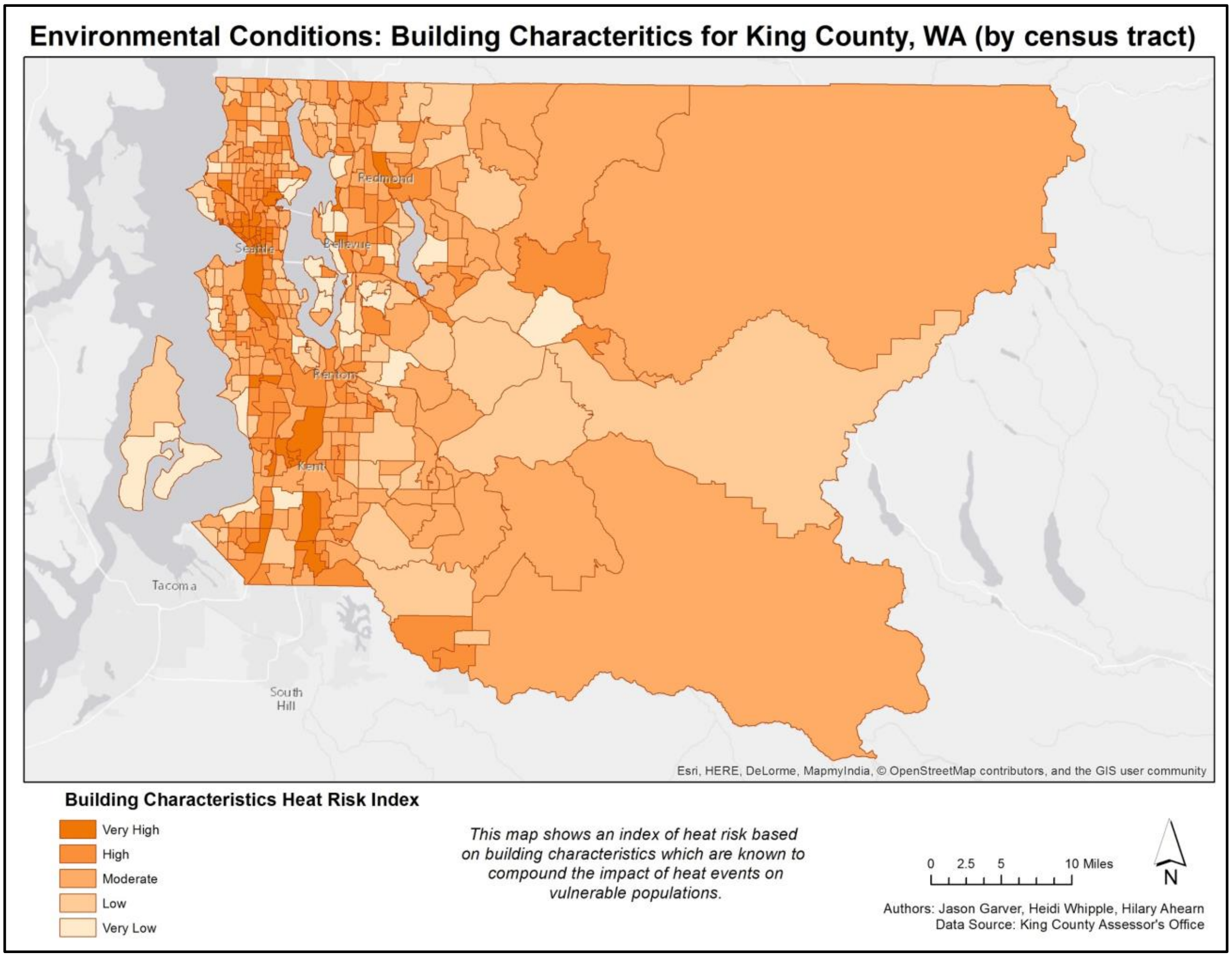
Before examining the Environmental Conditions Index as a whole, see the impervious surface data below in Figure 4.5. The trends are logical - downtown Seattle shows the highest value (high percentage of impervious surface to vegetation of any kind), and the North-South corridor following the I-5 highway follows closely behind. Filtering East, the tracts begin to lessen in severity with the large rural tracts showing the lightest values. The NDVI data (found in Appendix A), presents very similar visual information. The urban areas along the Western coastline contain the least vegetation, with the cities of Auburn and Kent popping out with the same level of concern as Seattle proper.

Figure 4.5: Impervious Surface in King County



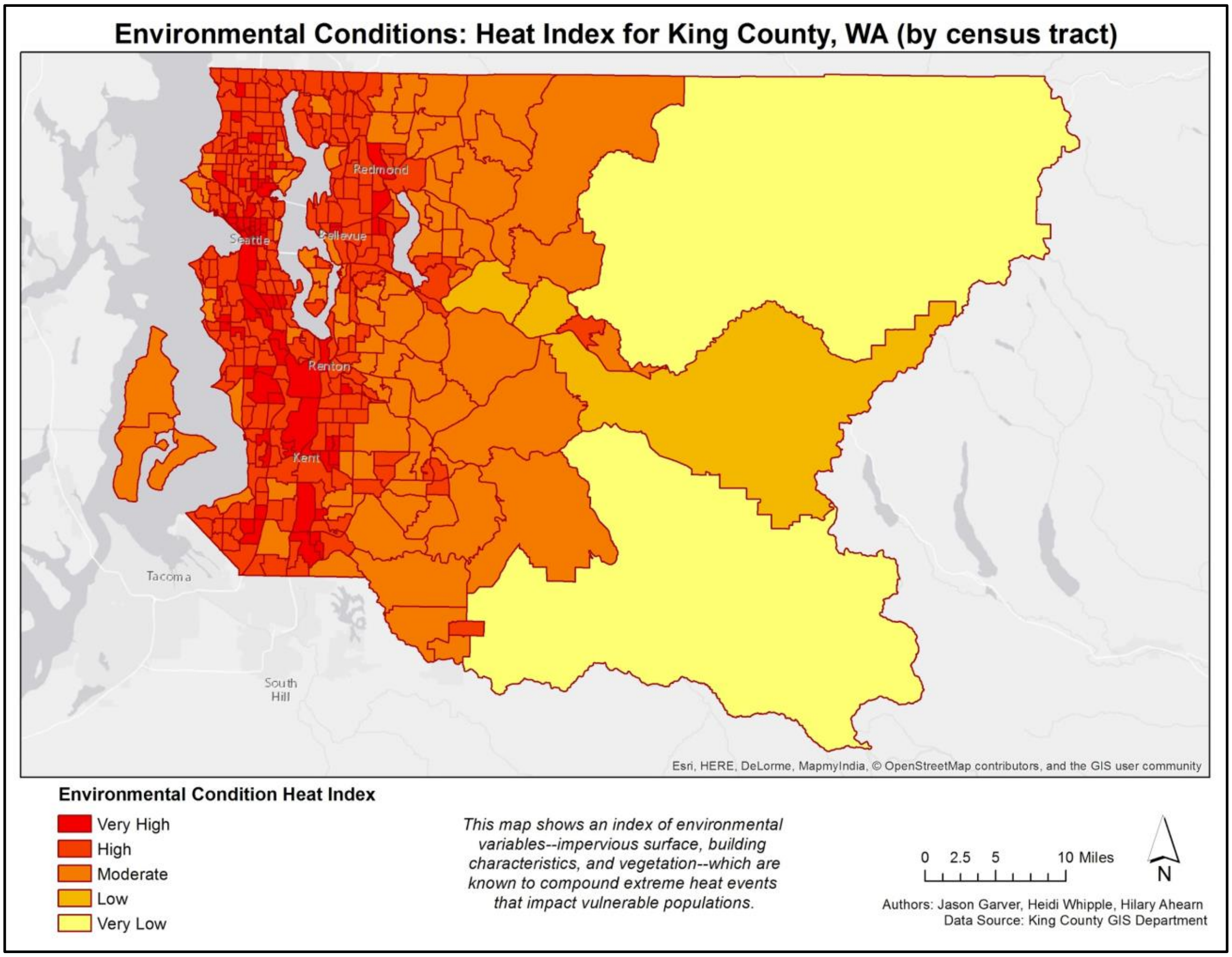
Building characteristic data tracks along the same lines as the impervious surface. Figure 4.6 illustrates the compilation of residences with small total living area, low condition, multiple stories, and older buildings. Seattle, Kent, and Auburn show up again with the highest values.

Figure 4.6: Building Characteristics Index



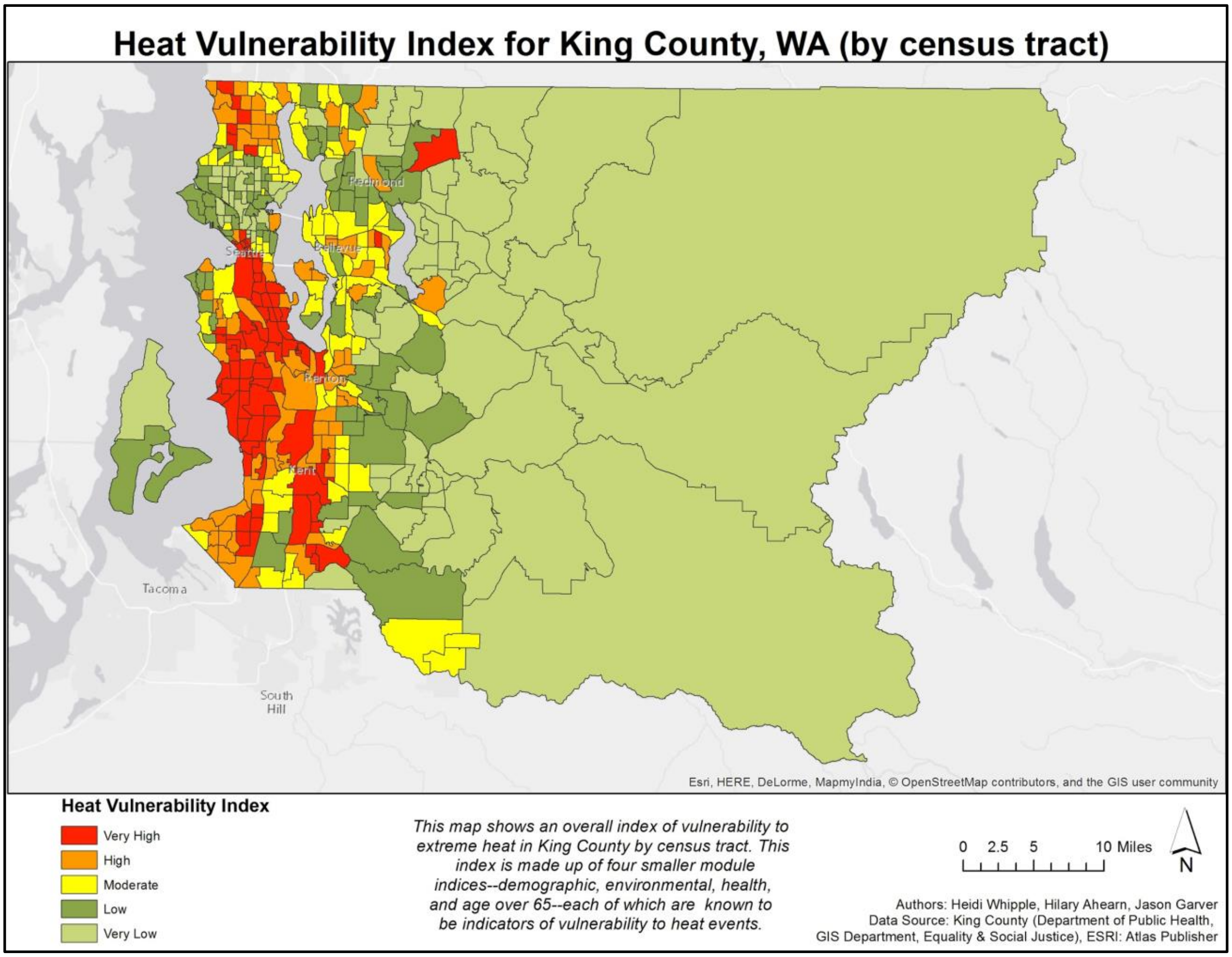
The overall Environmental Index in Figure 4.7 combines impervious surface data, NDVI, building characteristics, and tract area, and we can see the trends exhibit consistency with the individual layers.

Figure 4.7: Environmental Conditions Index



Finally, we see in Figure 4.8 the Final Heat Vulnerability Index. This includes the ESJ Demographics Index, Age Data, the Hospitalizations Index (asthma, diabetes, heart disease), and the Environmental Index. The emerged pattern will be explored in more detail below in Section 5 - Discussion.

Figure 4.8: Final Heat Vulnerability Index



5. Discussion

The results of these analyses and the accompanying web application demonstrate the ability GIS has to identify areas of the county that are especially vulnerable to climate change events, like extreme heat, in a dynamic, interactive manner. We are aware that King County DNRP is interested in expanding this effort and considering more effects of climate change and associated variables. Our results provide a prototype for a functional method to carry this work forward - modules can be created from any number of variables and added for comparison, without becoming unwieldy. Modules can then be compared to each other to locate specific areas of concern and guide pro-equity human health climate preparedness actions by public, civic, and private actors.

The modular design of the indices provide the user a way to pick and choose which variables they would like to compare and assess. The indices are successful in differentiating between census tracts and highlighting geographies of concern. When the individual indices are overlaid with each other, the user can identify which communities experience the highest levels of vulnerability and where multiple vulnerability factors potentially compound each other.

The analysis indicates that areas of significant concern exist primarily along the westernmost parts of King County. The results confirm what one would expect, that the more urban and populated areas possess the greatest number and highest magnitude of vulnerability factors. However, the use of the indices allows for the discovery of statistically significant areas of concern, and the factors responsible for increased vulnerability. Factor influence can be determined by examining the mean z-score of all the factors for the area of concern. The factors with the largest mean z-scores will have the most influence driving the overall vulnerability score (see Figure 5.1).

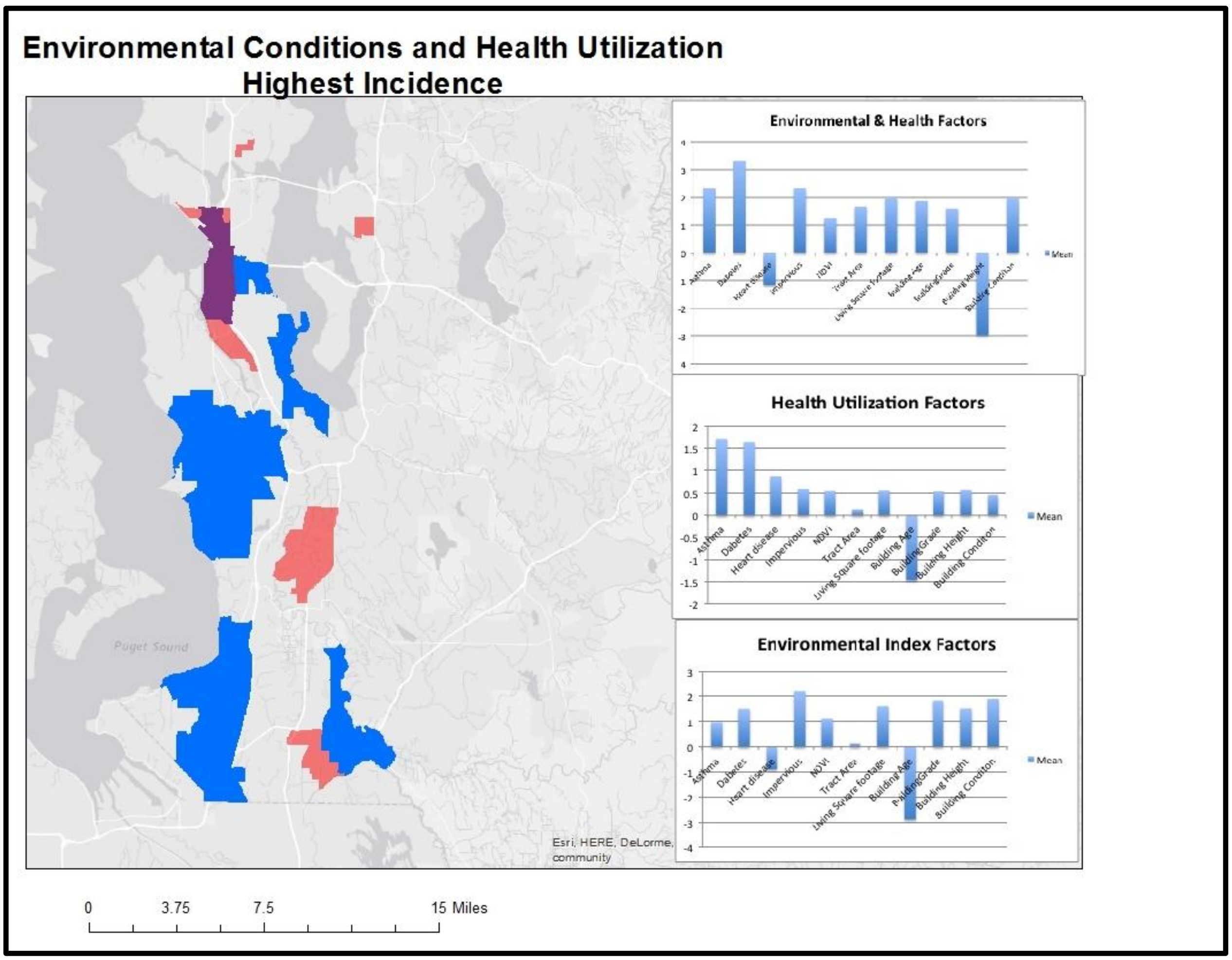


Figure 5.1: Environmental Conditions and Health Utilization Highest Incidence

The areas with the highest mean z-scores within Seattle proper exist from the Lower Queen Anne neighborhood down to the Georgetown neighborhood (See Figure 5.1). In these areas, the driving factors are asthma (mean z-score 1.7), followed closely by diabetes (z-score of 1.6). The environmental factors range between 0.57 and 0.45 mean z-score, with the exception of building age and tract area which are significantly lower, -1.45 and 0.13 respectively. This suggests there is not a dominant environmental factor for this area. Moving South from Seattle, most areas rank in the “High” factor category, however a few stand out as being exceptionally impacted either by health or environmental factors. Burien, SeaTac, Federal way, Auburn and the Northern part of Kent, all have significant areas of “High” environmental or health factors.

The mean z-scores were calculated using census tracts as the bounding areas, because of the limitations imposed by including multiple factors that were only available at that scale. However, the majority of the environmental data has also been compiled at the parcel level. This will allow for future analysis at other scales as King County moves this project forward. A particularly useful method of identifying clusters of values is to perform a ‘Hot Spot’ analysis. This method can be performed easily in ArcGIS using the “Optimized Hot Spot” analysis. The tool calculates the Getis GI* statistic to identify clusters of high and low values. A comparison of the z-scores displayed next to an optimized hot spot analysis demonstrates how the clusters emerge using the tool (see Figure 5.2).

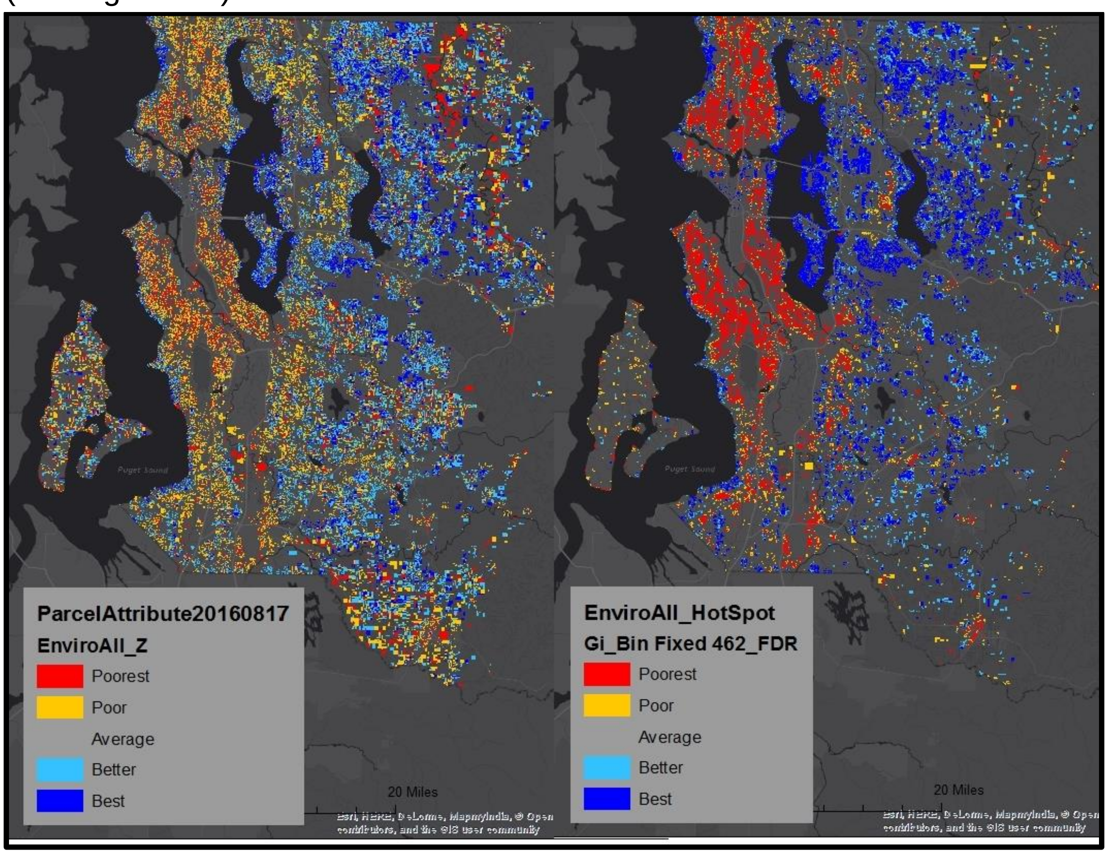


Figure 5.2: Optimized Hot Spot Analysis

Hot spot analyses were conducted on the two prevalent factors, Imperviousness and Building Condition (see Figures 5.3 and 5.4). These analyses demonstrate what is generally seen in the indices, but the clusters are not constrained by the arbitrary boundaries of the census tracts.

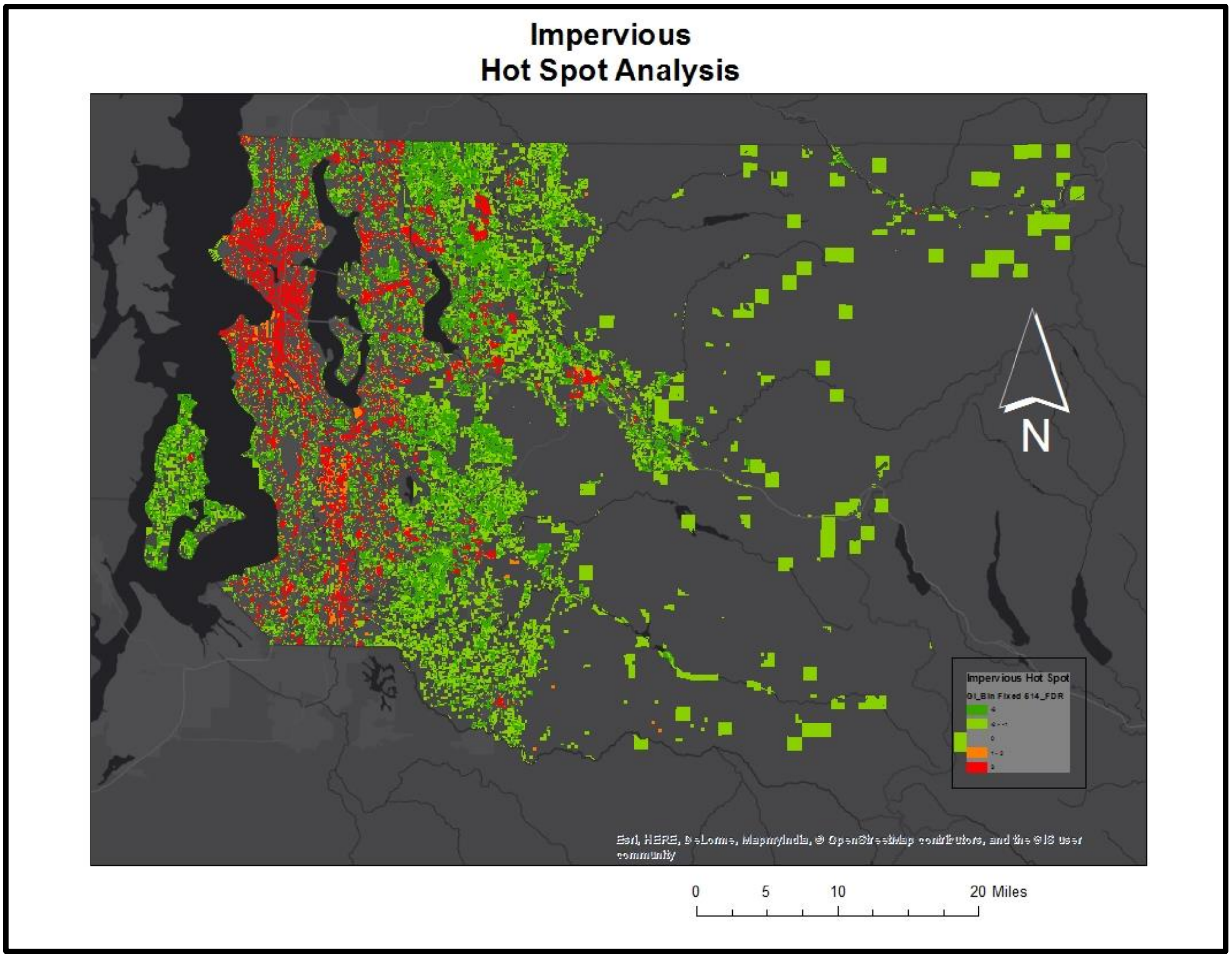


Figure 5.3: Impervious Hot Spot Analysis

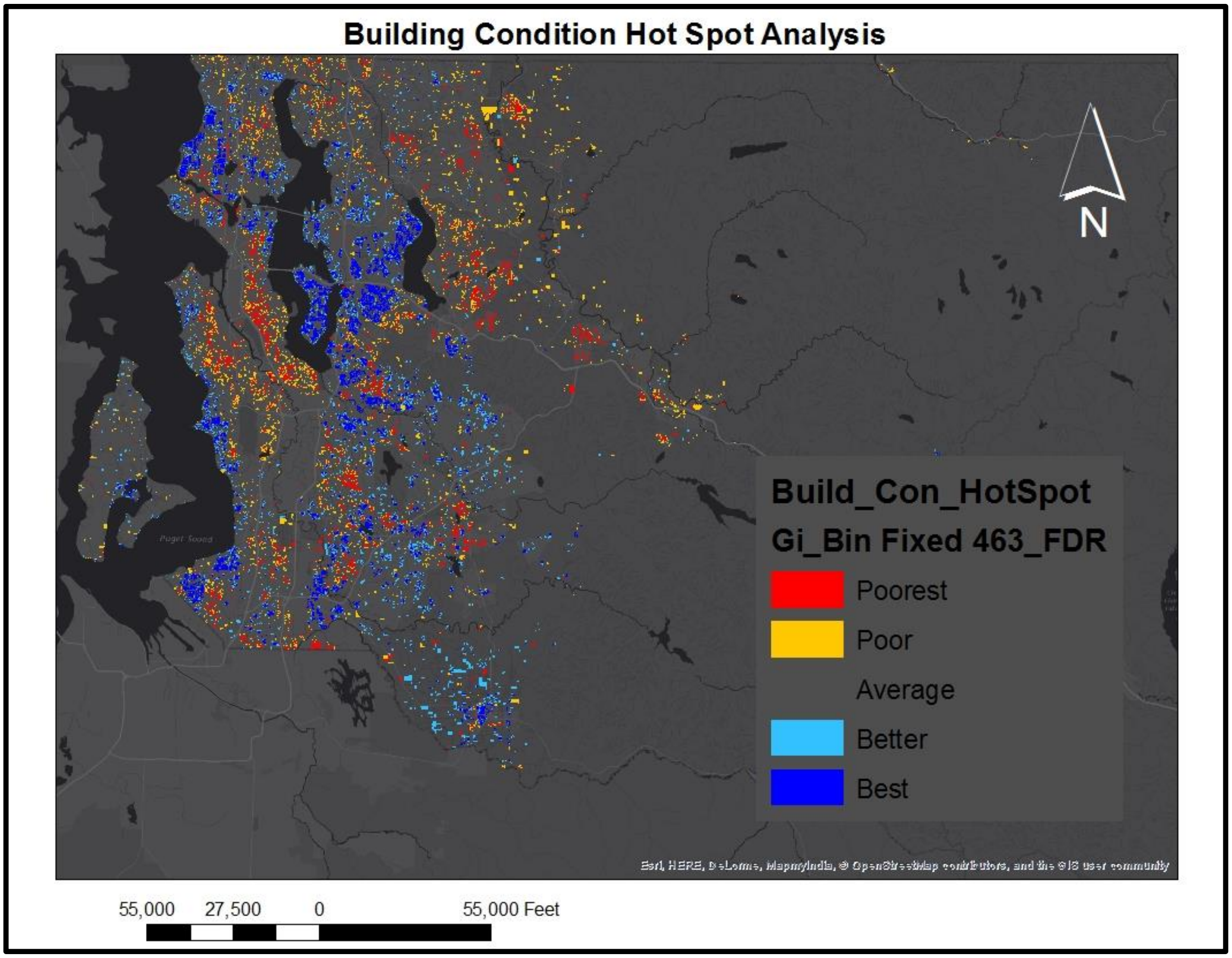


Figure 5.4: Building Condition Hot Spot Analysis

The hotspot analysis could be overlaid in the future with other boundaries to better understand how the factors interact with different jurisdictions, neighborhoods or municipalities (see Figure 5.5 for an example).

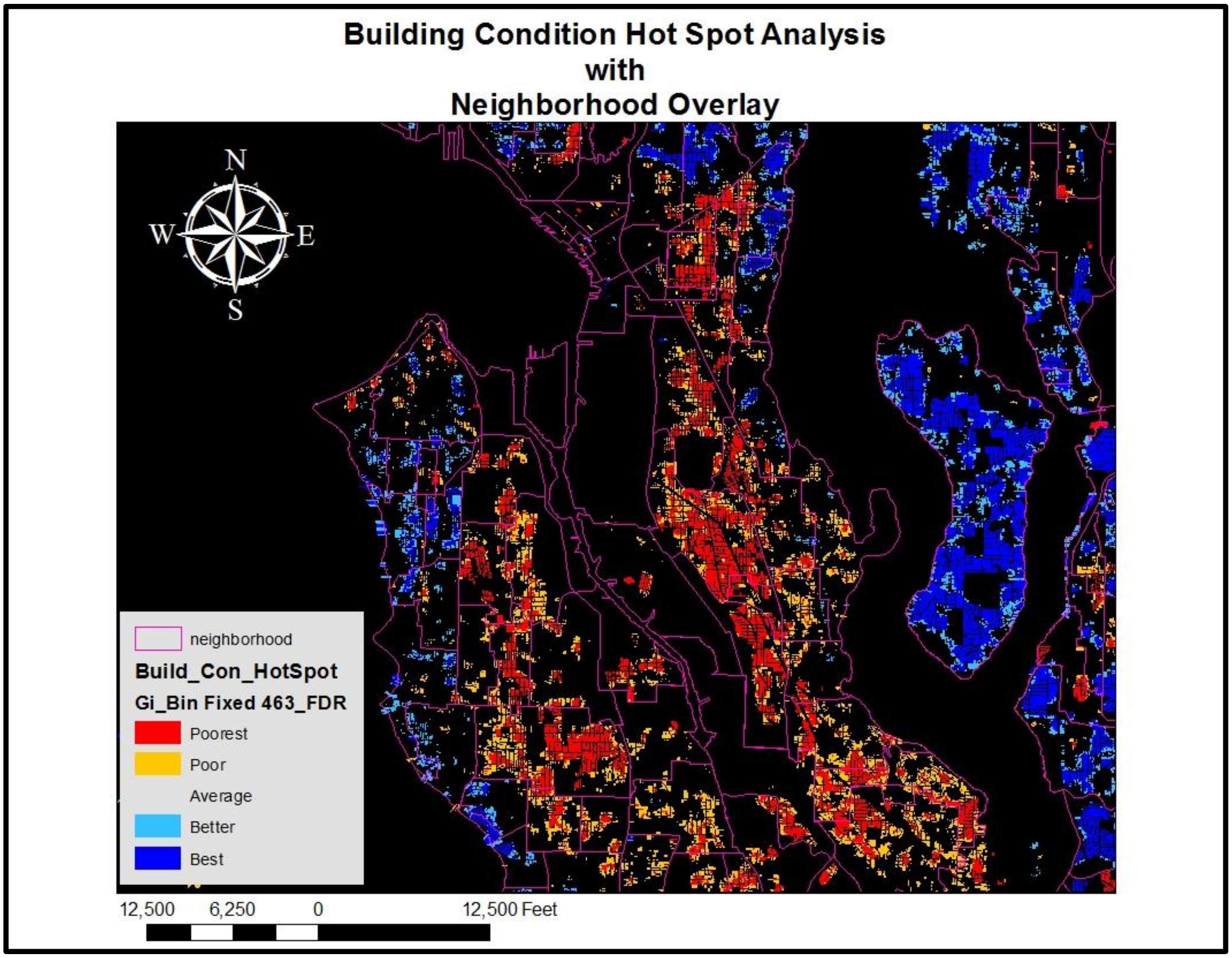


Figure 5.5: Building Condition Hot Spot Analysis with Neighborhood Overlay

As discussed, the results of our indices are generally consistent with what is commonly known about certain areas of King County. The Final Heat Vulnerability Index illustrates many of the census tracts that are classified as "Very High" are already known to King County as being high risk, such as the Lower Duwamish area, and the cities of Auburn-Kent. Similarly, the census tracts that are commonly known to be of less concern, such as Mercer Island, appear as "Very Low" or "Low". Our indices can be used as stand-alone elements or combined for multi-directional analysis. Using a well-known index methodology has allowed for geographies in King County to be meaningfully compared based on multiple datasets with differing units of measure, and will pave the way for replication as other variables are explored.

The web application that has been created provides a useful and flexible way for multiple parties to collaborate and contribute to the overall effort of increasing county-wide resilience to a changing climate. Using ESRI Web AppBuilder for this effort provided a platform that has extensive possibilities for future development. Web AppBuilder includes many options to analyze and display data. A slider widget has been included in the current version of the web app which provides a powerful tool for comparing and displaying multiple data layers. This visual platform can be used in a decision analysis context, as well as a communication tool to engage stakeholders.

6. Future Implementation

From the outset, this data analysis and web application has been developed with future implementation potential in mind. Representatives from King County DNRP, Public Health outreach programs, the Puget Sound Clean Air Agency have all expressed interest and intent in contributing to additions that will further identify communities of concern. While the investment of time and resources is not a small one, we understand that the stakeholders already recognize the value of creating sophisticated identification tools that can pinpoint vulnerable communities on a fine scale. The more detailed the collated information, the more efficient and precise the prevention and intervention strategies will be, ultimately saving the public, private, and civic sectors involved time and money. This project provides a prototype that serves as a motivating example of what is possible.

We recommend:

- Investigating and closing as many data gaps as possible: for example, health conditions prevalence and hospitalizations have many suppressed values for confidentiality purposes.

- Including air quality data and surface temperature analysis.

- Encouraging data research on a finer scale: we chose to represent the census tract level for our indices, but know that block or parcel level information would be more meaningful.

- Invest in developing the ability to weight variables as stakeholder knowledge of a variable’s relative importance is considered.

- Invest in developing the ability to recalculate variables for selected focal scales on demand.

- Continue to explore methods that meet the challenge of working with data of different scales and resolutions.

Incorporating these recommendations would result in an extremely timely and useful product that could be used by many organizations, and shared with other counties/states for further implementation.

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Appendix A

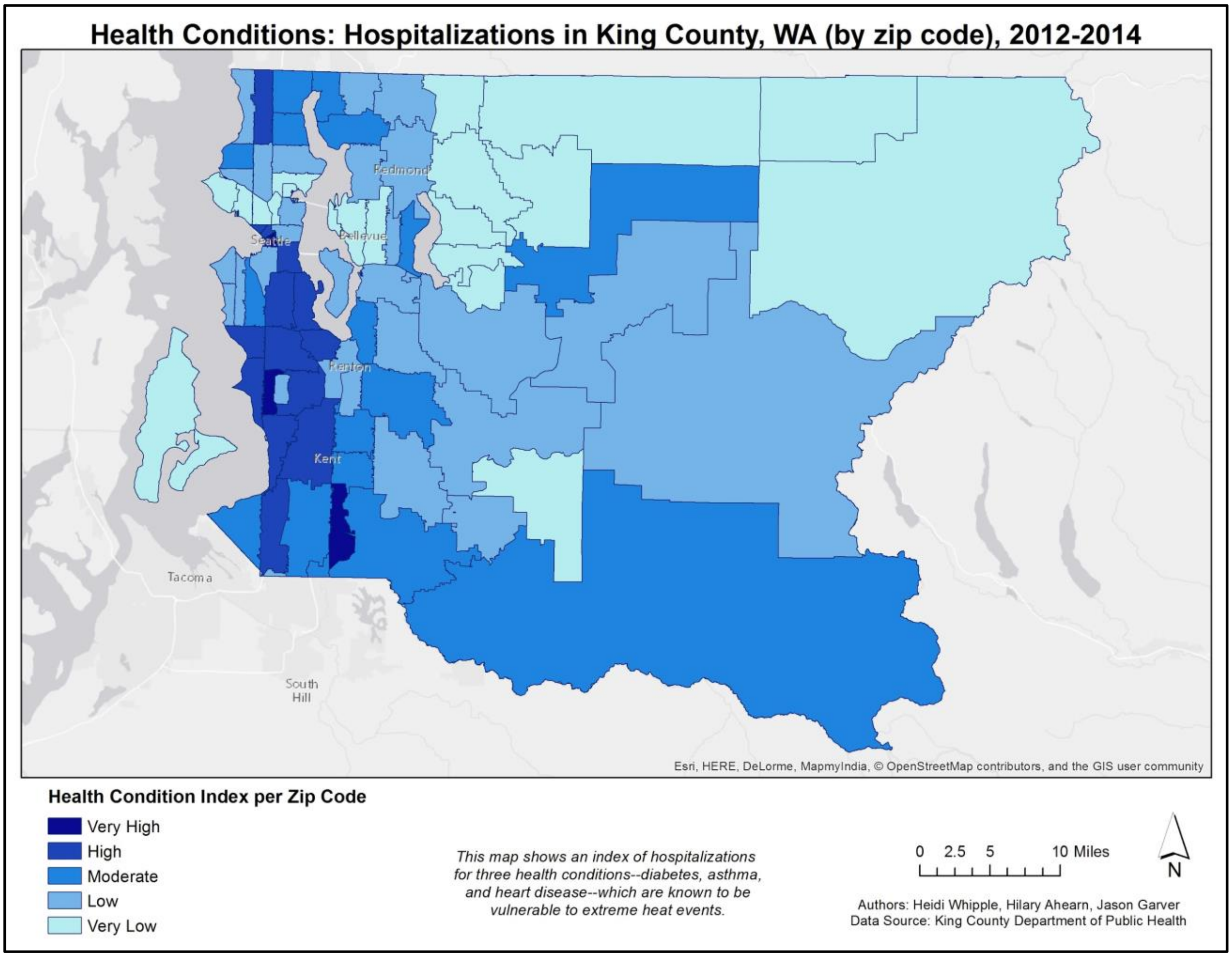

Figure A: Health Condition Hospitalizations Index by Zip Code

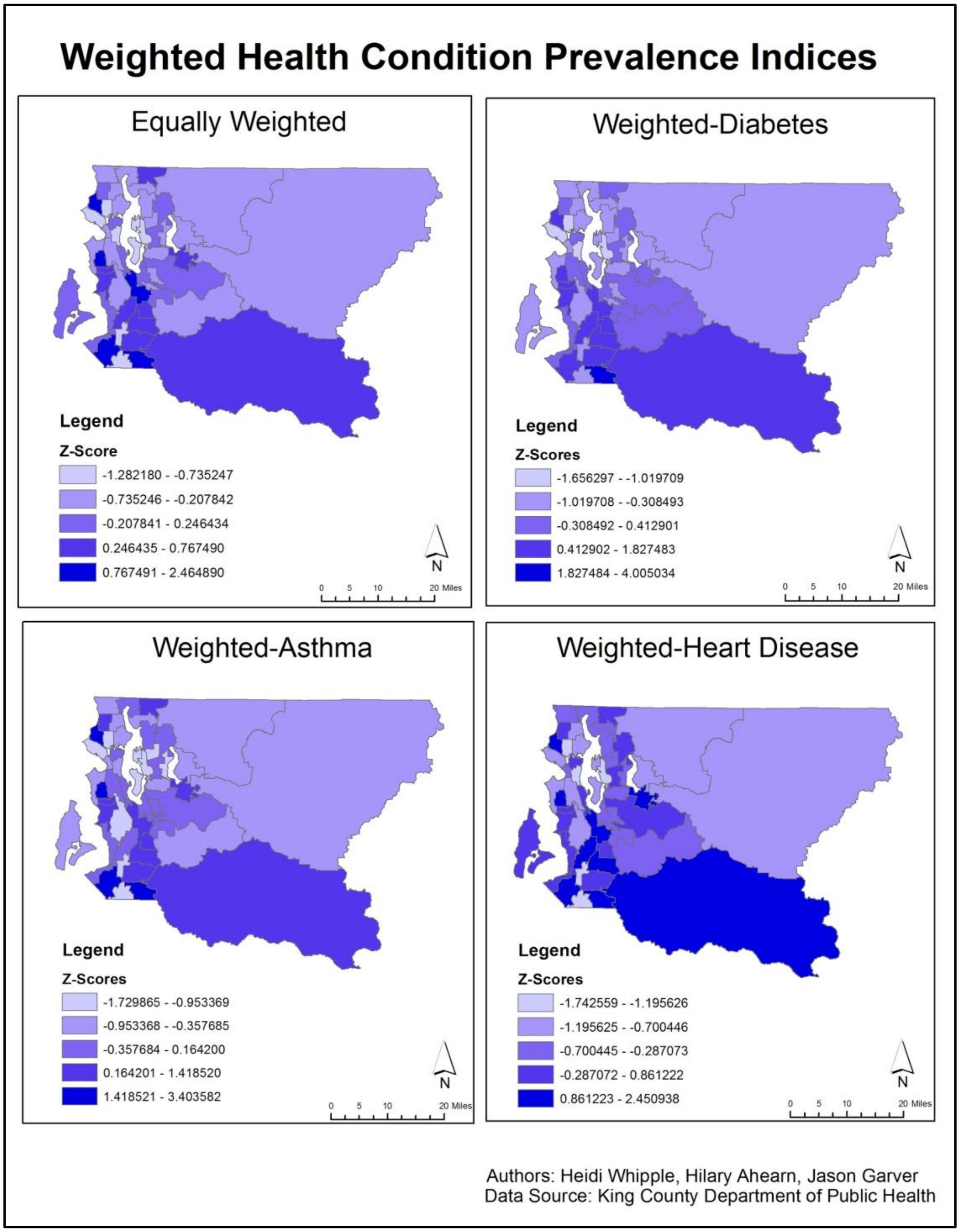

Figure B: Health Condition Prevalence Index, Weighted Examples

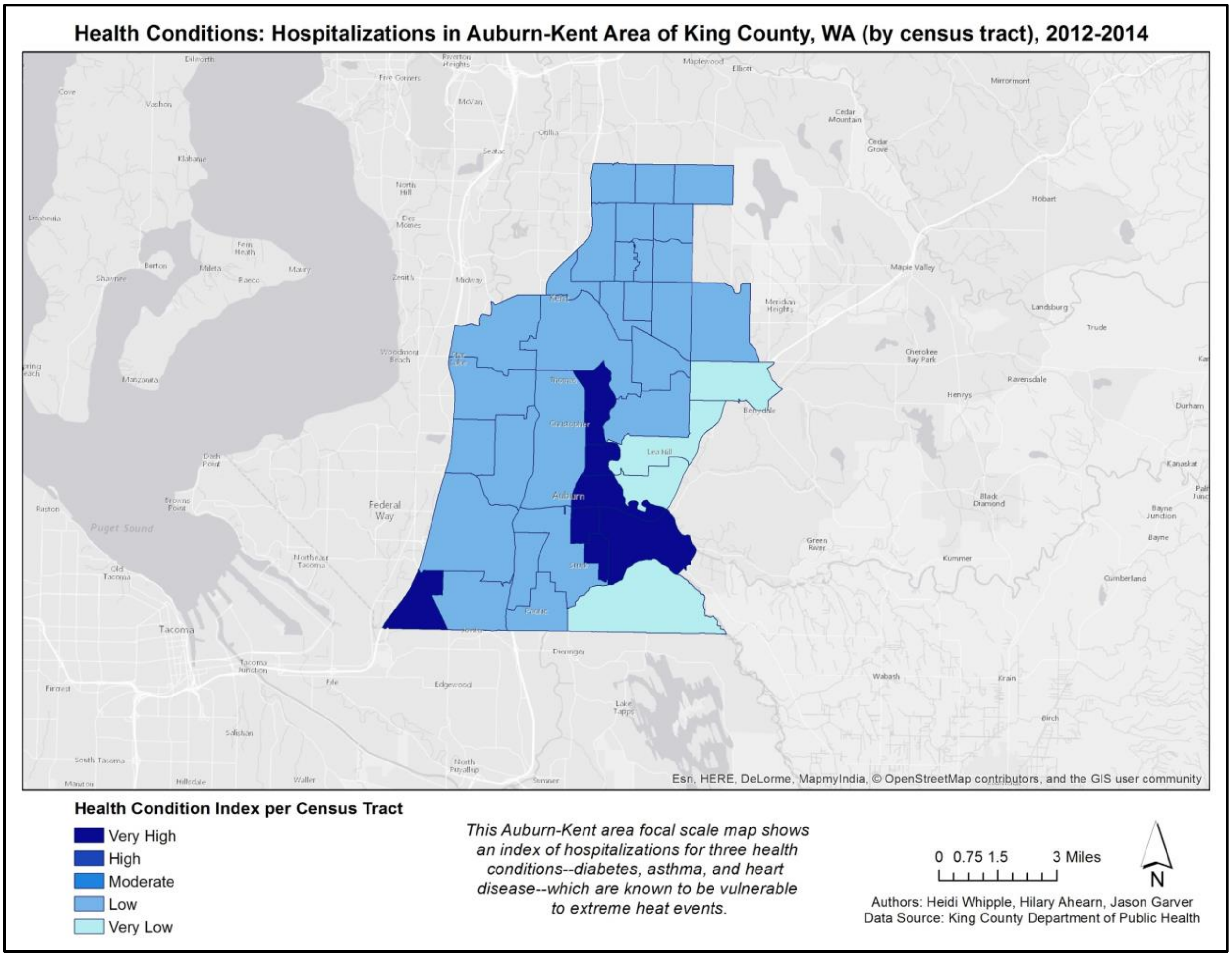

Figure C: Focal Scale Health Condition Hospitalizations Index Auburn-Kent Area

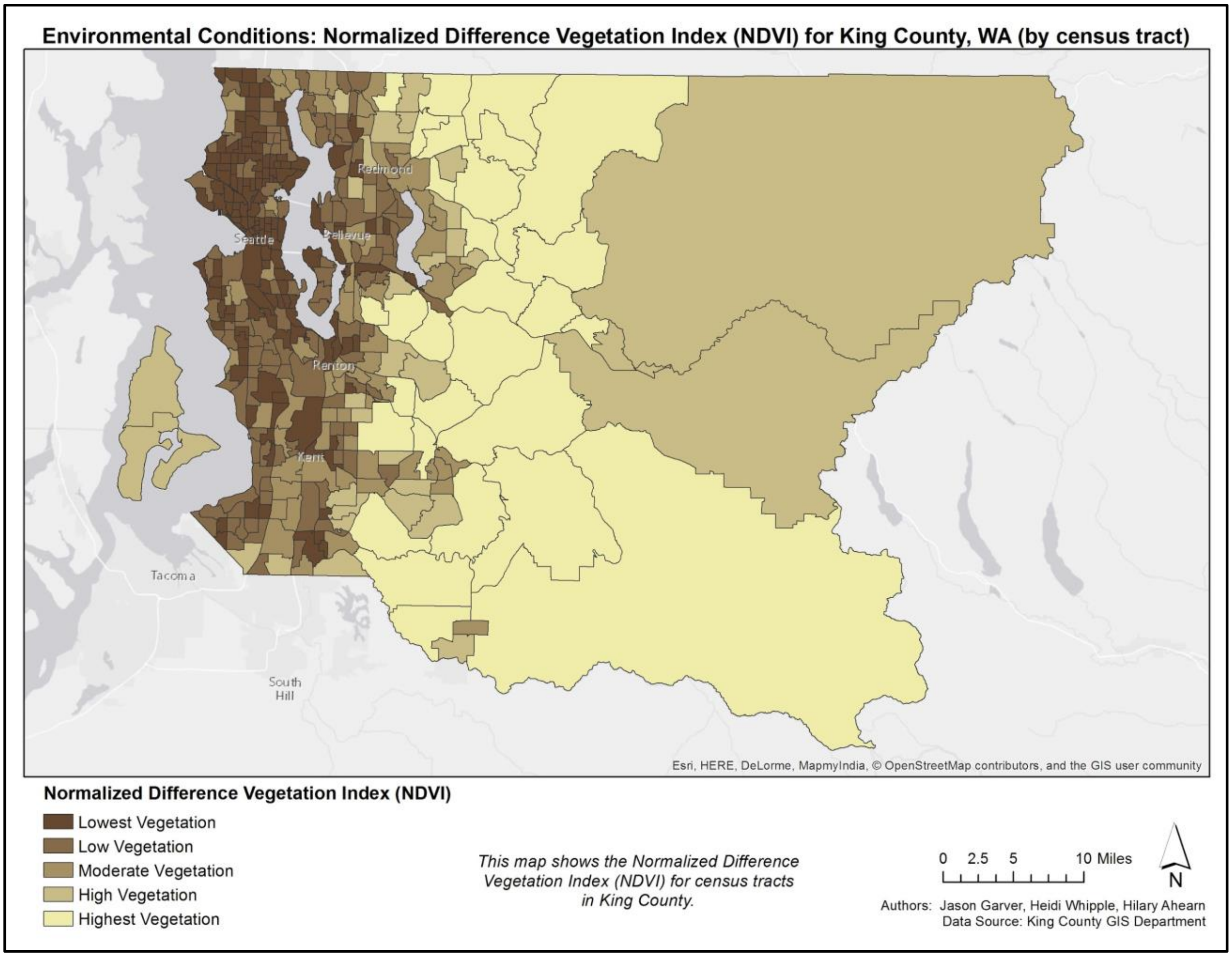

Figure D: Normalized Difference Vegetation Index (NDVI)

Extreme Heat Vulnerability - Data

Category	Name	Type	Source	Location	Size	Purpose	Description
Health	Zip Tract 122014	Table	King County Public Health, HUD USPS	https://www.huduser.gov/portal/datasets/usps crosswalk.html	749 records	Used for health utilization index, appears in web app	Table contains USPS zipcodes corresponding to King County census tracts, with associated rates for asthma, diabetes, and heart disease hospital utilization rates for rolling average years 2012-2014.
	Asthma by ZIP 2012 2014	Table	King County Public Health	see 'Health Tables' folder for original table	79 records	Raw health utilization data	Table contains zipcodes, population and corresponding counts and rates for asthma hospital visits in 2012-2014
	Diabetes by ZIP 2012 2014	Table	King County Public Health	see 'Health Tables' folder for original table	79 records	Raw health utilization data	Table contains zipcodes, population and corresponding counts and rates for diabetes hospital visits in 2012-2014
	Coronary HD by ZIP 2012 2014	Table	King County Public Health	see 'Health Tables' folder for original table	79 records	Raw health utilization data	Table contains zipcodes, population and corresponding counts and rates for coronary heart disease hospital visits in 2012-2014
	AsthmaAdults Prevalence	Table	King County Public Health	http://www.kingcounty.gov/healthservices/health/data/indicators.aspx	48 records	Raw data used for health condition prevalence index	Table contains King County Health Reporting Areas (HRA) with corresponding percentages of asthma prevalence in adults
	DiabetesAdults Prevalence	Table	King County Public Health	http://www.kingcounty.gov/healthservices/health/data/indicators.aspx	48 records	Raw data used for health condition prevalence index	Table contains King County Health Reporting Areas (HRA) with corresponding percentages of diabetes prevalence in adults
	CoronaryHeartDis Prevalence	Table	King County Public Health	http://www.kingcounty.gov/healthservices/health/data/indicators.aspx	48 records	Raw data used for health condition prevalence index	Table contains King County Health Reporting Areas (HRA) with corresponding percentages of heart disease prevalence in adults
	tracts10 shore	Shapefile	King County GIS Data Portal	http://www5.kingcounty.gov/gisdataportal/	n/a	census tract shapefile	American Census Survey - King County census tracts
	zipcodes kingcounty	Shapefile	King County GIS Data Portal; clipped by group	http://www5.kingcounty.gov/gisdataportal/	73 records	zipcodes shapefile	Zipcodes clipped to tracts10 shore
	Hospital Utilization (by census tract) (FinalUtilizIndex byTract)	Shapefile	UW GIS Grad Group - Ahearn, Whipple, Garver	See geodatabase	398 records	Published Layer	Index of mean z-scores by census tract for hospital utilization data for diabetes, asthma, and heart disease
	Hospital Utilization (by zip code) (FinalUtilizIndex byZip)	Shapefile	UW GIS Grad Group - Ahearn, Whipple, Garver	See geodatabase	109 records	Published Layer	Index of mean z-scores by zip code for hospital utilization data for diabetes, asthma, and heart disease
	Health Condition Prevalence (FinalPrevalenceIndex)	Shapefile	UW GIS Grad Group - Ahearn, Whipple, Garver	See geodatabase	48 records	Published Layer	Index of mean z-scores by Health Reporting Area for prevalence of diabetes, asthma, and heart disease
	Hospital Utilization (Focal Scale) (FinalUtilizIndex FocalScale)	Shapefile	UW GIS Grad Group - Ahearn, Whipple, Garver	See geodatabase	73 records	Published Layer	Index of mean z-scores by census tract for hospital utilization data for diabetes, asthma, and heart disease at a smaller focal scale (Lower Duwamish area)
Demographics	King County Demographics	Shapefile/Map Service	King County - Harkeerat K[illegible]	See geodatabase	5MB	Appears in web app	English profieciency, people of color, and household income
	USA Population 65 and Over Population	Map Service/ Polygon	AtlasPublisher	ArcGIS Online	unknown	Appears in web app	"This map shows the percentage of the population that is age 65 years and over in the U.S., by state, county, tract and block group. The data shown is from the U.S. Census Bureau's SF1 and TIGER data sets for 2010. The map is built between the scales of 1:73m and 1:36k, and switches from state, to county, to tract, to block group data as the map zooms in."
	ESJDemographicsIndex_KingCounty	Shapefile	UW GIS Grad Group - Ahearn, Whipple, Garver	See geodatabase	n/a	Appears in web app	Combines three demographic characteristics with common scoring: English profieciency, people of color, and household income
Environment	RESBLDG EXTR	Table	King County Assessor's Office	http://www5.kingcounty.gov/sdc/Metadata.aspx?Layer=resbldg extr	509, 435 records	Raw data for environmental index	Residential Building Characteristics - King County
	COMMBLDG EXTR	Table	King County Assessor's Office	http://www5.kingcounty.gov/sdc/Metadata.aspx?Layer=commbldg extr	n/a	Raw data for environmental index	Commercial Building Characteristics - King County
	Normalized Difference Vegetation Index (NDVI)	Raster	Ken Rauscher - King County GIS	See geodatabase	39MB	Raw data for environmental index	NDVI - King County
	2009 Impervious/Impacted Surface Interpretation	Raster	King County GIS	http://www.kingcounty.gov/services/gis/GISData/metadata/Landcover_data.aspx#ImperviousSurfaceUpdate	80GB	Raw data for environmental index	"Two-foot resolution, multi-source interpretation of impervious/impacted surface for King County and small portions of Snohomish and Pierce Counties. Basis is 2009 Color Infrared 1-foot imagery with significant enhancements from various vintages of building footprints, street networks, and other ancillary data from cities and agencies. Represents a current (to 2009) impervious surface interpretation."
	ImperviousSurface Final	Shapefile	UW GIS Grad Group - Ahearn, Whipple, Garver	See geodatabase	n/a	Appears in web app	Vulnerable census tracts per impervious surface data
	NDVI Final	Shapefile	UW GIS Grad Group - Ahearn, Whipple, Garver	See geodatabase	n/a	Appears in web app	Vulnerable census tracts per selected residential building characteristcs
	BuildingCharacteristic Final	Shapefile	UW GIS Grad Group - Ahearn, Whipple, Garver	See geodatabase	n/a	Appears in web app	Vulnerable census tracts per selected commercial building characteristcs
	EnvironmentalIndex Final	Shapefile	UW GIS Grad Group - Ahearn, Whipple, Garver	See geodatabase	n/a	Appears in web app	Environmental Index combining impervious, NDVI, and building characteristic data with common scoring

Table 1.2: Data Sources