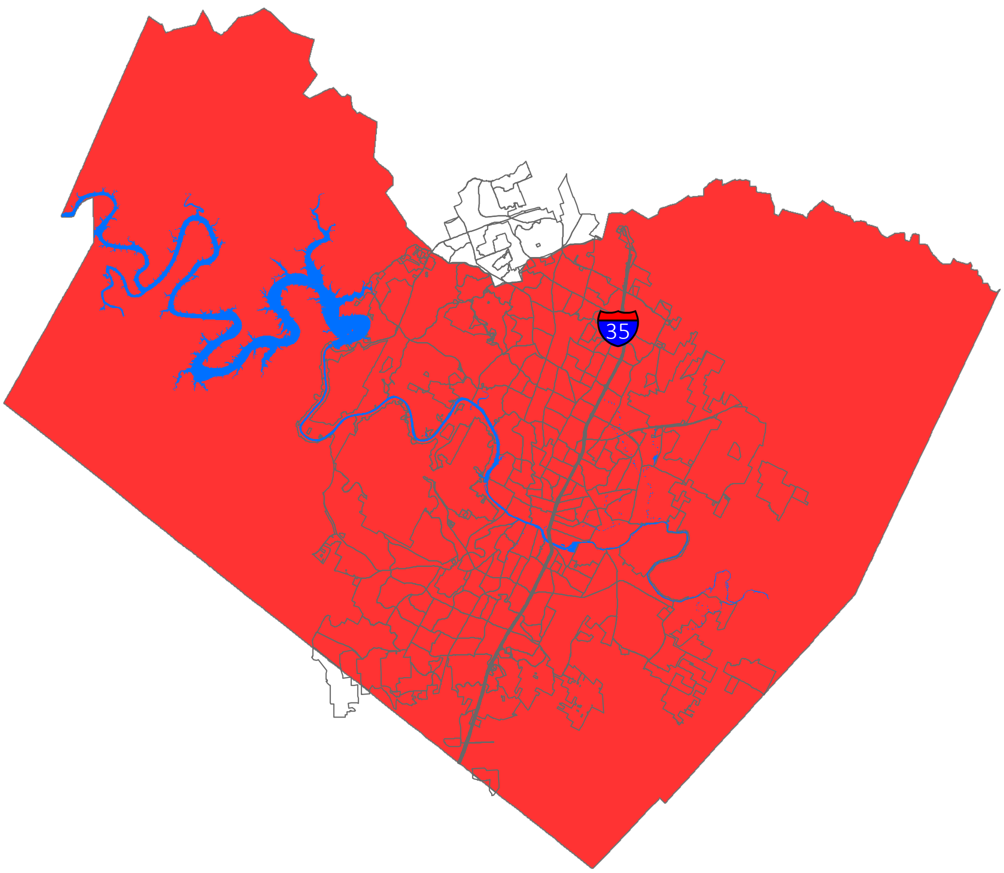
Food Insecurity in the City of Austin: A GIS Analysis of Structural Indicators



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Executive Summary

Food Insecurity is a term that is widely used to describe a population's ability to access food and their relative degree of hunger. Although an internationally recognized concept, the definition of food security widely varies. A commonly accepted definition, offered by the World Health Organization (WHO), describes food insecurity "when all people at all times have access to sufficient, safe and nutritious food to maintain a healthy and active life." The different factors that contribute to food insecurity, many of which are both social and structural issues, are widely agreed upon. Many of these factors, described in this study as structural indicators, are closely examined to determine the extent to which they impact food insecurity rates. The purpose of this paper is to map food insecurity rates at a small geographical level and conduct geospatial analysis in order to determine geographic areas within the City of Austin that are experiencing high rates of food insecurity as well as high rates of structural indicators. Additionally, this paper will explore whether limited access to food retail, defined as major grocery stores, has an impact on food insecurity. The majority of the data was contributed by *Feeding America,* which they compiled and adapted based on the American Community Survey five-year estimates. All data is mapped at the census tract level. The most vulnerable areas in Austin, referred to here as the focus area, has been identified based on a combination of two geospatial assessments. Results indicate that unemployment and poverty rates have the largest and most significant impact on food insecurity and areas with greatest distance from a major grocery store are also areas with the lowest vehicle ownership rates. Results from this study align with previous research on the subject, while also offer opportunities for further analysis that may include additional indicators for a deeper understanding of food insecurity in Austin. The intention of this study is to advise policy makers and planners for targeted outreach, future feasibility studies and potential policy interventions in the most high needs and vulnerable areas in the city.

Introduction

Food Insecurity

Food insecurity is internationally recognized with "broad agreement over the general concept," according to the UN Food and Agriculture Organization (FAO) but there are a wide variety of definitions and terms across the globe used to describe the problem of food access.[1] Furthermore, there lack "consistent and comparable" measurements of food insecurity. The US and Canada currently offer the worlds best examples of relatively consistent and reliable data collection on household experiences of food insecurity using household surveys.[2] In 1996, the World Food Summit developed a definition of food security that is widely recognized though not exclusively used today. The World Health Organization (WHO) defines food security "when all people at all times have access to sufficient, safe, nutritious food to maintain a healthy and active life," including both physical and economic use, availability and access to food.[3] In the US, the United States Department of Agriculture (USDA) has focused food security issues around access to food, diet variations and changes in food intake due to problems or limitations.

It is widely recognized and consistently cited in literature that food insecurity is largely the result of poverty and limited access to affordable healthy food, which simultaneously leads to obesity and other diet-related diseases. Furthermore, obesity is 50% more likely in occur poor areas. The 2000 census found that 79% of Americans live in urban settings and that urban policy makers have overlooked food systems issues in the last several decades. Urban agriculture contributes minimally to the food supply and yet urban populations are the "largest market for agricultural products."[4] The abundance of high calorie, cheap food and absence of nutritious foods create this dichotomy of issues.[5] Policy makers have been slow to address the structural drivers of food insecurity, such as income, cost of living, employment, and zoning as well as "potential levers", possibly because these issues are cross-sectional making it difficult to determine who and what exactly is responsible.[6] Yet understanding these issues is most relevant for policy makers and showing the impact of these determinants on food insecurity can strengthen the understanding of economic and policy influences.[7]

Since 1995 the USDA has monitored the severity of food insecurity in the US through annual, nationally representative surveys conducted by the Economic Research Service (ERS). While over 20 years of data has been collected, the USDA altered the way they define and describe food insecurity in 2005 and therefore, only data from then on can be accurately compared.[8] Data on food security is compiled by ERS using a supplemental survey to the monthly Current Population Survey (CPS) (**see Appendix A)**. The survey asks households members to answer a series of questions (**Appendix B**) about experiences and behaviors that indicate the degree of food security. Food security status of each household is determined based on the number of food-insecure conditions reported in the survey.[9] It is common for charitable organizations to measure food insecurity, inherently excluding all individuals who do not seek charitable food assistance but do experience food insecure conditions.[10] While "experiences and behaviors" reported in the ERS survey are extremely subjective, consistent and representative monitoring of food security provides a strong baseline for further analysis.

Although limited, there have been several studies measuring the impact of food access on food insecurity. Researchers cite that the built environment plays a significant role in understanding these issues and many studies have found that low-income areas lack adequate grocery stores. Additionally, there is also evidence showing that people tend to make healthier decisions about food when given the option, making the issue of food access both economic and geographic.[11]

Background Research

This analysis was guided by a series of studies conducted in the US using GIS methods to identify geographic areas with inadequate food access focusing on geographic accessibility. Leclair and Aksan address the need to strategically place food assets in the highest needs areas citing the correlation between poverty and food access. They focus their research in Bridgeport, Connecticut using GIS methods to determine food availability. These researchers investigate the price-distance relationship, which underscores the belief that people can access better quality food at a lower price but tend to require longer travel times and other associated costs that may outweigh the benefits, resulting in choosing unhealthier options. They create maps to locate food retailers at the zip code level, which in this area provides a more accurate scale of analysis do to little income variation by zip code. They use a 1/2 mile buffer around grocery stores and 1/8 mile around smaller stores, recognizing that including smaller stores may not provide an accurate account of healthy food access due to their inability to identify what is sold in each of these locations. Additionally, they overlay the study area with fast food retail outlets.[12]

Eckert and Shetty map food system accessibility in Toledo, Ohio and further quantify accessibility at the census block level. Their goal is to determine if spatial accessibility is a problem in the area. They find that socioeconomic factors are not good predictors of low fresh food access despite many census blocks having high proportions of both low-income residents and low rates of accessibility. They use GIS to map food access to fresh food locations, excluding convenience stores and membership-based stores because of low variety, higher prices and membership fees. A ¼ mile and ½ buffer are used to analyze accessibility. They use Census data for demographic information and the Network Analyst tool to determine the average distance from each household to the nearest food retail location. They use the following formula to draw census block conclusions and then overlay it with poverty data to determine the highest needs areas:

$$\frac{\textbf{\textit{Sum of distances between residential units and retailers}}}{\textbf{\textit{Total number of residential units}}} = \textbf{\textit{Mean distance to food retailers}}$$

McEntee and Agyeman focus on the general concept of a food desert, which is another term understood more conceptually than descriptively. In general, a food desert is described as “an area of relative exclusion where people experience physical and economic barriers to accessing healthy food.” Their goal is to contribute to the development of identifying food deserts by using GIS methods to study the connection between residential units and location of major grocery stores, also excluding convenience and membership stores from the data set. These researchers also cite the importance of the built environment and the negative influence of lack of healthy food options on diet. They use 500 meters (roughly 1/3 mile) as an acceptable distance for urban residents to live from a food retailer before being identified as lacking adequate access. They are careful not to measure Euclidean distance (“as the crow flies”), rather they measure accessibility using the roadways people actually travel. Their study is focused in Vermont and they use the same formula cited above to measure distance to food retail. They also look at rural food access and argue that rural census tracts with greater than a 10 mile distance from food retail are considered food deserts. Furthermore, they factor in educational attainment levels into their study, citing the strong correlation between education and poverty.[13]

Problem Statement

This study examines the relationship between structural drivers of food insecurity and measures food accessibility in the urban setting, specifically the City of Austin. Using a variety of literature, this paper incorporates both theories and methods cited in past studies. The hypotheses and supporting research questions are listed below.

Hypothesis

H_1: Poverty is the most significant indicator of food insecurity.

H_2: Access to a major grocery store is a barrier to food security in Austin.

Major Research Questions

1. Are highly food insecure census tracts clustered in any way?
    a. *Where is the clustering happening?*
    b. *Does this make sense based on anecdotal, residential knowledge?*
    c. *Is it possible that variables not included in this study can explain high food insecurity rates and/or significant variations in the model?*

2. Do the seven indicators, identified by *Feeding America,* significantly explain food insecurity?
    a. *Where are the areas that are "underperforming"?*
    b. *Is it possible that variables not included in this study can explain high food insecurity rates and/or significant variations in the model?*

3. Which indicators have the most significant impact on food insecurity?
    a. *Do these indicators have the highest impact in the highest food insecure areas?*

4. What is the relationship between average distance to the closest grocery store and vehicle ownership rates in each census tract?
    a. *If these rates are not included in the model, how can they be interpreted?*

Methodology

The purpose of this paper is to enhance future food systems planning based on an in-depth analysis of the most vulnerable areas within the City of Austin (COA). The use of GIS allows for a statistical and geographical analysis of US census data at the census tract level, which is currently the most reliable and available set of data describing these issues. All maps are projected using the NAD 1983 Stateplane Central Texas FIPS 4203 coordinated projection system and addresses are geocoded using the roadways layer from the COA open data portal.

The USDA estimates annual food insecurity rates at the national level and state level rates based on three-year estimates from the American Community Survey (ACS) to control for large margins of error at that scale. The data on food insecurity used in this report is from *Feeding America's Map the Meal Gap* report **(see Appendix C)** where they calculate food insecurity rates at county level using five-year ACS data on structural indicators that they have identified as most severely impacting food insecurity. Areas such as Austin had enough data to validate a sub-county estimate of food insecurity rates, which is used in this report, specifically at the census tract level. This study analyzes six indicators:

home ownership rates, poverty rate, unemployment rate, median family income and the African American and Latino population to determine the strength of *Feeding America's* model to describe and predict food insecurity in Austin. There are other variables cited across literature known to have an impact on food insecurity such as educational attainment and vehicle ownership, however, the scope of this study focuses on only the six variables suggested by *Feeding America*. Limitations to this restriction and opportunities for future analysis are suggested in the discussions and conclusions section of this report.

Geospatial analysis was used to determine a focus area for future outreach in food systems planning. Hot spot analysis, ordinary least squares and geographic weighted regression were used to provide a robust analysis of food insecurity and to identify a geographical focus area. While all models resulted in significant outputs, there are still limitations to the data set used based on anecdotal knowledge of the study area. Further investigation and modifications to the data set are recommended prior to determining the ideal target area.

Dependent Variable: Food insecurity, *Feeding America* census tract estimates

Independent Variables:

1. Home ownership rate
2. Poverty rate
3. Unemployment rate
4. Median family income
5. African American population
6. Latino population

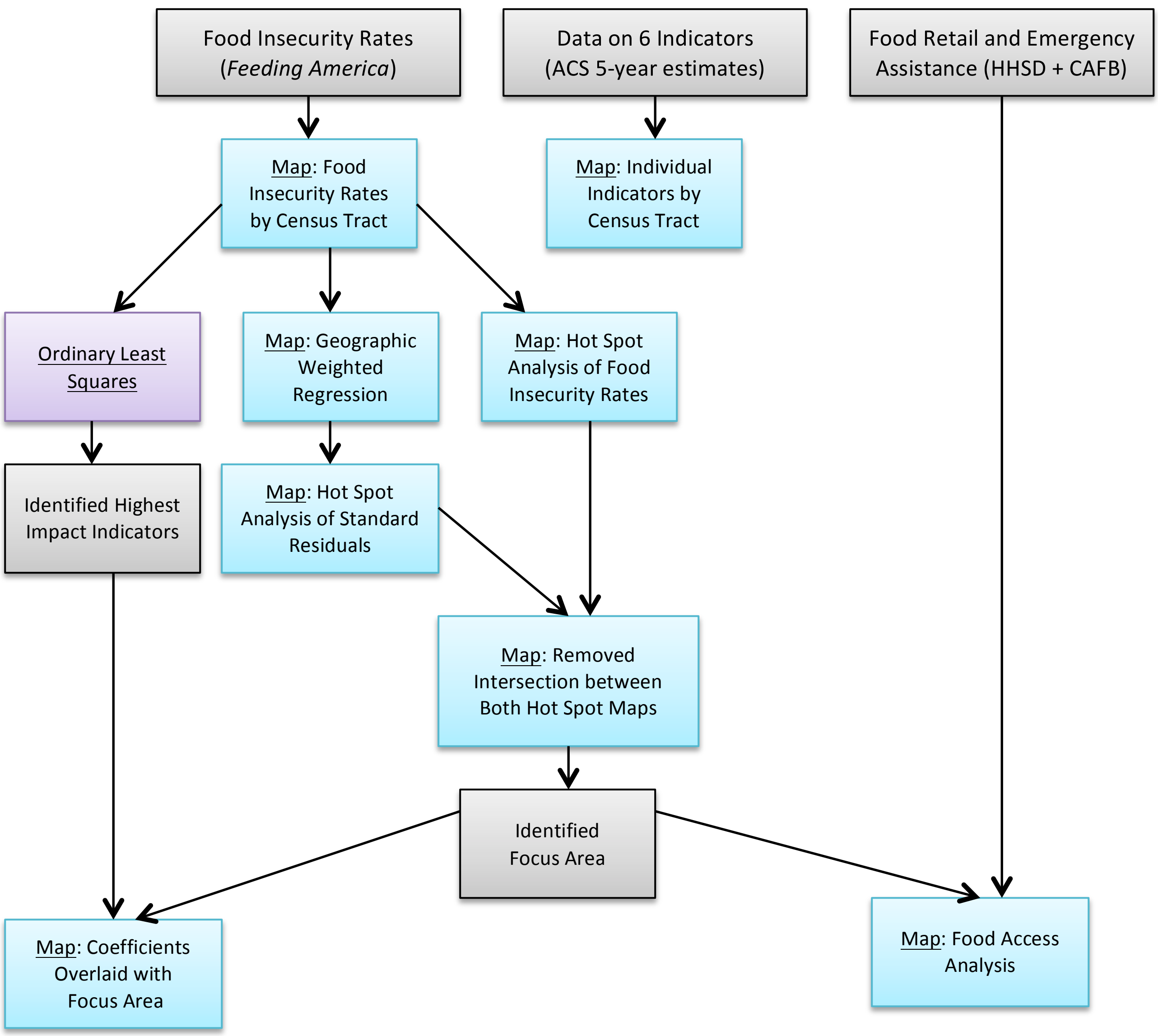
The Health and Human Services Department (HHSD) provided data on all food retailers holding food permits in Austin. This data was subjectively broken down to identify the major grocery stores and fast food retail outlets. Research consistently suggests that major grocery chain stores be used to determine access to reliable, consistent and fresh food. They have more overall opportunity compared to smaller stores or convenience stores, which have less variety, quality food and fresh produce as well as consistency higher prices. Membership stores, such as Costco, were excluded from the data set due to the cost of membership required to shop at those stores, which is a barrier to entry for certain income levels.[14] In 2011, the Sustainable Food Center published a report titled the "Central Texas Foodshed Assessment," using both qualitative and quantitative data to describe the food landscape in Central Texas. The author of this report categorized food retailers based on the Texas Nutrition Environments Assessment **(Appendix D)** and identified full service grocery stores as major chain stores, consistent with the literature that shows that chain stores tend to be less expensive and have more variety.[15]

A focus area was identified based on a combination of hot spot analysis of food insecurity rates, geographic weighted regression to determine areas where the model was underperforming and another hot spot analysis of those areas to control for variables excluded form the model. Attributes of this focus area were further explored for a closer examination of the food access landscape. The network analysis tool was used to determine the service area of the major grocery stores using a quarter- and half-mile buffer, which are distances consistently cited in research as acceptable walking distances from grocery stores in an urban setting.[16] Additionally, fast food retail outlets and food pantries were added for a visual comparison of quantity and accessibility to these different types of food options. Lastly, the average one-way distance to the closest major grocery store was calculated for each census tract and compared to vehicle ownership rates for the corresponding census tracts to determine the impact of vehicle ownership on access to a grocery store. Both the buffers and one-way distances were determined using roadway networks, rather than Euclidian distance, which calculates routes "as the crow flies" and may not necessarily be feasible paths for travel in reality.

See **Appendix E** for details on data used in this report.

Figure 1 summarizes the flow from data to analysis explored in this study.

Figure 1



Maps

Preparation for creating the maps and conducting geospatial analysis included modifying boundary shapefiles and creating an address locator for geocoding point data. A description of that process is listed below.

a) Roadways
   - Added roadways shapefile (street centerlines) from COA open data[17]
   - Selected (by attribute) I-35
   - Exported data as new shapefile
b) Water
   - Added waterways (major waterways) from COA open data[18]
   - Selected (by attribute) Lake Travis and Waller Creek
   - Exported data as new shapefile
c) Address Locator
   - Used roadways shapefile to create address locator
   - Fixed all aliases with a *
   - Under geocoding options in properties, changed 'map without zones' to 'yes'

Map 1: Reference Map

- Texas shapefile from Texas Natural Resources Information System[19]
- Added Travis County under "categories" in symbology
- Travis county symbolized in red, all other counties with no color

Map 2: Food Insecurity Rates

- Added City of Austin census tracts as base map
- Added file (converted to CSV format) provided by *Feeding America*[20] of food insecurity rates (and six indicators)
- Joined COA census tracts and food insecurity CSV file based on data from a table
- Classified food insecurity rates into 8 categories
  - Formatted labels into percentages
  - Manually adjusted classifications for even, logical breaks
- Selected (by attribute) the eight census tracts with insufficient data
  - Exported data as new shapefile and added to map
  - Symbolized these census tracts with unique pattern
- Added I-35 clip and waterways clip to map

Map 3: Food Insecurity Indicators

- Copied food insecurity rates layer into new map document
- Created separate data frames for each indicator
- Added I-35 clip and waterways clip to each map
- Classified each indicator into categories
  - Formatted labels into percentages
  - Manually adjusted classifications for even, logical breaks

- Symbolized lower half with a gray scale and upper half (most severe) with a unique color ramp
- Median family income symbology was reversed showing the most severe (lower half) in color and the less severe (upper half) with a gray scale

Map 4: Hot Spot Analysis: Food Insecurity Rates

- Used hot spot analysis tool
- Used 'fixed-distance-band' but got results that did not seem accurate
- Reran hot spot analysis with 'contiguity-edges-corners' and got better results
- Added I-35 clip and waterways clip to map
- Symbolized hot spots using z-scores and p-values showing only positive (hot spots) in pink color ramp, no spots with no color and cold spots in gray scale
- Selected (by attribute) hot spots (z-scores > -1.65 and p-values < 0.1)
- Exported data and created new shapefile

Map 5: Geographic Weighted Regression (GWR)

- Added field to food insecurity rates attribute table and copied median family income data as 'double' (all other explanatory variables were double and MFI was not recognized as 'string')
- Ran ordinary least squares regression to determine global coefficients (identified coefficients with highest impact and saved results)
- Ran geographic weighted regression
- Symbolized standard residuals greater than 0.5 to represent the underperforming areas (where food insecurity rates should be lower based on the model prediction)
- Exported data and created new shapefile (standard residuals > 0.5)
- Added I-35 clip and waterways clip to the map

Map 6: Hot Spot Analysis: Standard Residuals of GWR

- Used hot spot analysis tool with 'contiguity-edges-corners'
- Added I-35 clip and waterways clip to map
- Symbolized hot spots using z-scores and p-values using same color scheme
- Selected (by attribute) hot spots (z-scores > -1.65 and p-values < 0.1)
- Exported data and created new shapefile

Map 7: Focus Area

- Created base layer of City of Austin census tracts
- Added shapefile for hot spots of food insecurity rates
- Added shapefile for hot spots of standard residuals
- Identified overlapping tracts
- Selected by attribute non-overlapping tracts within food insecurity hot spot area
- Removed hot spots of standard residuals and symbolized areas removed
- Selected (by attribute) census tracts in focus area and exported data as new shapefile
- Added I-35 clip and waterways clip to map
- Created extant indicator on larger map and added boundary road names

Map 8 and Map 9: Coefficients with Highest Impact revise to include outlines

- Created two maps showing the coefficients for unemployment rate and poverty rate by census tract (highest impact indicators revealed by OLS results)

- Used unique color ramp (same colors from individual indicator maps) to display lowest to highest coefficients
- Added I-35 clip and waterways clip to the maps
- Added colorful outline of focus area

Map 10: Focus Area: Food Access Analysis

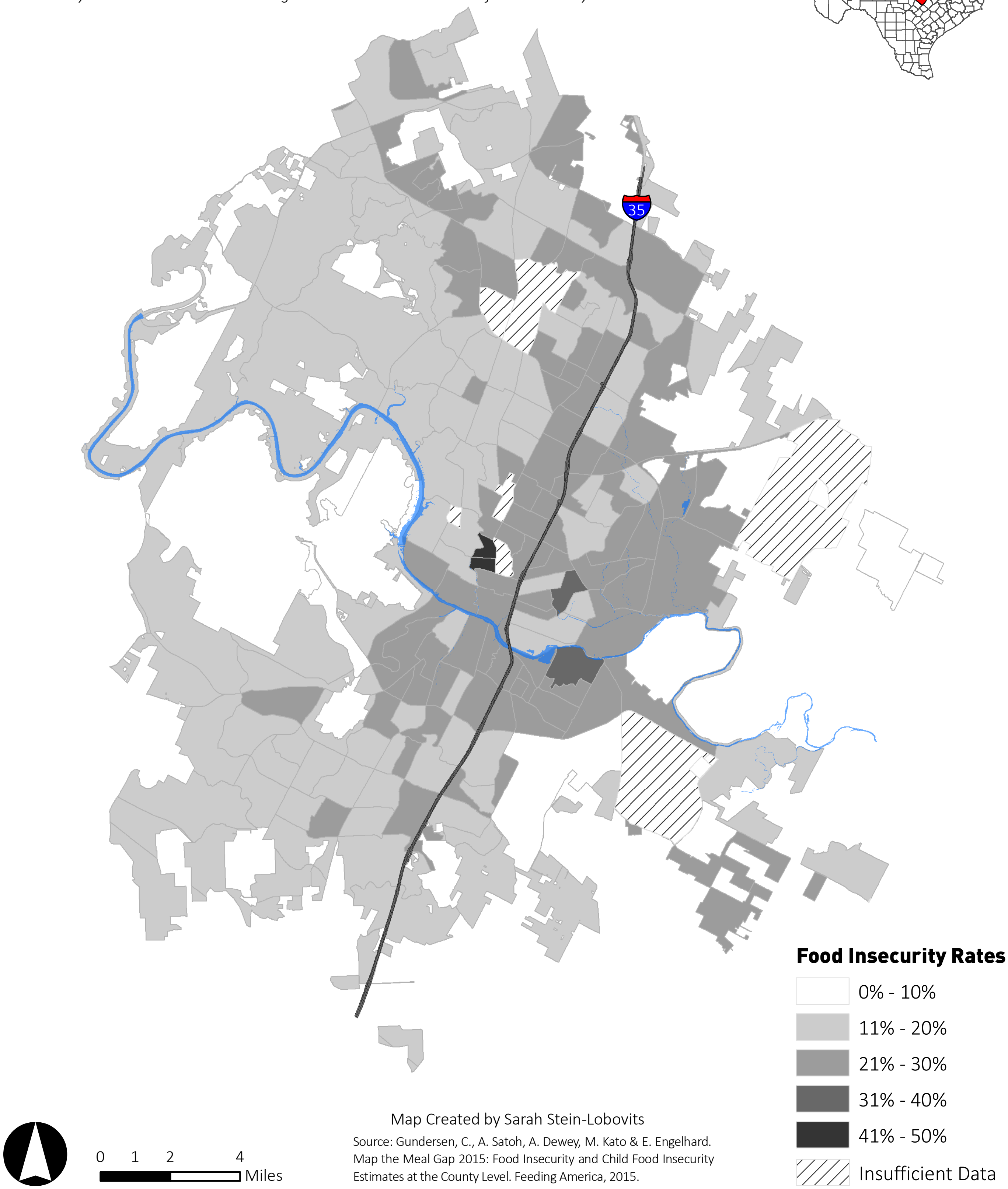
- Copied focus area: detail map into new layout and removed boundary roadways
- Added major grocery stores, fast food outlets, and food pantries CSV files[21]
- Geocoded CSV files using the address locator; re-matched addresses as necessary
- Symbolized each food outlet with different colored symbol
- Used network analyst to create service areas around the major grocery stores
    - Created 0.25 mile and 0.5 mile buffer (service area) using the incidence as miles and no u-turns allowed
    - Exported service area data as shapefile
- Added land use shapefile from the COA open data portal[22]
    - Clipped land use shapefile to focus area
    - Selected (by attributes) land use codes for residential areas
    - Exported data as shapefile
    - Converted residential shapefile from polygons to points (necessary for network analyst)
        - Arctoolbox data management tools→ features→feature to point
        - Exported points as shapefile
    - Joined residential points shapefile to census tracts
        - Join based on spatial location
        - Repeatedly selected (by attribute) each census tract and created new shapefile (to allow for analysis by tract)
- Used network analyst to determine the closest facility (facilities = grocery stores; incidences = residential points) to each incidence
    - Ran network analyst (closest facility) 24 times (24 census tracts in focus area)
    - Exported routes data as shapefile (24 total)
    - Symbolized all routes uniformly
    - Looked at statistics for 'total miles' field in attribute table (routes) for each census tract and recorded the mean distance in separate excel file for analysis
- Removed residential points shapefile (only residential polygons shown)

Findings

The following series of maps provide a visual understanding of food insecurity in Austin, geospatial analysis and the food access landscape.

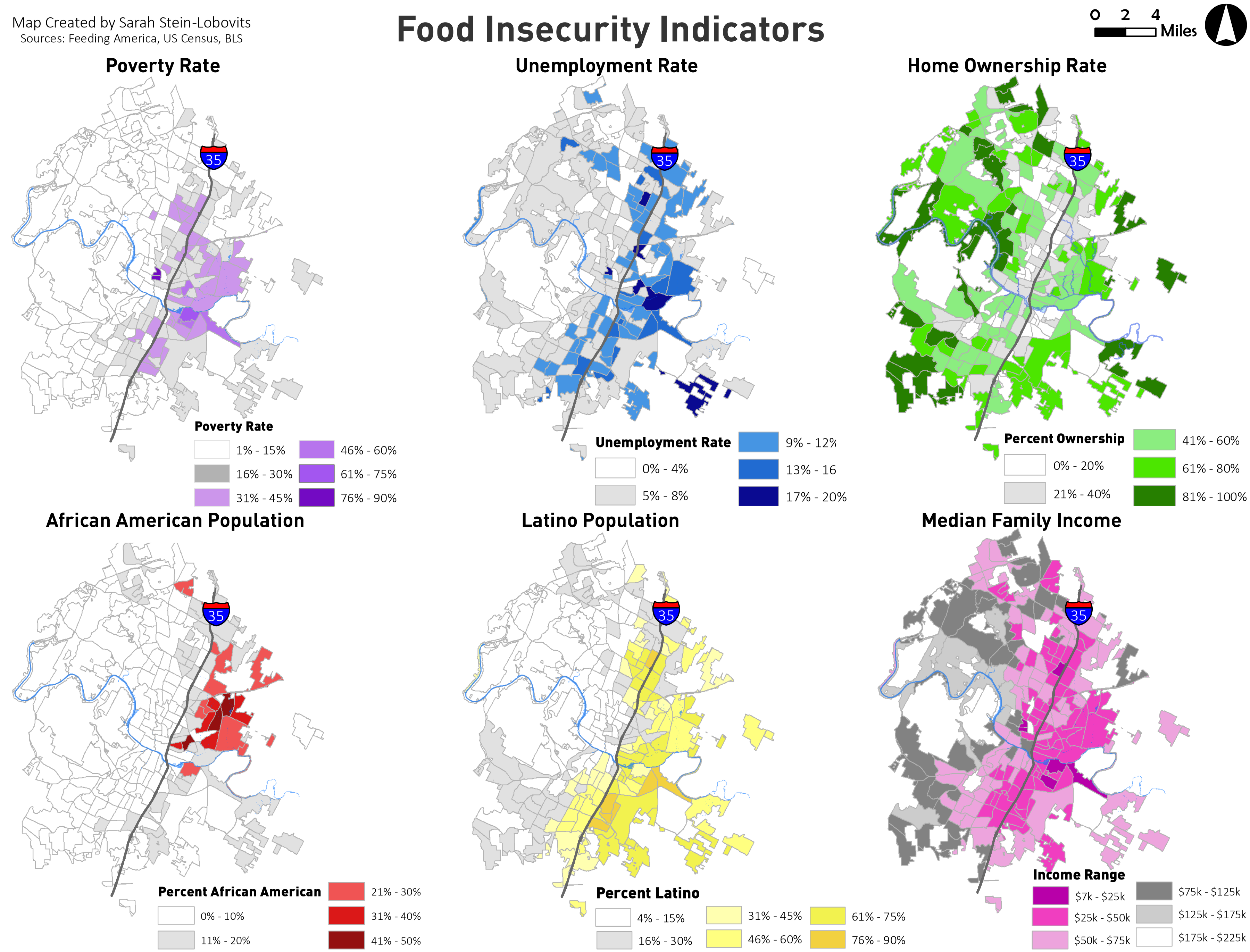
Food Insecurity Rates

Food insecurity rates were calculated by Feeding America using the USDA's estimates for national and state-level rates. They did an analysis of the relationship between the USDA's rates of food insecurity and its determinants to generate food insecurity rates by census tract. Only 8 census tracts were missing too much data to calculate food insecurity rates.



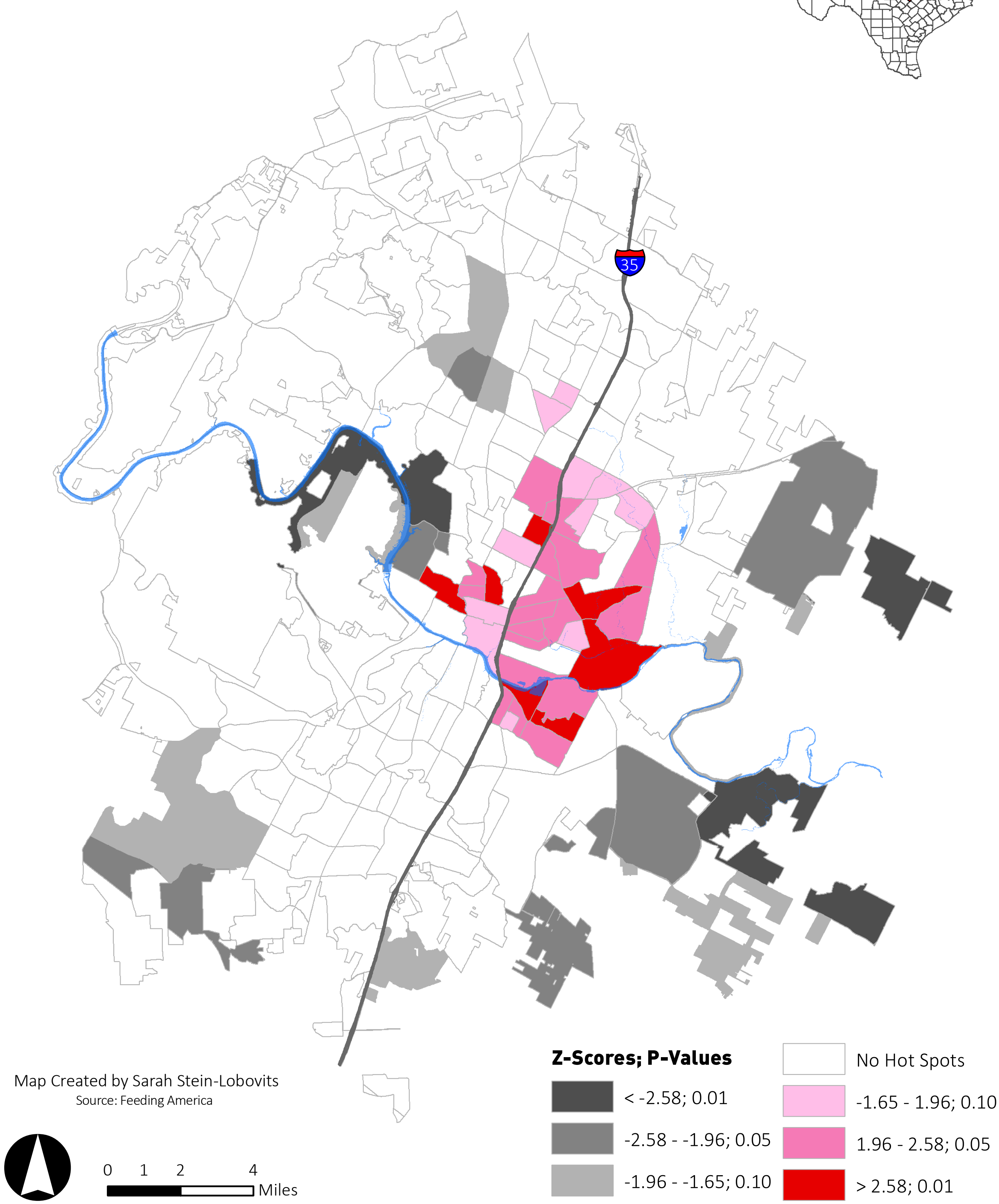
Map Created by Sarah Stein-Lobovits

Source: Gundersen, C., A. Satoh, A. Dewey, M. Kato & E. Engelhard. Map the Meal Gap 2015: Food Insecurity and Child Food Insecurity Estimates at the County Level. Feeding America, 2015.


Map Created by Sarah Stein-Lobovits
Sources: Feeding America, US Census, BLS
Food Insecurity Indicators
0 2 4 Miles
Poverty Rate
35
Poverty Rate
1% - 15%
16% - 30%
31% - 45%
46% - 60%
61% - 75%
76% - 90%
Unemployment Rate
35
Unemployment Rate
0% - 4%
5% - 8%
9% - 12%
13% - 16
17% - 20%
Home Ownership Rate
35
Percent Ownership
0% - 20%
21% - 40%
41% - 60%
61% - 80%
81% - 100%
African American Population
35
Percent African American
0% - 10%
11% - 20%
21% - 30%
31% - 40%
41% - 50%
Latino Population
35
Percent Latino
4% - 15%
16% - 30%
31% - 45%
46% - 60%
61% - 75%
76% - 90%
Median Family Income
35
Income Range
$7k - $25k
$25k - $50k
$50k - $75k
$75k - $125k
$125k - $175k
$175k - $225k

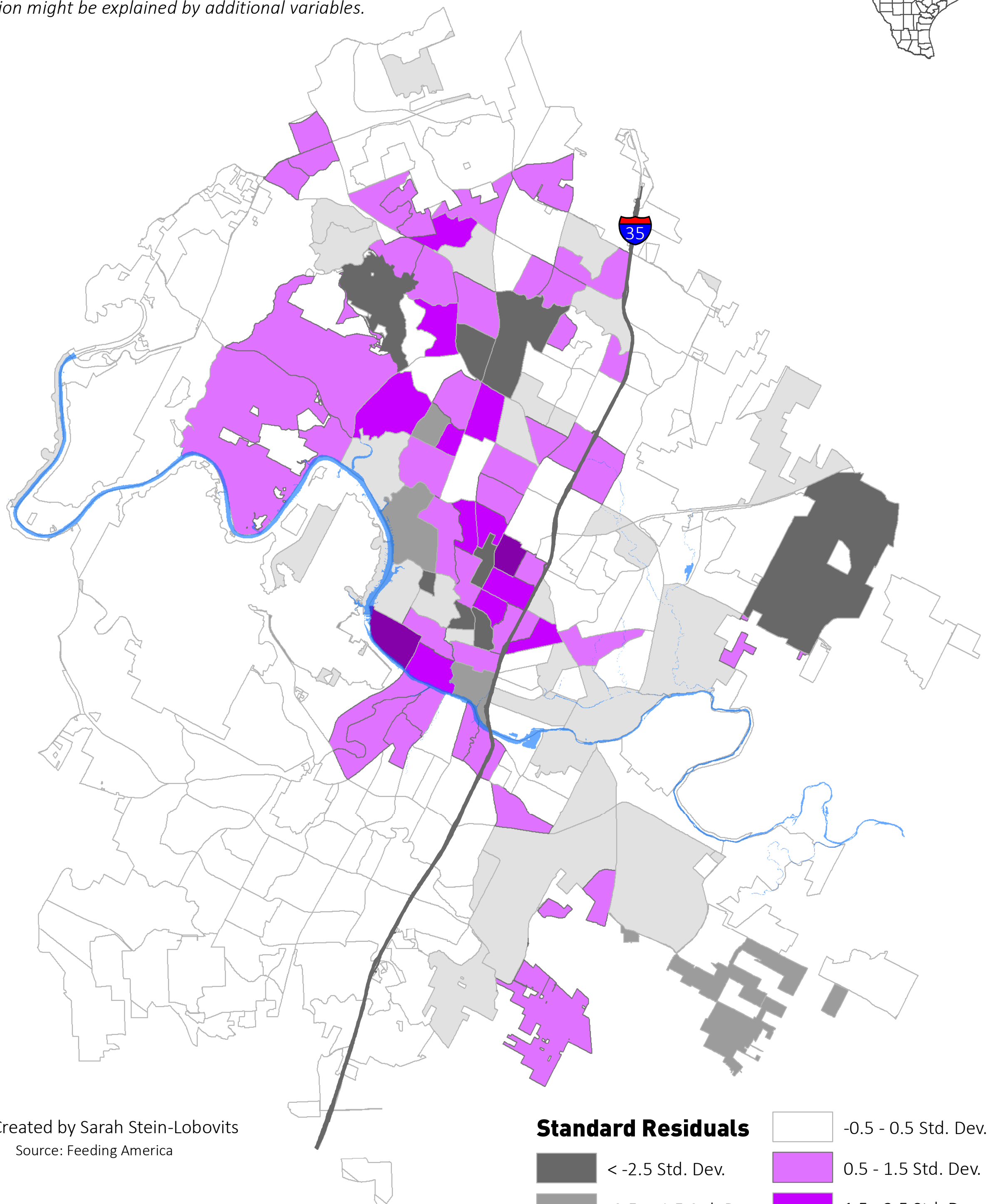
Hot Spot Analysis: Food Insecurity Rates

This map shows the locations of clusters of hot spots of food insecurity rates. Z-scores associated with p-values less than 0.05 indicate clustering of high (or low values) and with 95% confidence the clustering is not due to random chance.

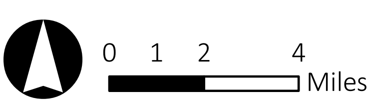


Geographic Weighted Regression
Standard Residuals

The areas with a standard deviation greater than 0.5 are census tracts that are underperforming according to the model.This means that the food insecurity rates in these census tracts should be lower than what is is actually occurring and this variation might be explained by additional variables.



Map Created by Sarah Stein-Lobovits
Source: Feeding America

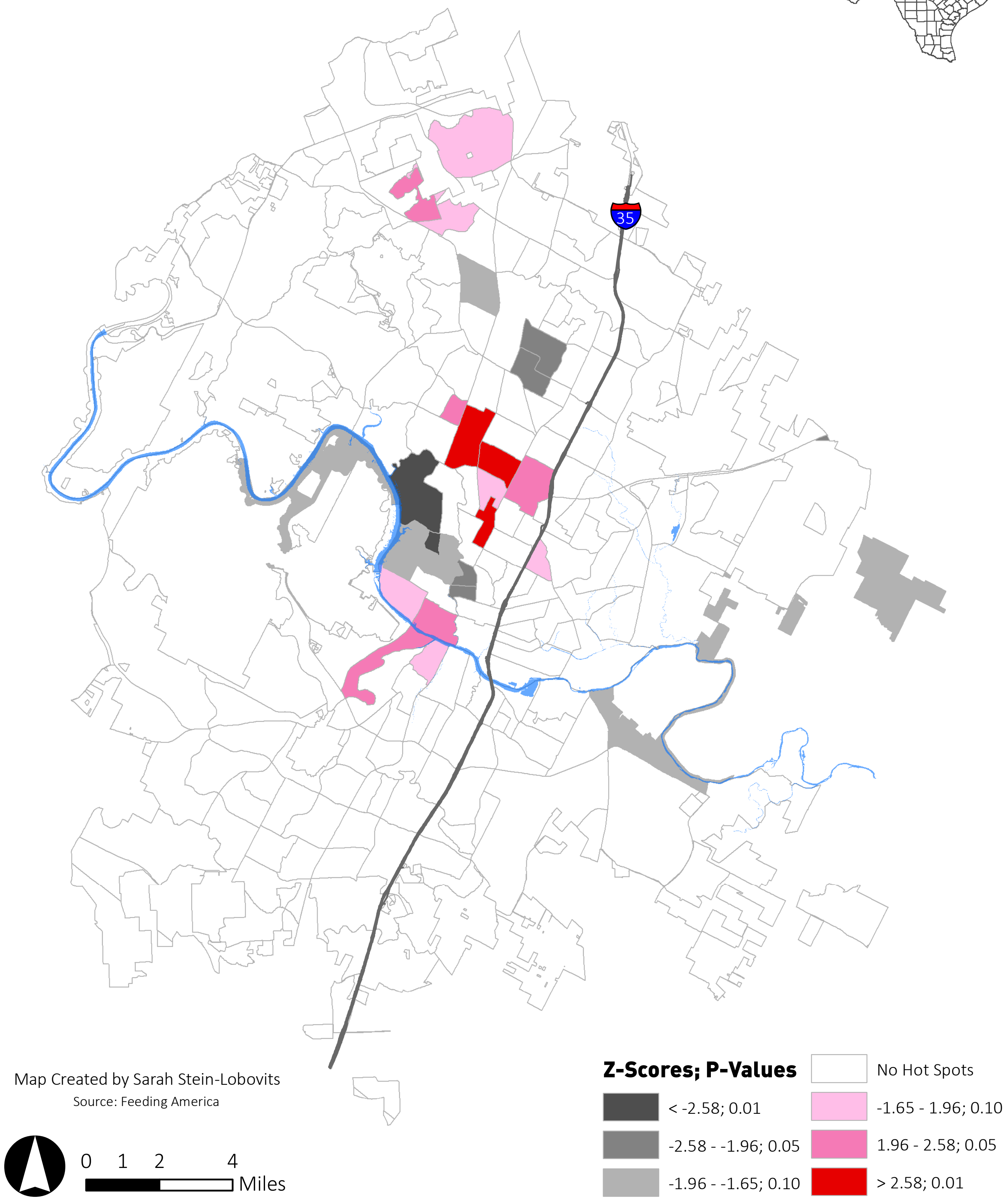


Standard Residuals

- < -2.5 Std. Dev.
- -2.5 - -1.5 Std. Dev.
- -1.5 - -0.5 Std. Dev.
- -0.5 - 0.5 Std. Dev.
- 0.5 - 1.5 Std. Dev.
- 1.5 - 2.5 Std. Dev.
- > 2.5 Std. Dev.

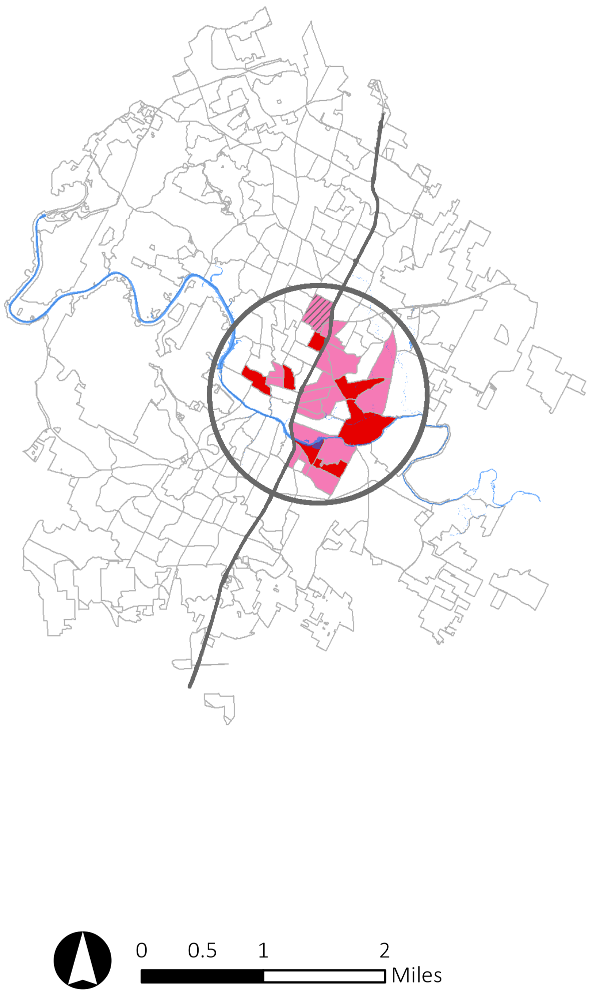
Hot Spot Analysis: Standard Residuals

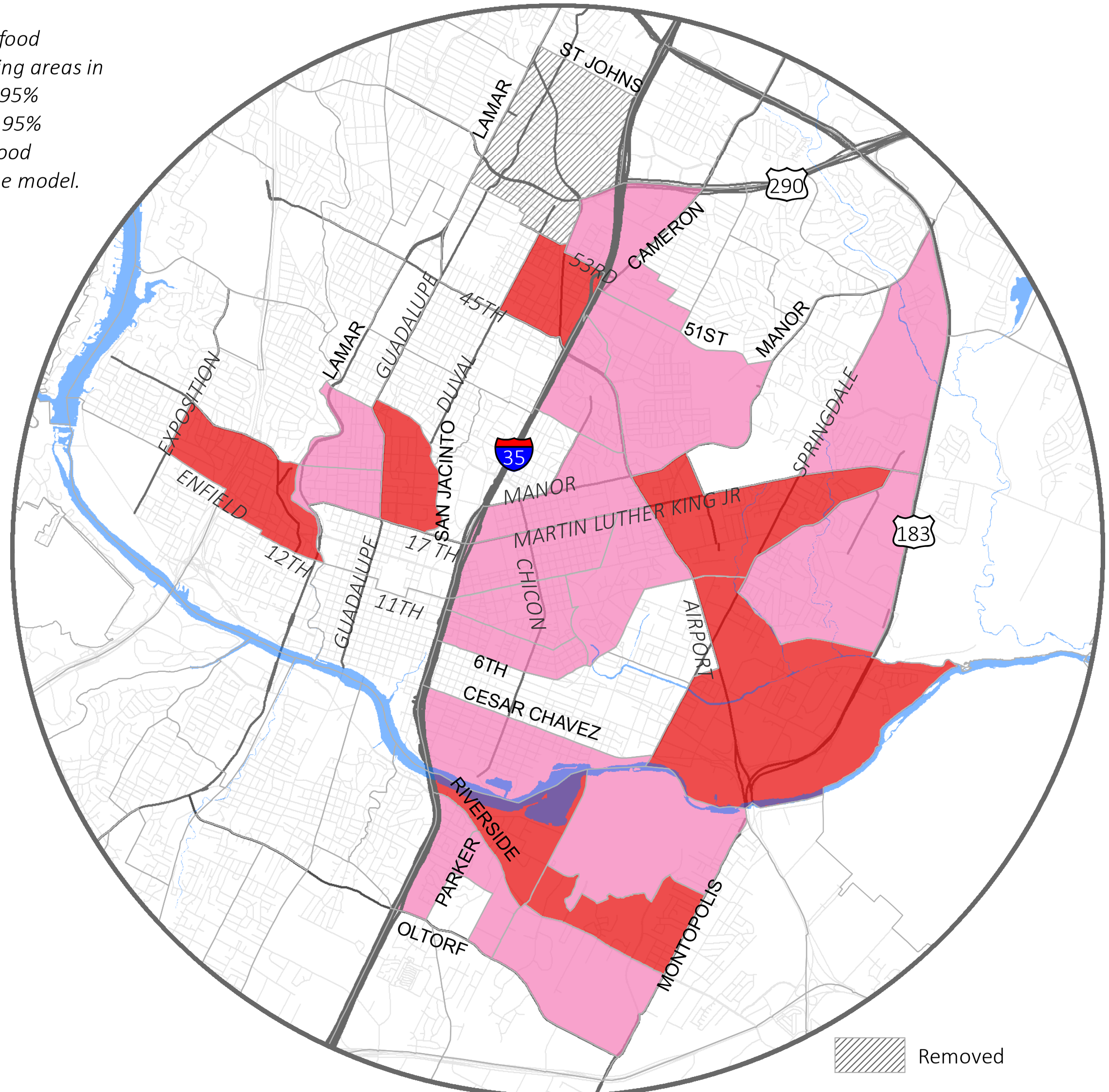
This map shows the locations of clusters of hot spots of the standard residuals (underperforming areas) from geographic weighted regression analysis. Z-scores associated with p-values less than 0.05 indicate clustering of high (or low) values and with 95% confidence the clustering is not due to random chance.



Focus Area

The focus area was chosen based on the hot spot analysis of food insecurity rates controling for the clustering of underperforming areas in the model (hot spots of standard residuals with greater than 95% confidence were removed). Areas selected have greater than 95% condifence that clustering is not due to random chance and food insecurity is likely not explained by variables excluded from the model.





Removed

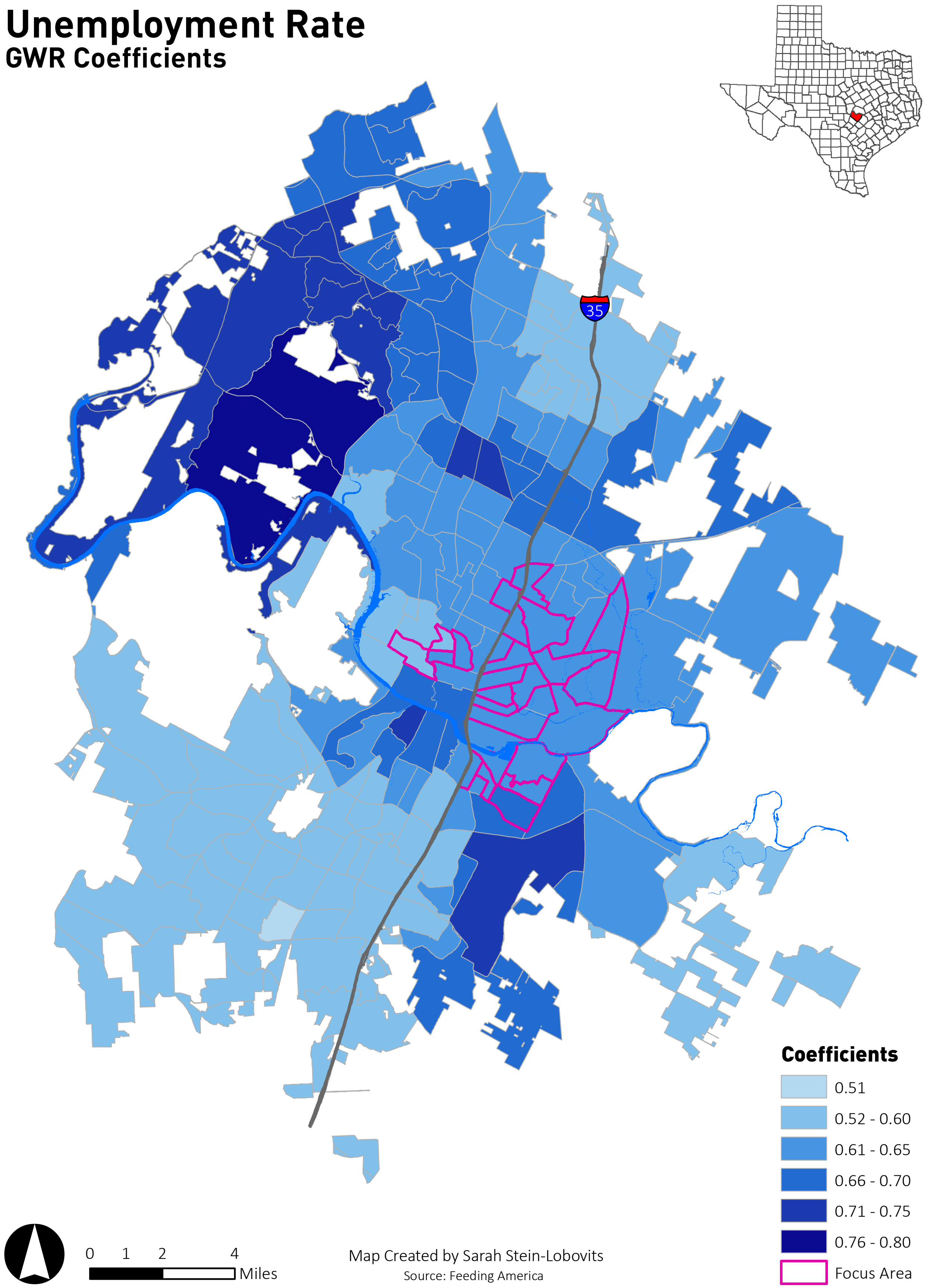
Confidence Interval

95%

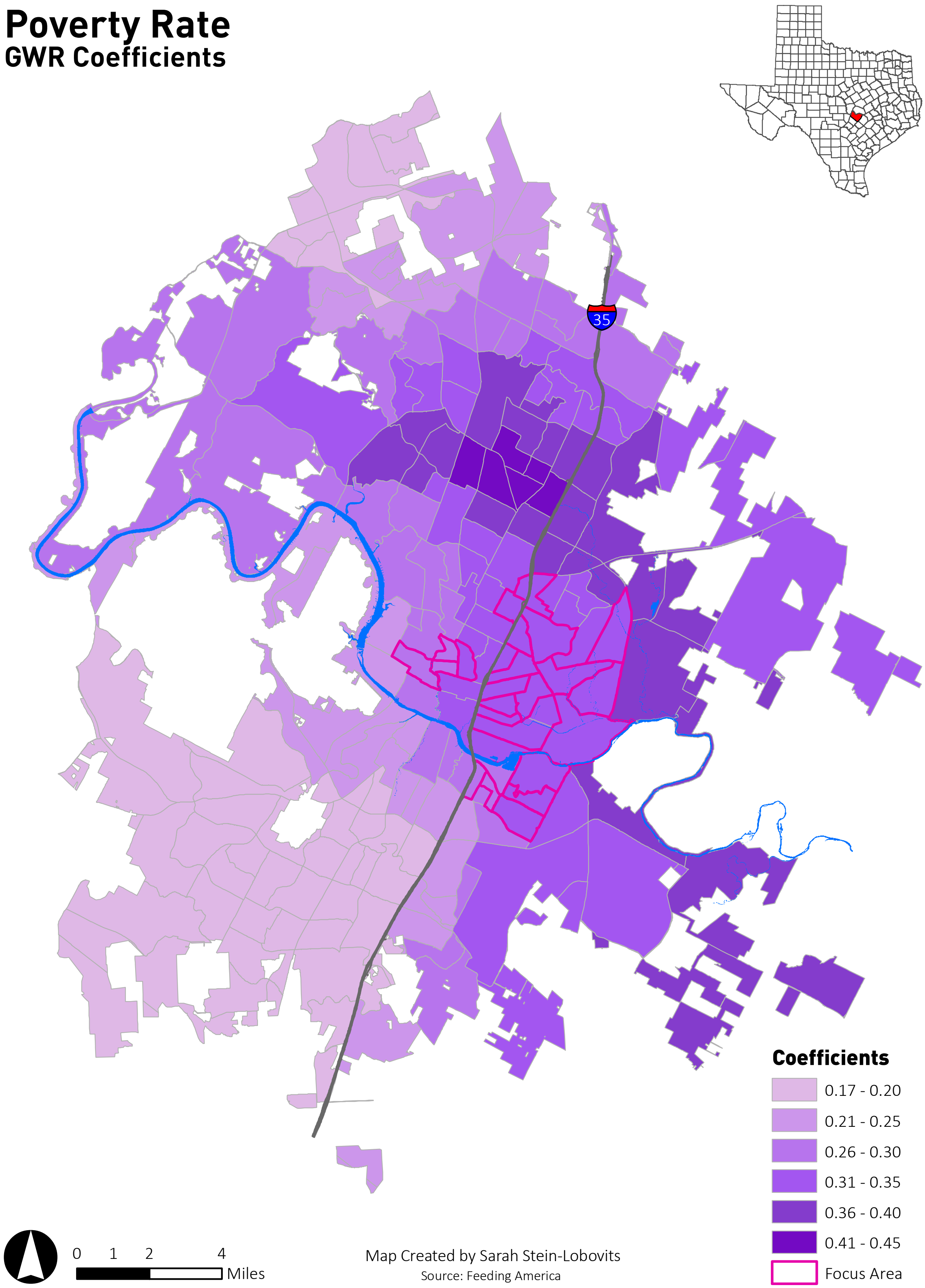
99%

Map Created by Sarah Stein-Lobovits
Source: Feeding America

Unemployment Rate
GWR Coefficients

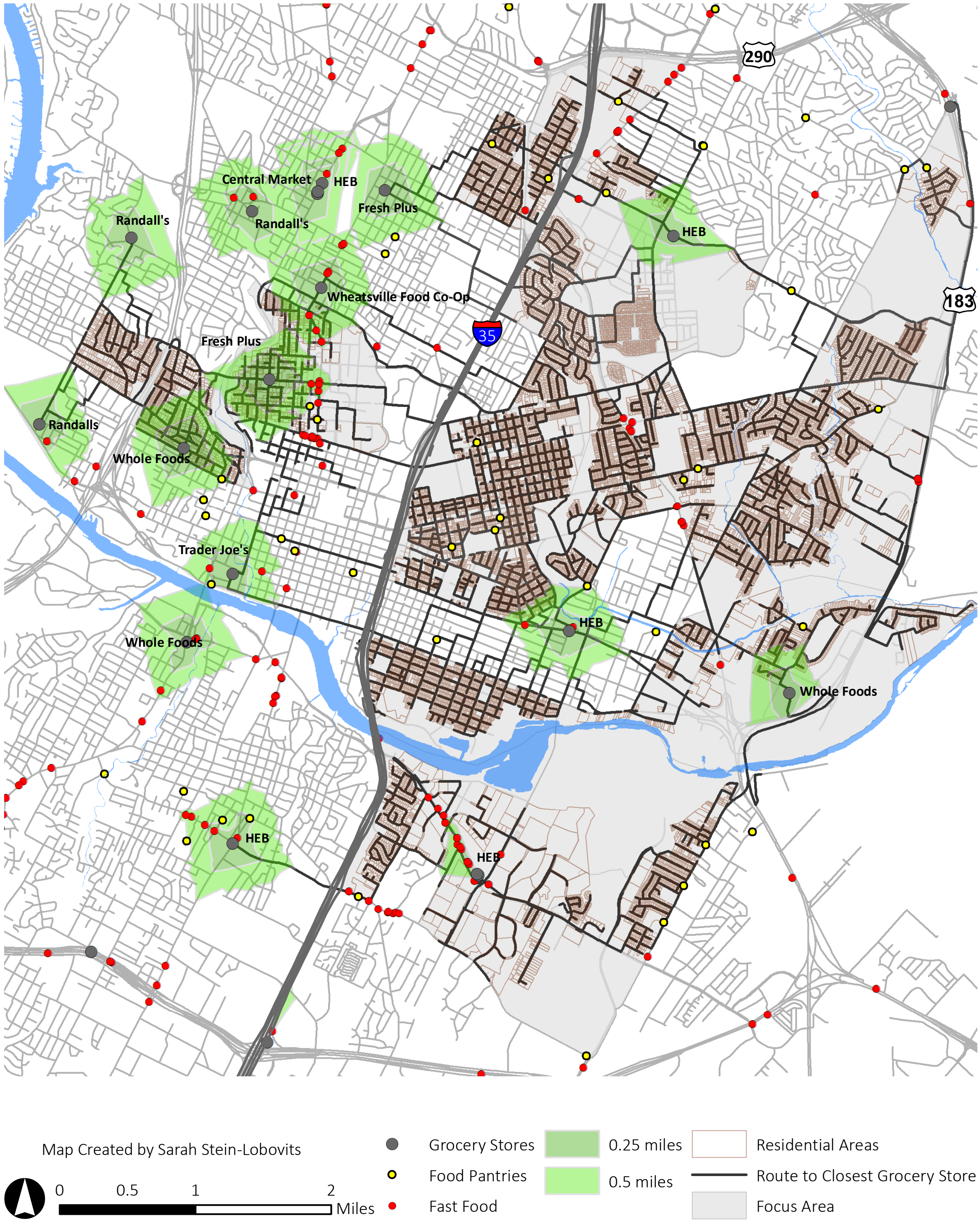


Poverty Rate
GWR Coefficients



Map Created by Sarah Stein-Lobovits
Source: Feeding America

Focus Area: Food Access Analysis



The following tables summarize the results of the geospatial analysis, which are further explained in the discussion section.

Table 1: Ordinary Least Squares

Dependent Variable	Independent Variable (Indicator)	Coefficient
Food Insecurity Rate	Unemployment Rate	0.76*
	Poverty Rate	0.28*
	African-American Population	0.13*
	Latino Population	-0.10*
	Home Ownership	-0.09*
	Median Family Income	0.00*

Indicates p-values less than 0.05

Table 2: Geographic Weighted Regression

Dependent Variable	Independent Variable (Indicator)	R^2
Food Insecurity Rate	Unemployment Rate	0.91
	Poverty Rate	
	African-American Population	
	Latino Population	Adjusted R^2
	Home Ownership	0.88
	Median Family Income	

Figure 2: Focus Area by Census Tract

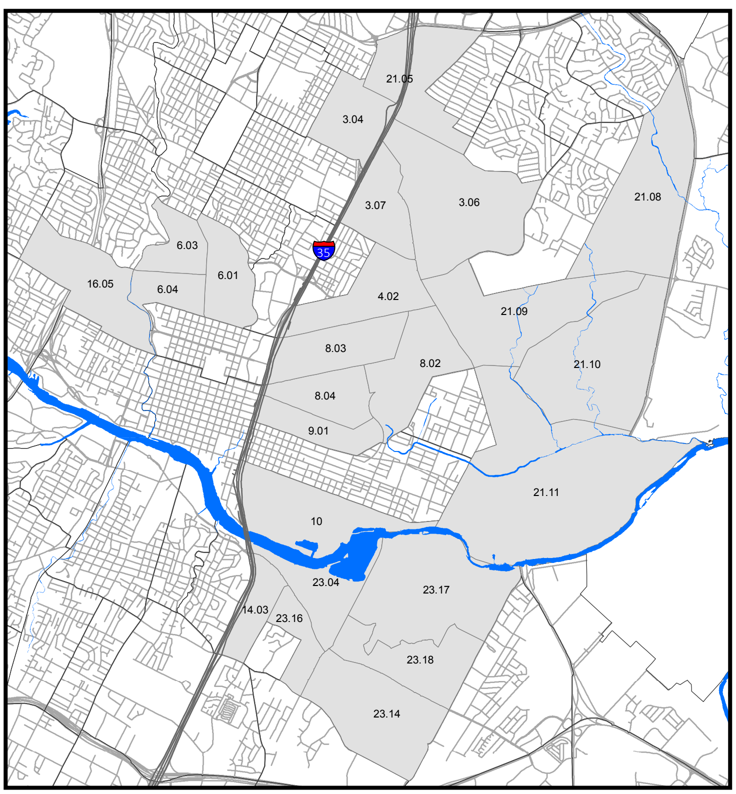


Table 3: Food Access Analysis by Census Tract

Average Distance (miles)	% with NO Vehicle[23]	Census Tract	
0.33	19.1%	6.04	Within acceptable walking distance (0.5 miles)
0.4	11.4%	6.03	
0.47	10.4%	6.01	
0.59	5.2%	16.05	Between 0.5 and 1 mile distance
0.61	8.2%	7	
0.76	19.3%	23.16	
0.77	13.3%	23.14	
0.82	19.0%	23.04	
1.07	10.4%	3.06	Greater than 1 mile distance
1.08	28.9%	8.04	
1.18	8.2%	3.04	
1.19	13.4%	14.03	
1.2	13.8%	21.11	
1.29	22.1%	10	
1.4	24.9%	8.02	
1.42	7.8%	3.07	
1.5	9.5%	9.01	
1.52	9.2%	8.03	
1.74	17.3%	23.18	
1.86	6.4%	4.02	
2.11	14.2%	21.09	Greater than 2 mile distance (11.9% average with NO vehicle)
2.18	6.4%	23.17	
2.26	15.0%	21.08	
2.33	11.9%	21.1	
1.25 miles	**13.5%**	**Average**	

Discussion

Rejecting or Accepting the Hypothesis

H_1: Poverty is the most significant indicator of food insecurity

This hypothesis is rejected based on the data from this study. While the poverty rate was seen to have a strong and significant impact on food insecurity, the unemployment rate proved to be a greater indicator of food insecurity than poverty. However, further exploration of different models may be considered before completely rejecting this hypothesis. With the inclusion of other variables and exclusion of some of the variables used in this study, the effects of poverty may vary. Regardless of the outcomes, it can be concluded that poverty rate does have a strong and significant impact on food insecurity in Austin.

H_2: Access to a major grocery store is a barrier to food security in Austin

This hypothesis is accepted based on the research used to guide this study. Only three census tracts (6.01, 6.03 and 6.04) were found to be within reasonable walking distance (less than 0.5 miles) from a major grocery store. Based on this determinant of accessibility, 21 out of the 24 census tracks in the identified focus area have less than adequate accessibility to a major grocery store. 12 census tracts have greater than a one-mile distance to the closest grocery store and four census tracts are more than two miles away. Additionally, in nearly all census tracts, multiple fast food retailers are appear to be closer (more accessible) than a major grocery store, indicating that unhealthy food options may be more easily accessible and more widely available than healthy options.

A closer examination of the correlation of vehicle ownership and accessibility might be considered to determine the strength of this hypothesis. Roughly 14% of census tracts in the focus area lack vehicle access and the census tracts with greater than a two-mile distance from a grocery store have an average of 12% lacking vehicle access. Nonetheless, the research examined in this report cited the importance of this relationship but not the degree to which it should be evaluated. Census tract 23.17 has one of the highest average distances from a major grocery but one of the lowest percentages of residents with no vehicle access. This indicates that these discrepancies ought to be further examined.

Furthermore, additional exploration of the relationship between vehicle access and owner-occupied versus renter-occupied housing may provide for a more robust understanding of accessibility as it relates to income-level opportunities. While not specifically cited in this report, the data used to calculate vehicle access rates revealed consistently higher accessibility rates with owner-occupied residences.

Further Analysis of Results

Census tracts in the focus area east of I-35 have higher rates of no vehicle access as well as overall higher rates of food insecurity. Additionally, there are only 4 major grocery stores close to these census tracts compared to 11 found near the focus area census tracts west of I-35. The census tracts part of Austin neighborhoods found on the west side of I-35 should not be underperforming nor demonstrate such high rates of food insecurity based on anecdotal evidence and intimate knowledge of the community. One census tract (15.03) was removed from the original hot spot analysis because it also appeared in the hot spot analysis of standard residuals. The standard residuals greater than 0.5 suggest that the model is underperforming in those areas and food insecurity rates may be better explained by variables excluded from the model. These variables may include previously suggested indicators such as educational attainment and vehicle ownership rates. Furthermore, based on the close proximity of these areas to the University of Texas, it is possible that a large percentage of residents in these tracts include students. While students may self-report high levels of hunger, low incomes, lack of home ownership, and unemployment, the characteristics of students are quite different than the typical resident population. Further analysis may include controlling for the student population.

Ordinary least squares (OLS) shows that all six indicators were statistically significant; they each had p-values less than 0.05. This means that each of the indicators can explain food insecurity rates with greater than 95% confidence. Additionally, all coefficients have VIF scores under 4, which indicates that none of the independent variables are redundant and should not be excluded from the model. The unemployment rate, poverty rate and the African-American population rate all have a positive relationship with food insecurity. This means that with a 1% increase in each of these indicators, food insecurity can be expected to increase 0.76%, 0.28% and 0.14% respectively. Unemployment and poverty rates have the largest impact on food insecurity. Both the Latino population rate and home ownership rate have a negative relationship with food insecurity. This means that with a 1% increase in the Latino population rate and home ownership rate, food insecurity rates can be expected to decrease by 0.10% and 0.09% respectively. There is research that supports that home ownership is negatively correlated with food insecurity further validating these results. However, the negative correlation between Latino population and food insecurity was surprising because there is an abundance of evidence demonstrating the positive relationship between food insecurity and minority populations. Although statistically significant, median family income has almost no impact on food insecurity when increased or decreased. It is possible that because this figure was not tabulated as percentage, the model was not able to accurately calculate its impact accurately.

Geographic weighted regression (GWR) uses the independent variables (the six indicators used in the OLS analysis) to create a model to predict what the dependent variable (food insecurity rates) should be based on the data provided. The most pertinent results of GWR are the values for R^2 (and adjusted R^2, which acts as a penalty for including multiple variables in the model) and the standard residuals. The R^2 results (R = residuals) indicate how well the variation in the dependent variable can be explained by the independent variables. Adjusted R^2 takes into account the effect of all the independent variables in the model and is typically lower to control for the fact that there are multiple variables (six in this case) included in the model. Residuals calculate the difference between the observed values (from the data) and the predicted values (from the GWR model). The closer R^2 is to 1, the better the model is able to explain the impact the independent variables have on the dependent variable. **Table 2** shows the R^2 values (and adjusted R^2), which are extremely close to 1. Therefore, it can be concluded that the six indicators have a strong and significant impact on food insecurity rates in Austin, as estimated by *Feeding America,* and overall little variation between the observed and predicted values.

The standard residual outputs indicate where the model is over and underperforming. Standard residuals greater than 0.5 show where the model is underperforming, meaning the food insecurity rate that the model predicts is actually lower than what the data shows. Based on the model using these six indicators, food insecurity should be lower in the census tracts (shown in the purple areas on the map) than in reality what it is. The greater the standard residual, the more severe the model is underperforming. The GWR map shows all census tracts with standard residuals greater than 0.5.

The areas where the model is underperforming (standard residuals are greater than 0.5) can be explained in several ways. These may be the most concerning food insecure areas because the independent variables in those census tracts may be outliers in the data set, meaning the rates for those indicators may be significantly higher compared to other census tracts. It is also likely that other variables that can better explain why these variations exist but were not included in the model. These additional variables may enhance the understanding of food insecurity rates and control for this variation. A mentioned earlier, the high percentage of the student population living in identified food insecure areas may account for the variation in the model in addition to data on education and vehicle ownership rates.

The two maps showing the coefficients by census tract of unemployment and poverty rates demonstrate the distribution of impact these indicators have on food insecurity. An outline of the focus area was overlaid for a visual perspective of the impact these indicators have on food insecurity in the most vulnerable areas.

Limitations

There are several limitations to this study and further exploration of these issues may enhance the understanding of food insecurity in Austin and better advise planners and policy makers moving forward. Major grocery stores in Austin were chosen using national and local chain stores only. It is possible that non-chain, local grocery stores that fit the descriptive model exist but were excluded from this data set due to a lack of area knowledge. Fast food retail locations were chosen based the researchers knowledge of large, national and local chains and the data set was not selected using any literature defining fast food retail. Though a very small number, there were some fast food retailers and food pantries unmatched in the geocoding process.

Close analysis of food insecurity and its indicators was focused on the intersection between the hot spot analysis of food insecurity rates and the hot spot analysis of GWR standard residuals, excluding a close analysis of the highest food insecure census tracts. Additionally, food insecurity rates were calculated using a model designed by *Feeding America*, which although relevant, is not necessarily a widely accepted method and may have its own limitations. Furthermore, the explanatory variables analyzed in this study were limited to those chosen by *Feeding America* and further analysis of additional variables such as educational attainment, vehicle ownership rates, average distance to food retail and the Kirwin Index of social opportunity may provide a more comprehensive insight into food insecurity in Austin as well as better explain the inconsistency of the model seen in certain areas. It would also be worth investigating more literature on the relationship between vehicle ownership rates and accessibility to food retail.

Conclusion

There are several opportunities to strengthen this analysis for future food systems planning and policy intervention. In addition to addressing the limitations cited above, this study may be enhanced by conducting a price-index comparison at major grocery stores in Austin. Furthermore, given the city is contributing a large sum of money to Healthy Corner Store Initiatives, examining the small scale grocery store and convenience store landscape may be a good opportunity within the current political environment for further analysis. Additionally, an examination of public transportation opportunities would provide a different perspective on food access, especially in lower income areas with lower vehicle ownership rates. Finally, it might be beneficial to supplement this study with a geospatial analysis of food assistance benefit rates compared to the availability of food assistance retailers. High proportions of low-income households receive food assistance benefits, impacting their access to food options.

While there are many ways this study can be strengthened, ultimately it provides a strong baseline for understanding food insecurity moving forward. Consistent with the literature, poverty has a high impact on food insecurity in Austin and access to a major grocery store does appear to be a major barrier. The identified focus area offers a starting point for future outreach and intervention, although restricting the focus area to the census tracts east of I-35 might be ideal considering these areas have the highest rates of food insecurity combined with the lowest rates of vehicle ownership and greatest distances to major grocery stores. It is recommended that further analysis be given to the highest food insecure areas with the inclusion of additional indicators before additional focus areas are identified. Finally, although access was identified as a barrier, addressing larger structural issues that affect poverty and employment through policy, are likely to have a stronger, more sustainable and positive impact on food security in the long run.

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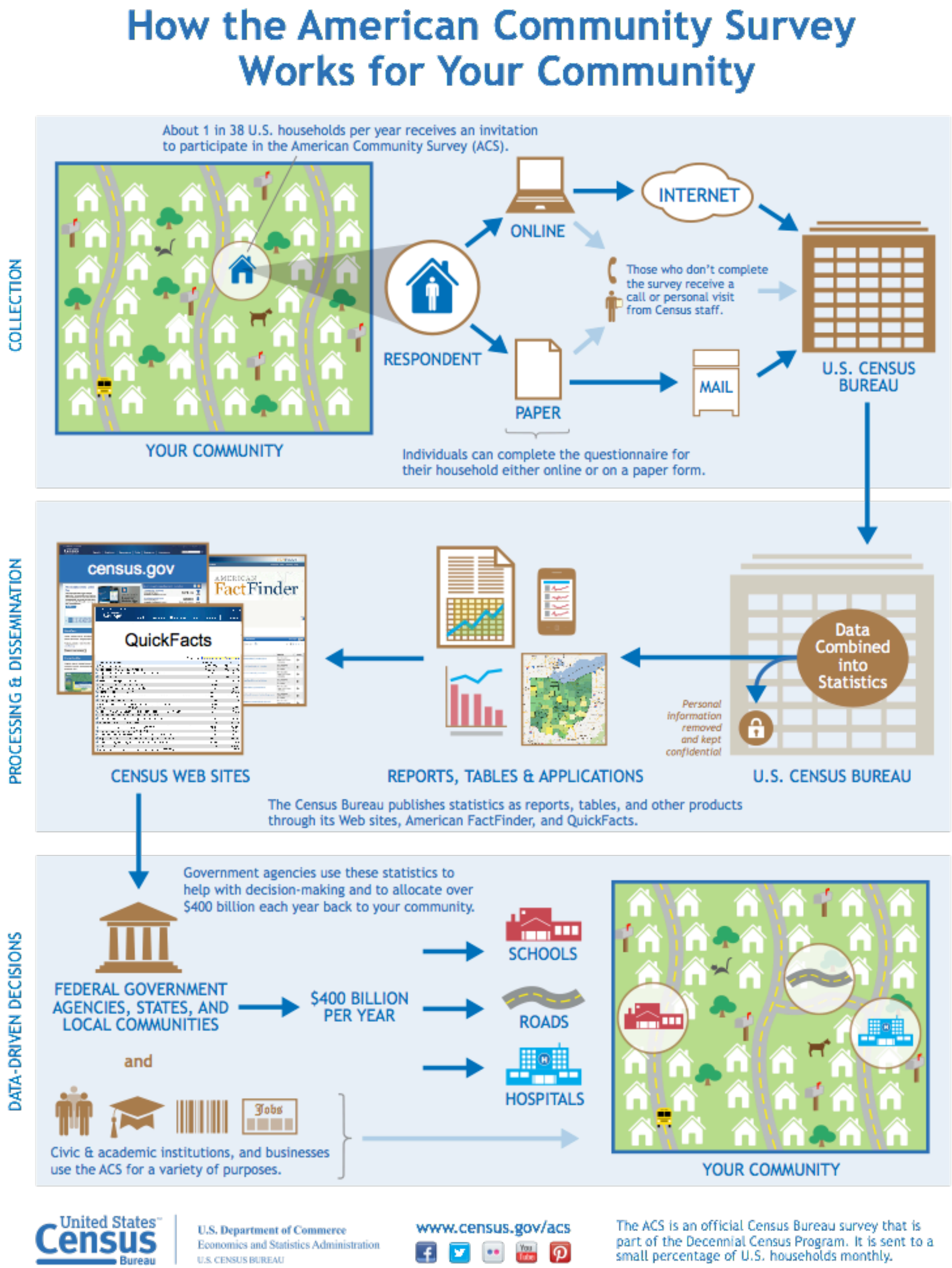
Appendix

Appendix A: US Census Data Collection Methods



Appendix B: US Census Food Security Survey Questions

Questions Used To Assess the Food Security of Households in the CPS Food Security Survey

1. "We worried whether our food would run out before we got money to buy more." Was that often, sometimes, or never true for you in the last 12 months?
2. "The food that we bought just didn't last and we didn't have money to get more." Was that often, sometimes, or never true for you in the last 12 months?
3. "We couldn't afford to eat balanced meals." Was that often, sometimes, or never true for you in the last 12 months?
4. In the last 12 months, did you or other adults in the household ever cut the size of your meals or skip meals because there wasn't enough money for food? (Yes/No)
5. (If yes to question 4) How often did this happen—almost every month, some months but not every month, or in only 1 or 2 months?
6. In the last 12 months, did you ever eat less than you felt you should because there wasn't enough money for food? (Yes/No)
7. In the last 12 months, were you ever hungry, but didn't eat, because there wasn't enough money for food? (Yes/No)
8. In the last 12 months, did you lose weight because there wasn't enough money for food? (Yes/No)
9. In the last 12 months did you or other adults in your household ever not eat for a whole day because there wasn't enough money for food? (Yes/No)
10. (If yes to question 9) How often did this happen—almost every month, some months but not every month, or in only 1 or 2 months?

(Questions 11-18 were asked only if the household included children age 0-17)

11. "We relied on only a few kinds of low-cost food to feed our children because we were running out of money to buy food." Was that often, sometimes, or never true for you in the last 12 months?
12. "We couldn't feed our children a balanced meal, because we couldn't afford that." Was that often, sometimes, or never true for you in the last 12 months?
13. "The children were not eating enough because we just couldn't afford enough food." Was that often, sometimes, or never true for you in the last 12 months?
14. In the last 12 months, did you ever cut the size of any of the children's meals because there wasn't enough money for food? (Yes/No)
15. In the last 12 months, were the children ever hungry but you just couldn't afford more food? (Yes/No)
16. In the last 12 months, did any of the children ever skip a meal because there wasn't enough money for food? (Yes/No)
17. (If yes to question 16) How often did this happen—almost every month, some months but not every month, or in only 1 or 2 months?
18. In the last 12 months did any of the children ever not eat for a whole day because there wasn't enough money for food? (Yes/No)

Source: Coleman-Jensen, Alisha, Matthew Rabbitt, Christian Gregory and Anita Singh. "Household Food Security in the United States in 2014." *USDA Economic Research Service,* Report 194 (2015).

Appendix C: *Feeding America's* Explanation of Food Insecurity Estimates

Food-Insecurity Rate Estimates

Methods

Full Population of Counties (and Congressional Districts)

We proceed in two steps to estimate the extent of food insecurity in each county. In what follows, the descriptions are for counties but, except where otherwise noted, they also apply to congressional districts. Because congressional districts were redrawn in 2012, MMG estimates are available for the current congressional districts only for 2012 and 2013 (the last two years).

Step 1: Using state-level data from 2001-2013, we estimate a model where the food-insecurity rate for individuals at the state level is determined by the following equation:

$$FI_{st} = \alpha + \beta_{UN}UN_{st} + \beta_{POV}POV_{st} + \beta_{MI}MI_{st} + \beta_{HISP}HISP_{st} + \beta_{BLACK}BLACK_{st} + \beta_{own}OWN_{st} + \mu_t + \upsilon_s + \varepsilon_{st} \quad (1)$$

where s is a state, t is year, UN is the unemployment rate, POV is the poverty rate, MI is median income, HISP is the percent Hispanic, BLACK is the percent African-American, OWN is the percent of individuals who are homeowners, μ_t is a year fixed effect, υ_s is a state fixed effect, and ε_{st} is an error term. This model is estimated using weights defined as the state population. The set of questions used to identify whether someone is food insecure, i.e., living in a food-insecure household, are defined at the household level. A household is said to be food insecure if the respondent answers affirmatively to three or more questions from the Core Food Security Module (CFSM). A complete list of questions in the CFSM is found in Table 1.

Our choice of variables was first guided by the literature on the determinants of food insecurity. We included variables that have been found in prior research to influence the probability of someone being food insecure. (For an overview of that literature in this context see Gundersen, 2013; Gundersen et al., 2012.) Next, we chose variables that are available both in the CPS and at the county level, such as those in the American Community Survey (ACS) or other sources (described below). The model does not include variables that are not available at both the state and county level.

Source: Gunderson, C., A. Satoh, A. Dewey, M. Kato and E. Engelhard. "*Map the Meal Gap 2015: Food Insecurity and Child Food Insecurity Estimates at the County Level*." Feeding America, 2015.

Appendix D: Food Establishment Categories

Grocery Store:

- Retail food outlet with a full range of items from all food categories including fresh fruits and vegetables, raw meat and other items that require preparation/cooking in addition to convenience items such as chips, canned goods, sodas, etc.).
- Typically offers a service deli, frequently offers a service bakery and sometimes has a pharmacy. (Pharmacy and health care items are not majority of merchandize sold in store).
- May carry some general merchandise items, but these items do not account for a large percent of the store.

Examples include: HEB, Randall's, Fiesta, Whole Foods, Super Wal-Mart, Super Target

Convenience Store:

- A small store that offers a limited selection of staple groceries, non-foods, and other convenience food items, i.e., ready-to-heat and ready-to-eat foods.
- Includes food marts within gas stations.
- May have limited fresh produce or raw items.
- May include refrigerated items such as milk and cheese.

Examples includes: Jif-E-Mart, Exxon Food Mart, etc.

Food/Drug Combo Store:

- A combination of pharmacy, grocery, and convenience under a single roof, with common checkouts.
- Mainly carries personal health and pharmacy type items but also carries limited general merchandise, foods for immediate consumption, and some refrigerated foods.
- Examples include: CVS, Walgreens, and family owned drug stores that carry food

General/Discount Store:

- Mainly carries general merchandise, but sometimes carries limited selection of staple groceries and other convenience food items, i.e., ready-to-heat and ready-to-eat foods.
- May include refrigerated and/or frozen food items.
- May or may not offer items at a discounted price.

Examples include: General Dollar, Family Dollar, The Dollar Tree, Wal-Mart (not super), and Target (not super).

Other:

- Specialty Stores such as meat markets, health stores, seafood markets, or grocery stores that specialize in culturally specific foods (Chinese, Asian, Indian, etc.).

Source: E-mail attachment from Karen Banks, author of the Sustainable Food Center's Central Texas Foodshed Assessment, 2011

Appendix E: Data Sources

Data Sources

***All of the data from the American Community Survey (ACS) are 2009-2013 five-year estimates.**

DATA POINT	Source	ACS NAME/OTHER NAME
Percent Latino	**ACS**	Percent; HISPANIC OR LATINO AND RACE - Hispanic or Latino (of any race)
Percent African American	**ACS**	Percent; RACE - Total population - Black or African American
Poverty Rate	**ACS**	Percent below poverty level; Estimate; Population for whom poverty status is determined
Median Family Income	**ACS**	Estimate; Median household income in the past 12 months (in 2013 inflation-adjusted dollars)
Unemployment Rate	**ACS**	Unemployment rate; Estimate; Population 16 years and over
Homeownership Rate	**ACS**	Percent; HOUSING TENURE - Owner-occupied
Vehicle Ownership	**ACS**	Tenure by Vehicles Available; Occupied housing units
Roadways	**COA**	City of Austin; TRANSPORTATION.street_segment
Waterways	**COA**	City of Austin; INLANDWATERS.lakes
Land Use	**COA**	City of Austin; PLANNINGCADASTRE.land_use_2012
Food Insecurity Rates	***Feeding America***	Compiled by Feeding America using national ACS estimates
Major Grocery Stores	**HHSD**	Health and Human Services Department; Table of permitted food retail
Fast Food Restaurants	**HHSD**	Health and Human Services Department; Table of permitted food retail
Farmers Markets	**COA**	Compiled by the Office of Sustainability
Food Pantries	**CAFB**	Capital Area Food Bank; List on website

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