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A Spatiotemporal Analysis of Food Pantry Accessibility in Washington County, Arkansas

Coleman Warren
University of Arkansas, Fayetteville

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An Honors Thesis submitted in partial fulfillment of the requirements for Honors Studies in Industrial Engineering

By

Coleman Warren

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Thesis Advisor: Ashlea Bennett Milburn, Ph.D.

Abstract

Food pantries are an essential resource for impoverished and food insecure communities. Washington County, Arkansas has a food insecurity rate of 14.3% as compared to the national average of 10.9% (Feeding America, 2019). The Northwest Arkansas Food Bank has a robust pantry network in Washington County to support families and individuals who struggle with food insecurity.

We conducted a spatiotemporal analysis of food pantry accessibility in Washington County, Arkansas to evaluate the effectiveness of the food pantry network in Washington County at supporting communities with the most need. This analysis was conducted using the Two-Step Floating Catchment Area (2SFCA) method and data from the Northwest Arkansas Food Bank and the U.S. Census Bureau. Two separate analyses were considered – one consisting of a spatial accessibility model and another that included temporal in addition to spatial patterns. The temporal dimension was based on a pantry's number of hours open per week. The models provide relative pantry accessibility scores at the census block group level of aggregation, allowing for identification of block groups with relatively lower and higher access. The results were compared to food insecurity rates of Washington County as well as food insecurity risk index scores based a variety of socioeconomic and demographic factors (Fitzpatrick, Spialek, & Cascante, 2018). This document provides suggestions for the NWA Food Bank based on the results of this thesis.

In the future, further research should be conducted to better understand human mobility patterns regarding travel to food pantries. A spatial accessibility model is dependent on assumptions regarding human transportation patterns. In the absence of data to support good assumptions, model insights are limited. Future work could also extend the models in this thesis to include a variable catchment size to represent difference in transportation patterns between rural, suburban, and urban block groups. Finally, the desirability of "when" a pantry is open could be considered in addition to the quantity of hours the pantry is open.

Acknowledgements

I would like to thank the University of Arkansas and the College of Engineering for the opportunity to pursue an excellent education enhanced by the opportunity to conduct undergraduate research that is focused on my career and educational goals. I am incredibly grateful for the chance to work on this research and hope to continue to build upon what I have learned here in the future.

I am grateful for the work of the Northwest Arkansas Food Bank in supplying Washington, Madison, Benton, and Crawford counties with nutritional food for families and individuals who need it most. Without the support of the NWA Food Bank, this thesis would not be as specific in helping to identify areas of need in our community, and I am excited to collaborate with them further. I hope any and all recommendations listed in the thesis come with the knowledge that the NWA Food Bank does an incredible job at supporting our community here in Northwest Arkansas.

There are many individuals I would like to thank beginning with Dr. Ashlea Milburn. She has been not only very helpful throughout this process but has allowed me the space to think about how we approach these problems and think about conducting research. I truly appreciate all she has done for me in research and as a mentor over the past 3 years. In addition to Dr. Milburn, I am proud and grateful to have been able to spend 4 years with the Department of Industrial Engineering's faculty and staff members. I would also like to thank my family and partner, Bailee King.

Sincerely,

Coleman Warren

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Introduction

Arkansas is one of the poorest states in the U.S. when measured by poverty rate and median household income (USDA, 2021). A family of 4 is considered impoverished when the annual household income is below $27,949 (USCB, 2021). In 2020, the national poverty rate was 11.4% (USCB, 2021). Arkansas' rate was 15.2 % (USCB, 2021). A Feeding America study showed that 499,950 Arkansans, 1 in 6, face hunger (Feeding America, 2019). 1 in 5 children struggle with hunger in Arkansas, 149,670 of them in 2019 (Feeding America, 2019). Food insecurity is defined as "a household-level economic and social condition of limited or uncertain access to adequate food" (USDA, 2022). Hunger is defined as "an individual-level physiological condition that may result from food insecurity" (USDA, 2022).

In Arkansas, there are hundreds of thousands of Supplemental Nutrition Assistance Program participants, with 48.3% of recipients providing for families with children (Feeding America, 2019). Arkansas food insecurity in 2020 skyrocketed to estimated rates of 47.4% due to COVID-19 (Fitzpatrick, 2020). The relationship between child hunger and poverty is cyclical (Cook & Jeng, n.d.). When children are hungry, their development is disadvantaged (Cook & Jeng, n.d.).

Food pantries are an essential resource for impoverished and food insecure communities. Washington County, Arkansas has a food insecurity rate of 14.3% as compared to the national average of 10.9% (Feeding America, 2019). The Northwest Arkansas Food Bank has a robust pantry network in Washington County to support families and individuals who struggle with food insecurity. We performed a spatiotemporal analysis of pantry accessibility in the county to support the NWA Food Bank in their work. This analysis revealed areas where pantry access is relatively low compared to other areas in Washington County. Access disparities across the

county can be addressed in a variety of ways by the NWA Food Bank including increasing supply of food at pantries, extending the hours of availability, or creating additional food pantries in Washington County.

Background

The concept of access is multidimensional and includes availability, accessibility, accommodation, affordability, and acceptability (Penchansky & Thomas, 1981). First, accessibility is a product of the relationship between supply and demand nodes of a given good or service. This relationship is described by location, distance, modes of transportation, and more (Penchansky & Thomas, 1981; Kilinc, Stamm, & Milburn, 2018). Spatial accessibility is typically measured by travel time or distance and the number of supply nodes within a particular travel time or distance. Next, accommodation is the method by which the goods or services are delivered to the client, or demand nodes (Penchansky & Thomas, 1981). This can take the form appointment systems or hours of operation. Temporal accessibility would fall under the access dimension of accommodation, or the ability for a demand node to access a supply node during a given time. Next, availability is the relationship between the volume of supply and demand of a given good or service. Affordability and acceptability are not factors considered in the proposed model. Affordability is the relationship between the price of goods and access, but we are focused on charitable, free food provided to food pantries. Acceptability refers to the type of food and if it is acceptable for the consumer's diet including constraints of allergies, cultural norms, or other preferences. Acceptability is explored in Dr. Fitzpatrick's qualitative analysis of food pantry accessibility (2018).

Measurement of spatial accessibility can be conducted in a variety of ways. Spatial accessibility consists of two main components: availability and proximity (Luo & Wang, 2003). Spatial accessibility cannot be characterized by one factor alone because high availability with a lack of proximity will lead to low accessibility, and vice versa (McGrail & Humphreys, 2009). A common method of evaluating spatial accessibility is the 2-Step Floating Catchment Area (2SFCA) method, a spatial decomposition method that combines both components of spatial accessibility to create a quantitative evaluation of accessibility (Luo & Wang, 2003). 2SFCA is ultimately a derivation of the gravity-based method (Weibull, 1976). Other variations on 2SFCA exist to add complexity to the model including the three-step floating catchment area method (3SFCA) which incorporates a "spatial impedance-based competition scheme (Wan, Zou, & Sternber, 2011)" as well as the enhanced two-step floating catchment area (E2SFCA) method which addresses "the problem of uniform access within the catchment (Luo & Qi, 2009)." While some temporal accessibility analysis does exist in the literature (i.e. disaster relief response time constraints from Indrakanti, Mikler, O'Neill, & Tiwari, 2016), the application of temporal factors to food accessibility issues, specifically the availability of the supply nodes to clients due to hours of operation, is lacking (Widener & Shannon, 2014). On top of this, the analysis of spatial accessibility of charitable foods, like that from food pantries, is lacking in the literature.

Spatial accessibility models have been applied extensively to health services applications including disaster relief (Indrakanti, Mikler, O'Neill, & Tiwari, 2016), home health care (Kilinc, Stamm, and Milburn, 2018), and demographic health care access disparities (Dai, 2010). The application of a spatiotemporal model to food pantry accessibility has not been conducted in the literature, but a spatiotemporal analysis of accessibility to emergency food systems was conducted in south-central Indiana (Kaplan et al., 2020). Kaplan's model considered food

pantries as supply nodes in emergency food response. A qualitative analysis of emergency food provider accessibility was performed in New Haven, CT and identified important barriers to food access including transportation and time (Carroll et al., 2018). A similar study was conducted in Northwest Arkansas by Dr. Kevin Fitzpatrick and his team to identify areas to improve access to food for individuals experiencing food insecurity (Fitzpatrick et al., 2018). Fitzpatrick's findings include that food access is constrained by the hours food is available and the location of the food. Also, Fitzpatrick identified that the quality or type of foods were an additional limiting factor.

The literature regarding food pantry human mobility patterns is limited. Noulas et al. (2012) studied human mobility patterns using location sharing services (LSS) in large cities across the U.S. and establishes a model for predicting human mobility within cities using rank-distances, a product of the number of destinations between the origin and destination of a given trip. Kumar (et al., 2015) identified patterns in human behavior when selecting restaurants to eat based on transportation constraints. Lee and Sui (2021) studied human mobility patterns using millions of LSS data points. They identified key distributions of annual human mobility patterns including the radius of gyration, or a measure of how frequently and far an individual moves. While these contributions provide important first steps to understanding human transportation patterns when seeking restaurant meals, not much is known regarding transportation patterns when obtaining charitable food. More research should be conducted to better understand human mobility with regards to transportation to food pantries.

Methodology

A spatiotemporal accessibility analysis was performed using mapping and routing software to evaluate the accessibility of food pantries in a given region. The Two-Step Floating

Catchment Area (2SFCA) method was used to assess accessibility. The below section outlines the process used to apply the 2SFCA model, which has not previously been used to evaluate food pantry accessibility, to food pantries. The section begins by outlining the core components of 2SFCA.

2SFCA Components

To evaluate pantry accessibility using the Two-Step Floating Catchment Area method, the core components of the 2SFCA evaluation were identified and obtained. The necessary components to perform 2SFCA analysis for this system are shown in Table 1.

Table 1: 2SFCA Components

Component	Symbol
Pantry-to-population ratio	R_j
Pantry supply (meals/month)	S_j
Block group demand (number of people)	P_k
Block group to pantry distance (miles)	d_{ij} or d_{kj}
Maximum travel distance (miles)	d_0
Block group accessibility	A_i

There are two steps in 2SFCA (Luo & Wang, 2003). First, for each pantry location *j*, all population locations, *k*, within a threshold travel distance, d_0, from the pantry location must be used to calculate the pantry-to-population ratio, R_j. The population locations for our analysis are census block groups. Equation 1 represents this system.

$$R_j = \frac{S_j}{\sum_{k \in \{d_{kj} \leq d_0\}} P_k}$$

Equation 1: 2SFCA Pantry-to-Population Ratio

Next, for each block group (population location) i, the second step is to sum each pantry-to-population ratio (R_j) for pantries that are within the threshold travel distance, d_0. Equation 2 represents this system.

$$A_i = \sum_{j \in \{d_{ij} \leq d_0\}} R_j$$

Equation 2: 2SFCA Accessibility Scores

Temporal Factors in 2SFCA

Spatial accessibility scores (A_i scores above) were adjusted to account for the temporal dimension as follows. When calculating the R_j score, the new time data was applied to the valuation of S_j inputs. Recall that S_j is the total number of individuals served by each pantry in a given month. Define S_j' as the temporally adjusted supply of facility j.

$$S_j' = S_j \times \frac{h_j}{h_{max}}$$

Equation 3: Temporally Adjusted Supply

In Equation 3, h_j is the number of hours pantry j is open per week, and h_{max} is the maximum hours a pantry could be open in a week. When performing spatiotemporal accessibility analysis, S_j' will replace S_j in Step 1 of 2SFCA. All other aspects of the 2SFCA method will remain the same as in the spatial (no temporal factor) scenario. We demonstrate the application of these methods to a case study in Washington County, Arkansas.

Case Study

A spatiotemporal accessibility analysis was performed in Washington County, Arkansas to evaluate the accessibility of food pantries sourced by the Northwest Arkansas (NWA) Food Bank. The Two-Step Floating Catchment Area (2SFCA) method was used to assess accessibility. The below section outlines the process used to apply the methodology to Washington County and identifies data sources for the analysis.

Supply Data

Data sources were identified to evaluate accessibility of food pantries using the 2SFCA Method. In the original Luo and Wang (2003) physician accessibility analysis, the supply component, S_j, is the number of physicians at a given healthcare center. Translating this use to food pantries, the supply component can be defined as the number of meals served per month at a given pantry. This information was provided by the NWA Food Bank for the month of September 2021 (Smith & Cowan, 2021) and is summarized in Table 2. We acknowledge that meals served is a measure of realized accessibility and may underestimate the number of meals that could potentially be served (potential accessibility).

Table 2: Food Pantry Supply Summary Table

Food Pantry Supply (S_j)	
Count	38
Mean	958.5 meals/mo.
Standard Deviation	1870.6 meals/mo.
Minimum	6 meals/mo.
Maximum	9392 meals/mo.
Median	324.5 meals/mo.

Demand Data

The population demand, or in this case block group demand, P_k, required some assumptions for this analysis. Because the latest census data from 2020 was not available at the time the analysis was completed, data from the 2019 American Community Survey (ACS) 5-Year Estimates were used (USCB, 2019). One data table contained population estimates for Washington County at the block group level and were used directly. Another data table from the ACS contained poverty proportion estimates, defined by individuals below the poverty line in the previous 12 months, by census tract (USCB, 2019). The poverty proportion is used as a proxy for the food insecurity rate in a census tract. Because block groups aggregate to census tracts, the food insecurity estimate for a tract was applied to each block group within the census tract. Block group demand, P_k, can then be estimated as the product of population and food insecurity rate as shown in Equation 4.

$$P_k = Population\ of\ Block\ Group\ k\ \times\ Rate\ of\ Food\ Insecurity\ for\ Block\ Group\ k$$

Equation 4: Block Group Demand

The equation above was used to calculate demand values for each block group in Washington County. Table 3 summarizes these data for the 111 block groups in the study area, and the full data tables are provided in the appendix.

Table 3: Block Group Demand Summary Table

	Population	Poverty	Demand (P_k)
Average	2,093	17.6%	353.79
Minimum	0	4.2%	0
Median	1,658	13.6%	252.4
Maximum	5,974	52.6%	2,457.47

Figure 1 depicts poverty rate mapped by quintile in Washington County. Darker colors indicate relatively higher rates of food insecurity.

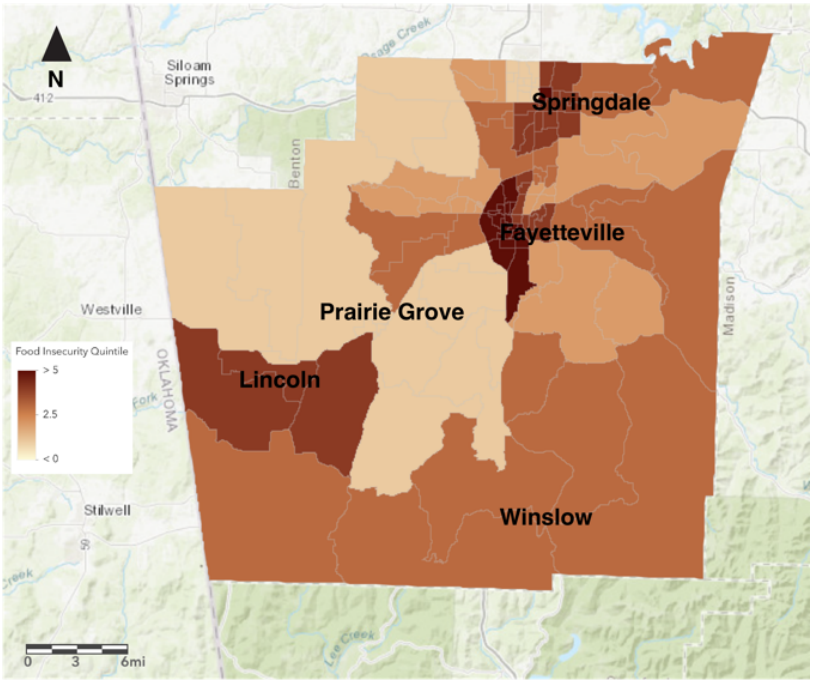

Figure 1: Poverty Map

Block Group to Pantry Distances

The distances between the block groups and pantries, d_{ij} or d_{kj}, were calculated using the ArcGIS mapping and routing software. Each distance was found using the centroid of each block group and the address of each pantry. The pantry addresses were provided by the NWA Food Bank. The centroid of each block group was identified using the ArcGIS mapping software alongside the polygon data provided by the U.S. Census Bureau (2010). The pantries, block groups, and block group centroids are shown in Figure 2.

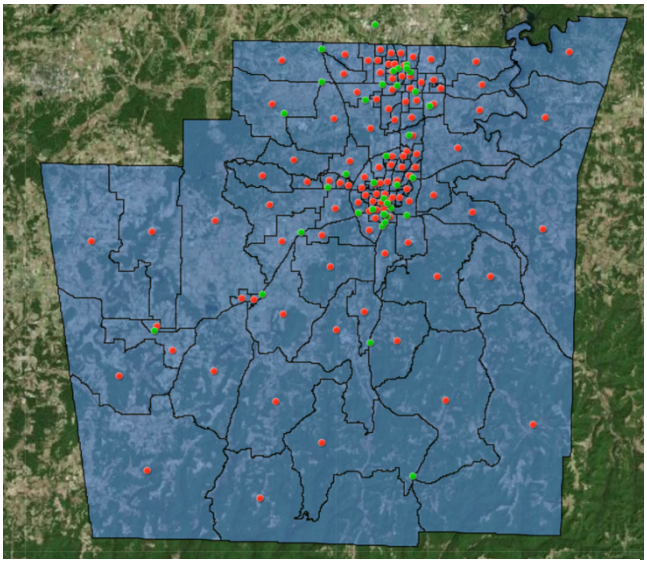

Figure 2: Block Groups & Pantries in Washington County

The maximum travel distance, d_0, which represents the furthest an individual is willing or able to travel to a food pantry, was difficult to identify. As was outlined in the Background section, the literature on human mobility when accessing food is not robust. Lee and Sui (2021) studied human mobility patterns using millions of location sharing services (LSS) data points. They found that in a given year, 34.5% of people exhibited a radius of gyration, or a measure of how frequently and how far an individual moves, of less than 10 miles (Lee and Sui, 2021). A radius of d_0=10 was adopted for this case study. Sensitivity analysis is also performed to better understand the effects of the maximum travel distance on pantry accessibility by evaluating the system with maximum travel distances of 8 miles and 12 miles.

ArcGIS mapping software was used to calculate travel distances between block groups and food pantries. The function used to calculate these distances is the "Connect Origins to Destinations" function with the following parameters:

1. Connect pantry location as origin destination

2. Route to destinations of each block group centroid (identified in the previous subsection)
3. Measure driving distance
4. Follow streets

Figure 3 shows a sample output from ArcGIS for the Washington Regional Food Pantry routed to each block group centroid in Washington County. The colors of the route lines are default and are not significant for the purposes of this thesis.

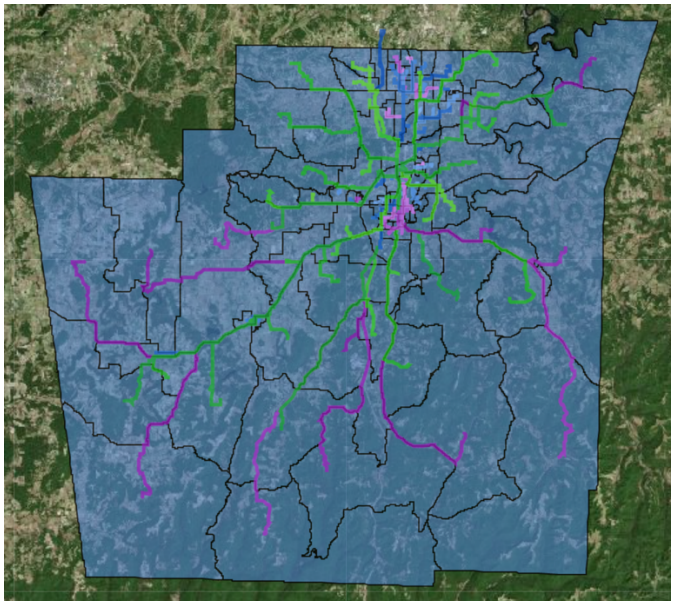

Figure 3: Block Group Centroids to Washington Regional Food Pantry Routes

Temporal Factors

An important aspect of this thesis is the introduction of time as a factor in the model. Using the information provided by the NWA Food Bank on how often and for how long pantries were open, total hours per week values were calculated. However, the temporal data were missing for 7 of 38 pantries. To impute values for these 7 pantries, a scatterplot of meals served to hours open was created, outliers were removed, and a trendline was created.

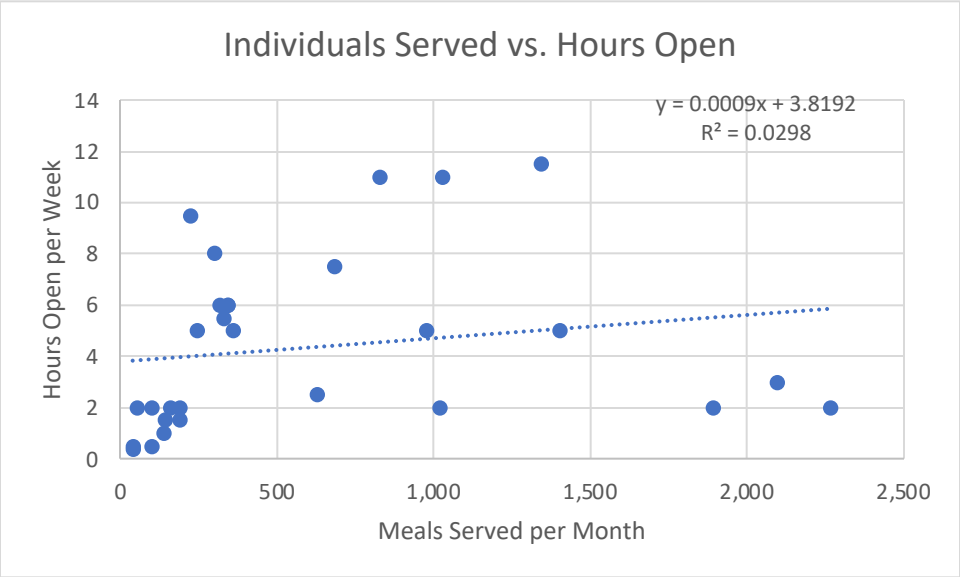

Figure 4: Pantry Hours vs. Meals Served Trendline

The trendline was used for estimating the total hours open for the pantries with missing data. While the R^2 value is low for the trendline, this model does explain more of the variation in the data than a simple mean of hours open across all pantries. Table 4 summarizes the pantries' total hours open per week. These data were utilized for assessing time as a factor in pantry accessibility. The full table can be found in the appendix.

Table 4: Food Pantry Hours

Food Pantry Hours	
Count	38
Mean	7.1 hr/week
Standard Deviation	8.7 hr/week
Minimum	0.4 hr/week
Maximum	42.5 hr/week
Median	5 hr/week

Without the temporal factor, S_j represents the total number of individuals served by each pantry in a given month. With the temporal factor, S_j' was calculated using equation 5.

$$S_j' = S_j \times \frac{h_j}{56\ hours\ per\ week}$$

Equation 5: Case Study Temporal Supply Equation

It is important to note that an assumption was made in this equation. The 56 hours per week is based on a hypothetical seven-day week having eight hours of possible service per day. As the denominator in S_j' is constant, all access scores are scaled down by the same amount. Therefore, using a different value than 56 hours per week would not change the ranking of the access scores relative to each other. Another noteworthy aspect of this analysis is that the original supply value, S_j, may be already influenced by the number of hours a pantry is open, so this method has the potential to underscore an existing pattern regarding the supply values of the pantries.

Food Insecurity Risk Index

Dr. Kevin Fitzpatrick, Dr. Matthew Spialek, and Diana Cascante created a food insecurity risk scale using a combination of 16 social, economic, demographic, and housing factors and assigned each census tract in Washington County, Arkansas with a risk index score (Fitzpatrick et al., 2018). The risk index scores are shown in Table 5.

Table 5: Risk Index Summary Table

Washington County Food Insecurity Risk Index

Tract	Risk Index	Tract	Risk Index
101.01	46	105.07	30
101.02	27	105.08	35
101.04	24	105.09	30
101.05	26	105.10	33
101.06	30	106.00	45
101.07	22	107.01	48
102.00	57	107.02	43
103.01	56	110.01	36
103.02	52	110.02	46
104.01	53	110.03	38
104.02	55	110.04	45
104.03	54	111.01	48
105.01	28	111.02	44
105.03	32	111.03	38
105.04	42	112.00	54
105.06	29	113.00	40

Dr. Fitzpatrick's team divided the range of index scores into three equal-width intervals to identify tracts with relatively low (score = 31 or less), medium (32 to 42), and high (43 or more) risk index scores. These are mapped in Figure 5.

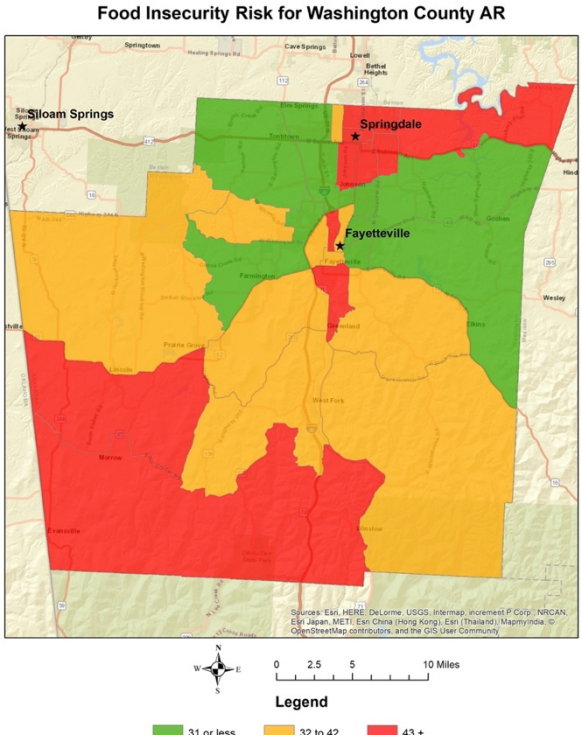

Figure 5: Risk Index Scores Map

Accessibility scores from this thesis are compared with the risk index scores using both qualitative and quantitative methods. Observations are constructed based on visual comparisons between accessibility and risk maps and based also on a box plot that links accessibility and risk scores.

Results

The results of the spatiotemporal analysis case study in Washington County, Arkansas using 2FSCA revealed some areas of improvement to support the NWA Food Bank's already robust work in addressing food insecurity in high-need communities. The findings illustrate the lack of pantry accessibility for rural census block groups in the region and identify a few key areas in Northwest Arkansas that may benefit from more access to food because of spatial and temporal factors. This section is organized into three subsections: spatial accessibility with 10 mile radius, spatiotemporal accessibility with 10 mile radius, and sensitivity analysis of spatial accessibility with 8, 10, and 12 mile radii.

Spatial Accessibility (Radius = 10 Miles, No Temporal Factor)

The first assessment of spatial accessibility with a 10-mile radius of travel yielded pantry spatial accessibility scores for each block group in Washington County, Arkansas. The summary statistics for the results are shown in Table 6.

Table 6: Spatial Accessibility (10-mile Radius) Summary Table

Spatial Accessibility (No Time Factor, 10-mile radius)	
Count	111
Mean	0.811
Standard Deviation	0.458
Minimum	0
Maximum	3.629
Median	0.712
Number of Zeroes	8

The histogram in Figure 6 shows the distribution of accessibility scores among all the block groups in Washington County. Access scores are given on the x-axis. For example, the left-most interval of access scores is [0, 0.125). In the spatial model with a 10-mile radius, approximately 9% of block groups have access scores in this range. Over one-third of block groups have access scores of 1.08 or more. The remaining majority of access scores in the distribution are in the range between 0.5 and 0.75.

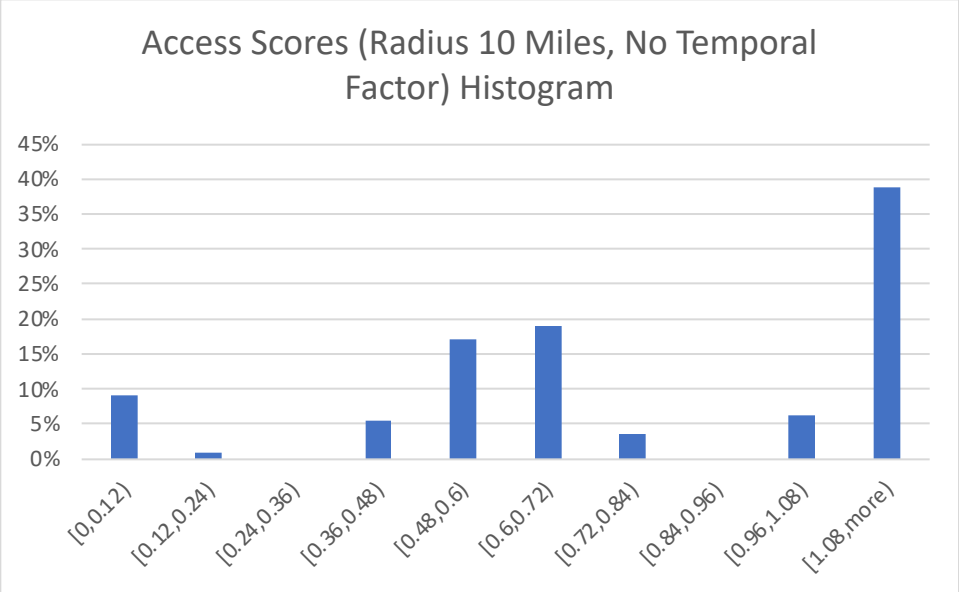

Figure 6: Spatial Accessibility (10-mile Radius) Histogram

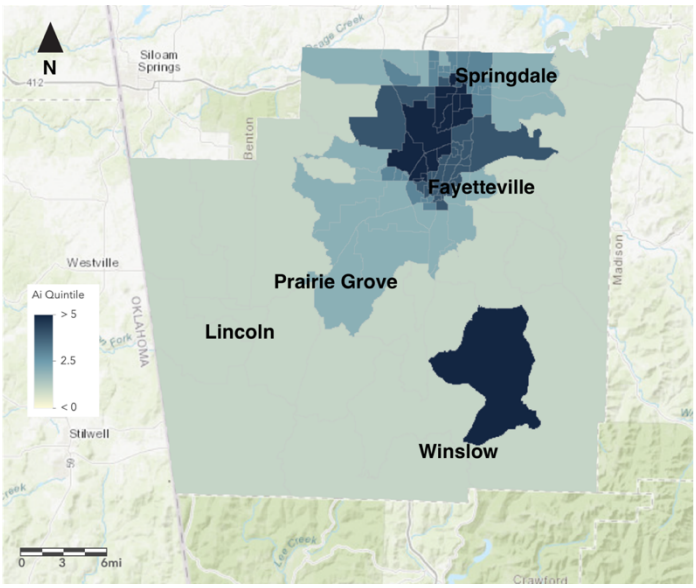

Figure 7: Spatial Accessibility Map

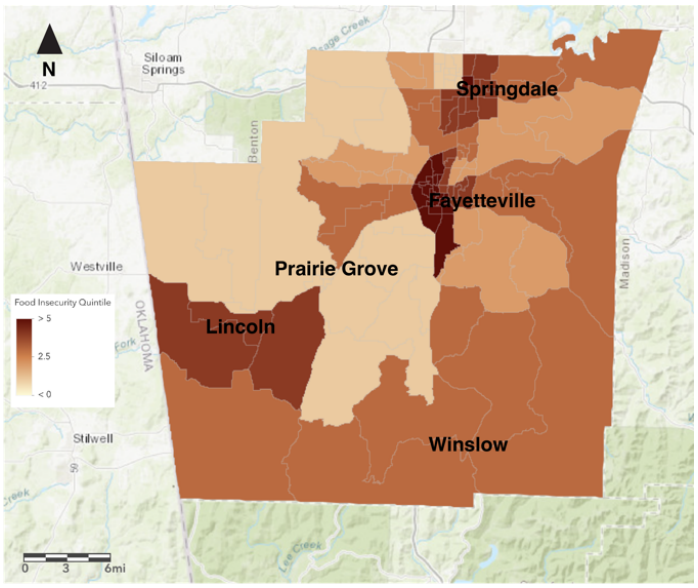

Figure 8: Poverty Map

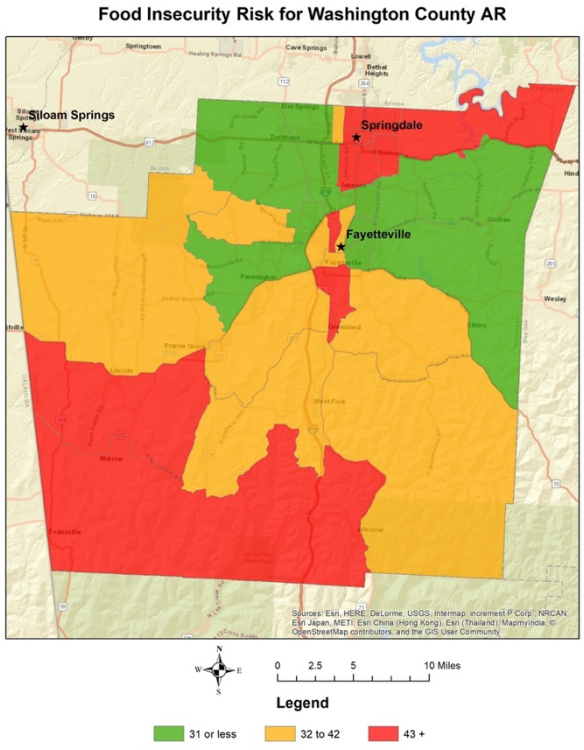

Figure 9: Risk Index Scores Map

ArcGIS mapping software was used to depict block group accessibility by quintile as shown in Figure 7 which is displayed alongside Figures 8 and 9, which will be discussed further.

In Figure 7, a "5" represents the 5th quintile, or the 20% of block groups with the highest access scores. It is important to note that 8 of the 111 block groups resulted in an accessibility score of 0 which would be reflected as 1st quintile, or the lightest blue on the map. These scores of 0 were caused by the centroids of 8 block groups not being within the 10-mile radius of any food pantries. This reflects the lack of pantry accessibility in many of the rural block groups in Washington County. Further sensitivity analysis will be conducted to better understand the effect of the radius of travel on accessibility scores in these rural areas.

This map exhibits how the rural populations in Washington County may be underserved by the NWA Food Bank's pantry network in the county. South Fayetteville and large portions of Springdale are shown as having low access to food pantries. The section of Fayetteville between the University of Arkansas campus and uptown is reflected as having high access to food pantries. The other high access region shown is the block group closest to the Winslow Community Meals food pantry. This pantry is the only pantry within the 10-mile radius of the centroid of block group 111.03-2, so the access score was calculated to be very high.

Figure 8 shows the rate of poverty by block group. In this figure, a "5" represents the 5th quintile, or the 20% of block groups with the highest rates of poverty. While the quintile maps offer only a relative assessment of poverty and pantry accessibility, respectively, comparison of the two maps helps to provide recommendations to the NWA Food Bank on addressing accessibility disparities to the populations that need the meals the most in any given month. Comparisons of the two maps reveal the following noteworthy patterns:

- Pantry access is strongest along Interstate 49 between Fayetteville and Springdale, but the poverty is not as pronounced in some of those same block groups.
- Downtown and south Fayetteville are in the highest quintile for poverty but are only in the 2nd, 3rd, and 4th quintiles for pantry accessibility.
- Southwest Washington County, specifically Lincoln, is underserved by the NWA Food Bank's pantry network as evidenced by its being in the bottom quintile for pantry accessibility and the 4th quintile for poverty.
- The edges of the county, or the most rural block groups, are underserved by the food bank's pantry network as evidenced by the bottom quintile access scores.

Additional observations can be made from comparison of the risk index map (Figure 9) and the food pantry access map (Figure 7):

- Central and south Fayetteville exhibit risk index scores ranging from 40-48 but are only in the 2nd, 3rd, and 4th quintiles for pantry accessibility.
- The southwest and northeast census tracts are at high risk for food insecurity yet are in the bottom quintile of food pantry accessibility.
- The mid-range risk index score census tracts have very limited pantry accessibility, with Winslow Community Meals being one of the only pantries within the 10-mile radius.

We created a box plot to assess the distribution of spatial food pantry access by risk index category. For the plot, we removed 9 outliers of the 111 data points. The outliers included 8 access scores of 0 distributed between the 3 categories as well as the very high access score of 3.6 from census block group 111.03-2 (in the mid-risk category). Removing these outliers and

adjusting the y-axis accordingly allowed for greater focus on the range of access scores experienced in the majority of block groups. The box plot is shown in Figure 10.

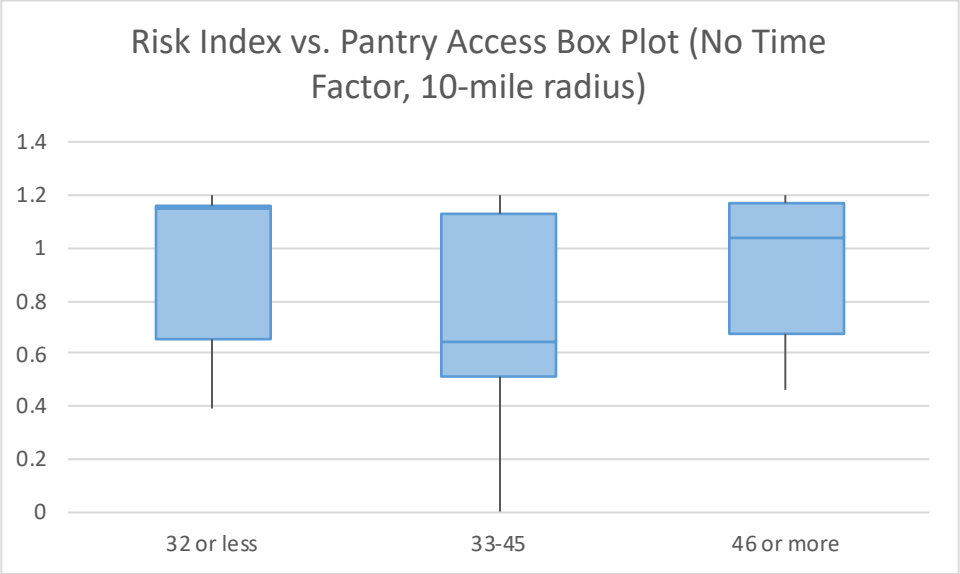

Figure 10: Risk Index vs. Spatial Access Box Plot

The box plot reveals some important findings that help illustrate who is being served by the NWA Food Bank in Washington County and how the food bank may consider expanding upon their work:

- The maximum food pantry access scores for each risk index category are similar, and, with the 1st quartile of each category being nearly at the maximum, the plot shows that many block groups have relatively good access to food pantries, regardless of risk category.
- Using the medians of each category as the criterion for ranking, the lowest risk population is the most well-served by the food pantry network followed by the highest risk population then followed by the mid-risk population.

- The middle 50%, or the block groups with the access scores between the 1st and 3rd quartiles, of each category are similar in access to food pantries, with the greatest variation in access experienced by the mid-risk population.
- The mid-risk block groups exhibit the most variation in food pantry access scores, with a 1st quartile of the population having very low access scores even with the scores of 0 having been removed.
- There were 2, 5, and 1 access scores of 0 in the low, mid, and high-risk categories, respectively. This adds to the concern for the mid-risk block groups and shows that not every block group with the highest risk has access to a food pantry within 10 miles.

Spatiotemporal Accessibility (Radius = 10 Miles, Temporal Factor)

The time-factor trial yielded pantry spatiotemporal accessibility scores for each block group in Washington County, Arkansas. The summary statistics for the results are shown in Table 7.

Table 7: Spatiotemporal Accessibility (10-mile Radius) Summary Table

Spatiotemporal Accessibility (Time Factor, 10-mile radius)	
Count	111
Mean	0.107
Standard Deviation	0.059
Minimum	0
Maximum	0.486
Median	0.096
Number of Zeroes	8

The histogram in Figure 11 shows the distribution of accessibility scores among all the block groups in Washington County. Access scores are given on the x-axis, for example, the left-

most interval of access scores is [0, 0.016). In the spatiotemporal model with a 10-mile radius, approximately 9% of block groups have access scores in this range. Over one-third of block groups have access scores of 0.144 or more. The remaining majority of access scores in the distribution are in the range between 0.064 and 0.096.

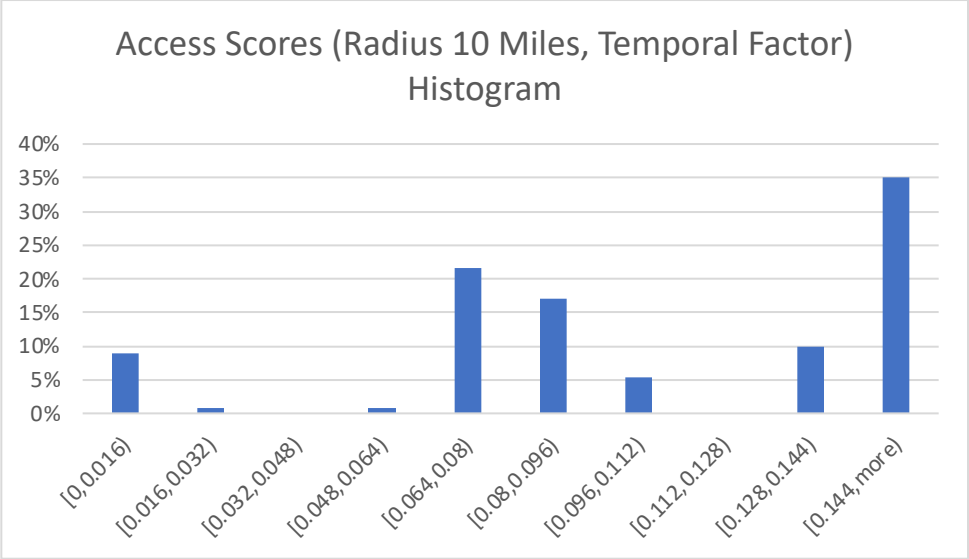

Figure 11: Spatiotemporal Accessibility (10-mile Radius) Histogram

To compare block groups within Washington County, ArcGIS mapping software was used to map accessibility by quintile as shown in Figure 12 which is displayed alongside Figures 13, 14, and 15, which will be discussed further.

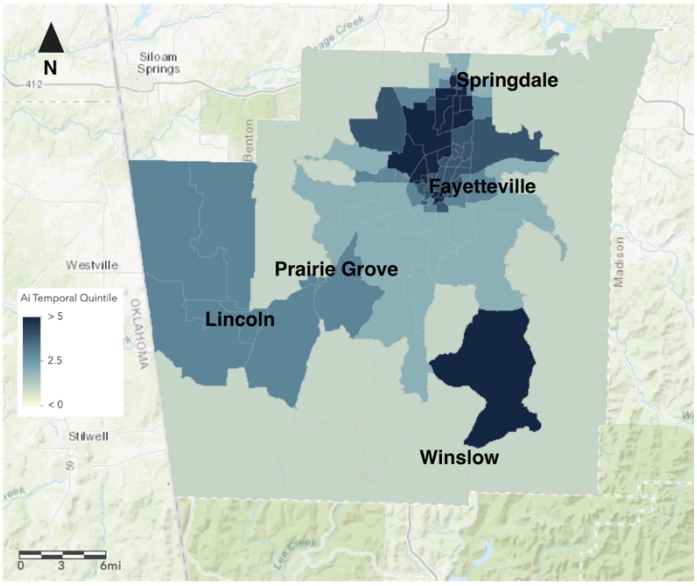

Figure 12: Spatiotemporal Accessibility Map

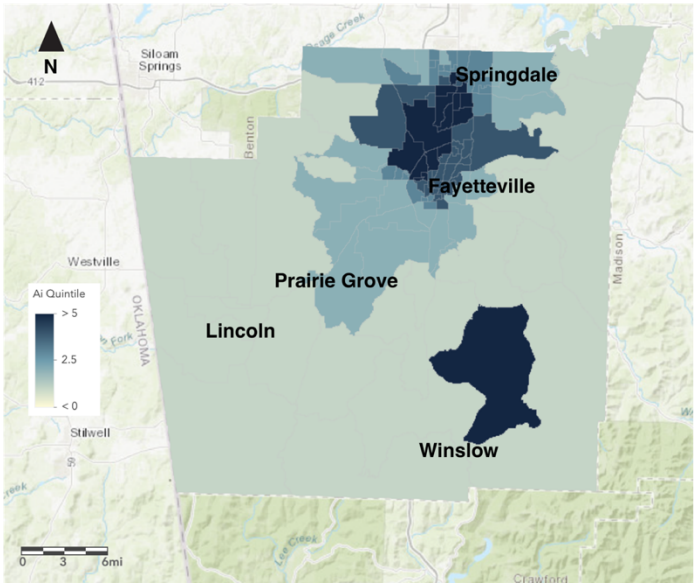

Figure 13: Spatial Accessibility Map (No Temporal Factor)

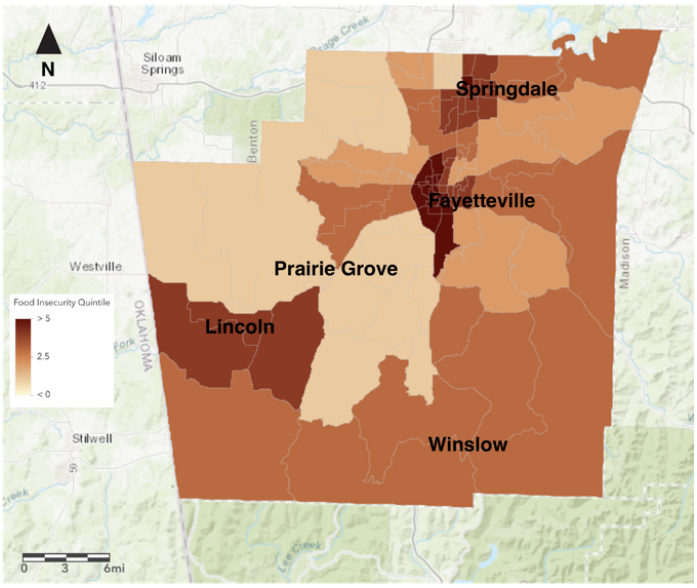

Figure 14: Poverty Map

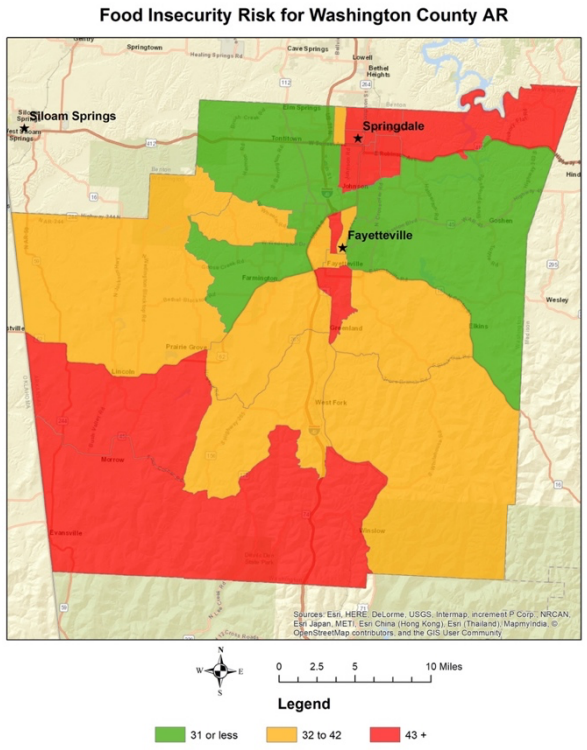

Figure 15: Risk Index Scores Map

In Figure 12, similar to the spatial accessibility map, a "5" represents the 5th quintile, or the 20% of block groups with the highest access scores. It is important to note that 8 of the 111 block groups resulted in an accessibility score of 0 which would be reflected as 1st quintile, or the lightest blue on the map. These scores of 0 were caused by the centroids of 8 block groups not being within the 10-mile radius of any food pantries.

The spatiotemporal accessibility quintile map has some significant differences when compared to the spatial accessibility (Figure 13) quintile map:

- Still, the rural edges of Washington County are underserved by the NWA Food Bank's pantry network, but the rural communities south of Fayetteville's 2nd quintile access scores have expanded in size.
- Lincoln and the western block groups yield 3rd quintile access scores, 2 quartiles higher than those of the spatial access scores.
- Almost every block group in Springdale changed quintile access score from 3rd quintile to 2nd quintile or from 2nd quintile to 1st quintile.
- The block groups making up the section of Fayetteville between the University of Arkansas and Springdale remain almost entirely unchanged.
- The Winslow Community Meals pantry's affected block group (111.03-2) remains in the 5th quintile.

These similarities and differences between the two quintile maps of access scores also point to the effects of time as a factor. For example, the Grace Place food pantry is the only pantry within 10 miles of the western block groups that yield 3rd quintile spatiotemporal access scores in the model. Further inspection of Grace Place's practices show that they are open for 11

hours per week which is in the 85th percentile of hours open for all the pantries in Washington County supplied by the food bank. In contrast, there are many food pantries in the Springdale area with 2 or less hours open per week including St. Joseph, St. Raphael, and Springdale 7th Adventist Church. Comparison of the spatiotemporal map with the poverty map (Figure 14) reveals the following noteworthy patterns:

- Pantry access is still strongest along Interstate 49 between Fayetteville and Springdale, but the poverty is not as pronounced in some of those same block groups.
- Downtown and south Fayetteville are in the highest quintile for poverty but are only in the 2nd, 3rd, and 4th quintiles for pantry accessibility with time as a factor.
- The edges of the county, or the most rural block groups, are underserved by the food bank's pantry network as evidenced by the bottom quintile access scores.
- Western Washington County, specifically Lincoln, has seen a significant increase in quintile score when time is a factor in the model, showing greater service the 4th quintile poverty block groups surrounding Lincoln.
- Many higher-poverty block groups in Springdale are underserved by the food pantry, and this is more pronounced with time as a factor in the model.

A few similar observations can be made from comparison of Dr. Fitzpatrick's risk index map and the food pantry spatiotemporal access map:

- Central and south Fayetteville exhibit risk index scores ranging from 40-48 but are only in the 2nd, 3rd, and 4th quintiles for pantry accessibility.
- The southwest and northeast census tracts are at high risk for food insecurity yet are in the bottom quintile of food pantry accessibility. However, census tract 110.02, the tract

containing Lincoln and the surrounding region, has much higher spatiotemporal access scores than spatial access scores and is serving this high risk population more effectively when time is a factor.

- The mid-range risk index score census tracts are shown to be better served when time is a factor.

We created a box plot to assess the distribution of spatiotemporal food pantry access by risk index category. For the plot, we removed 9 outliers of the 111 data points. The outliers included 8 access scores of 0 distributed between the 3 categories as well as the very high access score of 0.48 from census block group 111.03-2 (in the mid-risk category). The box plot is shown in Figure 15.

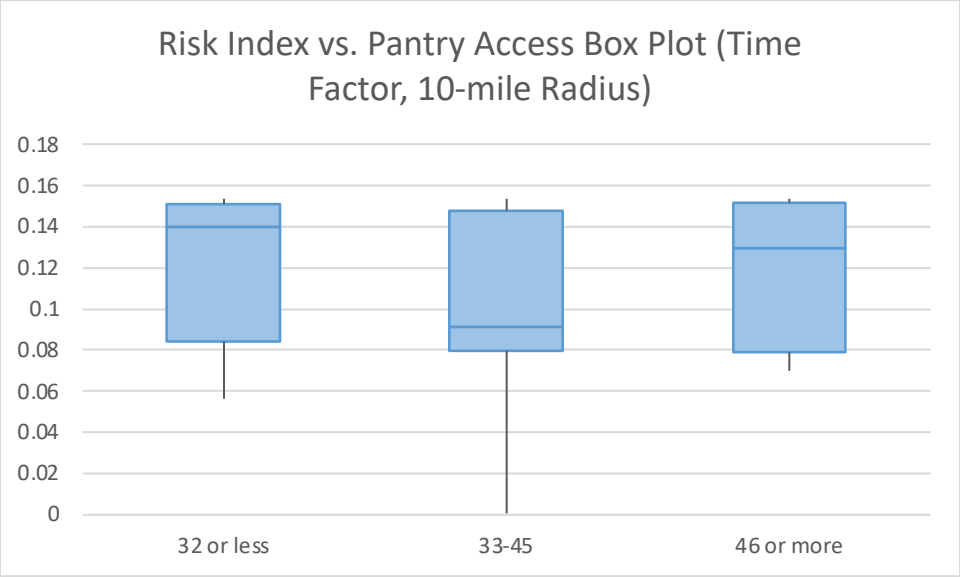

Figure 16: Risk Index vs. Spatiotemporal Accessibility Box Plot

The box plot is very similar to the spatial access scores box plot and reveals some important findings that help illustrate who is being served by the NWA Food Bank in Washington County and how some can potentially be better served:

- The maximum food pantry access scores for each risk index category are similar, and, with the 1st quartile of each category being nearly at the maximum, the plot shows that many block groups have relatively good access to food pantries, regardless of category.
- Using the medians of each category as the criterion for ranking, the lowest risk population is the most well-served by the food pantry network followed by the highest risk population then followed by the mid-risk population.
- The middle 50%, or the block groups with the access scores between the 1st and 3rd quartiles, of each category are similar in access to food pantries.
- The mid-risk block groups exhibit the most variation in food pantry access scores, with a 1st quartile of the population having very low access scores even with the scores of 0 having been removed.
- There were 2, 5, and 1 access scores of 0 in the low, mid, and high-risk categories, respectively. This adds to the concern for the mid-risk block groups and shows that not every block group with the highest risk has access to a food pantry within 10 miles.

Sensitivity Analysis

Finally, to better understand the effect of the maximum travel distance, d_0, in the results of this thesis, sensitivity analysis was conducted. We calculated spatial accessibility scores using 3 separate d_0 values: 8 miles, 10 miles (initial trial), and 12 miles. The temporal factor was not included in this analysis. We then created a histogram displaying the distribution of the accessibility scores from each trial to identify patterns. The histogram is shown in Figure 17.

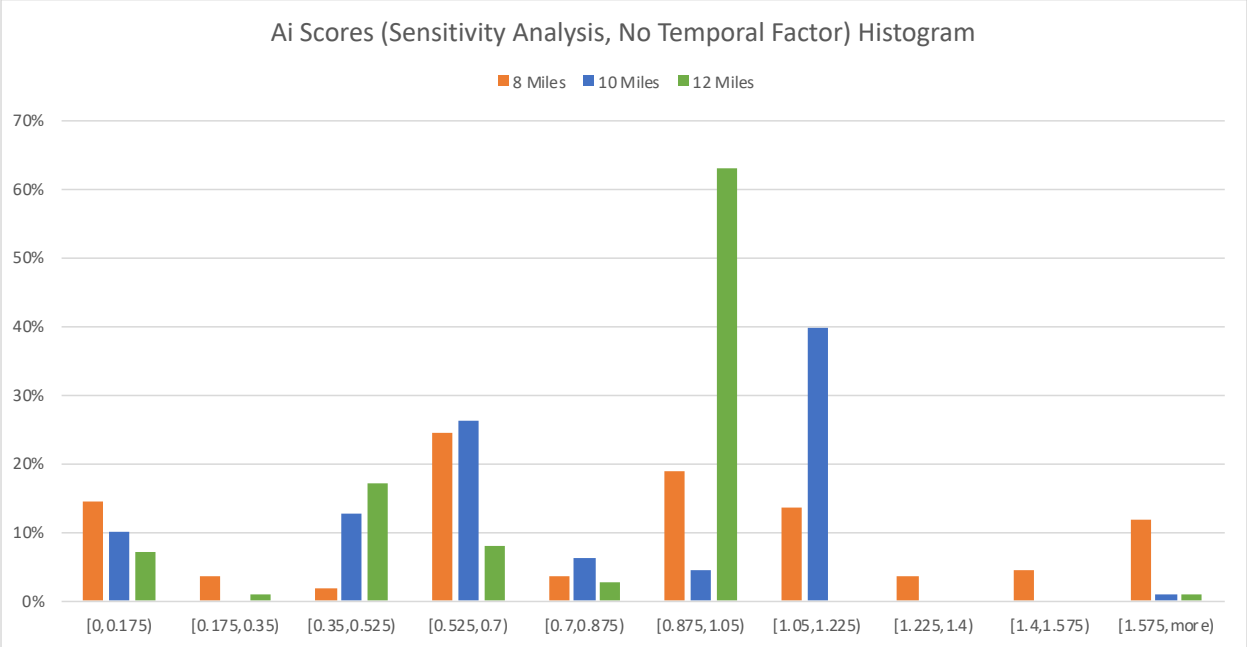

Figure 17: 8, 10, and 12 Mile Radii Histogram

A few conclusions can be drawn from the histogram:

- The 8-mile trial yielded the largest number of 0 values, 11, while the 12-mile trial yielded only 2. This is as expected, as the radius (d_0) directly determines whether a block group will have zero access as a result of not being within d_0 miles of any pantry.
- The 12-mile trial has over 60% of block groups with access scores between 0.875 and 1.05. The larger radius does reduce the number of access scores of 0.
- The 8-mile trial's distribution is the most varied, and, unlike the 10-mile or 12-mile trials, does not have a large proportion of block groups in one bin.
- Accessibility scores, and therefore the results of the thesis, are highly sensitive to the travel radius parameter, d_0.

We would recommend further exploration into human mobility literature as it relates to individuals seeking food access from a pantry or otherwise. We also would recommend having

varied catchment sizes, or maximum distance traveled, based on criteria such as population density or categorizations like urban, suburban, and rural.

Conclusion

We conducted a spatial analysis and a spatiotemporal analysis of food pantry accessibility in Washington County, Arkansas using the Two-Step Floating Catchment Area (2SFCA) method. Data from the Northwest Arkansas Food Bank were used to evaluate the effectiveness of the food pantry network in Washington County at supporting communities with the most need. The results were compared to food insecurity rates of Washington County as well as food insecurity risk index scores based a variety of socioeconomic and demographic factors (Fitzpatrick, Spialek, & Cascante, 2018). Sensitivity analysis was conducted to evaluate the effect of the maximum distance of travel, a key metric that lacked evidence in the literature. In the future, further research should be conducted to better describe human mobility patterns regarding food pantries. A spatial accessibility model is dependent on assumptions regarding human transportation patterns. Model outsights will remain tempered until better data to support good assumptions become available. Also, a variable catchment size can be considered in order to better assess the difference in travel patterns between rural, suburban, and urban block groups. In addition, the temporal factor could consider the desirability of "when" a pantry is open as factor instead of only the quantity of hours the pantry is open. For example, open hours of 1 AM – 3 AM should likely be considered as less desirable than open hours of 5 PM – 7 PM. In the current analysis, the original supply value, S_j, may be already influenced by the number of hours a pantry is open, so expanding on our method could provide more context to the influence of time as a factor of availability in food pantries.

Recommendations for NWA Food Bank

Recommendations that have the potential to increase access in areas that appear to be underserved with respect to the results in this thesis are as follows. However, these recommendations are tempered by a recognition of the limitations of this thesis. Namely, the use of 10 miles as the maximum distance an individual would be willing to travel to receive food from a pantry. A better understanding of willingness and ability to travel to reach a food pantry would improve the value of the models in this thesis and could lead to a different set of recommendations. Further, future work could focus on prescriptive analyses such as optimization that would prescribe hours of service at existing pantries to meet a particular objective or key metric. A separate model could also identify locations for creating new pantries that would increase access in lower access regions.

- Extend the hours of food pantries around Springdale including the following:
    - St. Raphael Catholic Church
    - Springdale Christian Church
    - Springdale 7th Adventist Church
    - Spirit of Truth COGIC Food Pantry Ministry
    - St. Thomas Episcopal Church
    - St. Joseph Tontitown Food Pantry
- Identify or create food pantries to supply with nutritional food in the following areas:
    - Along State Highway 412 near Spring Valley
    - In the Southwestern region of the county, some possibilities include:
        - Antioch Church

        - Hale Mountain Church
        - New Center Point Church
- Establish a stronger presence in the following towns/regions along the belt of mid-risk index scored census tracts:
    - West Fork
    - Prairie Grove
    - Wedington Woods
    - Savoy
- Further investigate the lack of food pantry accessibility in central and south Fayetteville.

Appendix

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Table 8: Pantry Supply Full Table

Pantry Name (j)	**Individuals Served (S_j)**
7hills Homeless Center	486
American Agape Foundation	100
Banford House -Mount Comfort Church of Christ	190
Bread of Life	1,402
Cooperative Emergency Outreach (CEO)	317
Daily Bread	977
Farmington SAWC	191
Fayetteville Christian School	360
Fayetteville School District (Outback)	269
Fayetteville Senior Center	6,682
FBC West Fork	6
Feed the 479	9,392
First United Presbyterian Church Fayetteville	100
Genesis Church	224
Grace Place	829
Harmon UMC	40
Jane B. Gearhart Full Circle Food Pantry	1,031
Life Ministries	345
LifeSource	1,345
Returning Home, Inc.	52
Saint Raphael Catholic Church	160
Second Mile Ministries	244
Sonora Baptist Church	102
Soul Food Pantry	345
Spirit of Truth COGIC Food Pantry Ministry	2,270
Springdale 7th Adventist Church	140
Springdale Christian Church	2,098
St. James Missionary Baptist Church	1,021
St. Joseph Tontitown Food Pantry	143
St. Paul's Episcopal Church	332
St. Thomas Episcopal Church	40
The Salvation Army - Fayetteville	1,892
Trinity United Methodist	629
Washington Regional Faith in Action	15
West Ridge Church	55
Winslow Community Meals, Inc.	682

Table 9: Block Group Demand Full Table

Tract	Block Group	Population	Food Insecurity	Demand (P_k)
10101	1	2,014	13.7%	275.918
10101	2	1,005	13.7%	137.685
10101	3	1,370	13.7%	187.69
10102	1	1,607	9.6%	154.272
10102	2	2,109	9.6%	202.464
10102	3	5,775	9.6%	554.4
10104	1	863	23.0%	198.49
10104	2	823	23.0%	189.29
10104	3	985	23.0%	226.55
10104	4	3,613	23.0%	830.99
10105	1	2,981	11.9%	354.739
10105	2	4,378	11.9%	520.982
10105	3	2,174	11.9%	258.706
10106	1	864	13.6%	117.504
10106	2	547	13.6%	74.392
10106	3	3,147	13.6%	427.992
10106	4	1,423	13.6%	193.528
10107	1	769	10.1%	77.669
10107	2	1,332	10.1%	134.532
10107	3	2,783	10.1%	281.083
10107	4	1,139	10.1%	115.039
10200	1	3,352	20.4%	683.808
10200	2	4,533	20.4%	924.732
10301	1	2,055	16.7%	343.185
10301	2	4,328	16.7%	722.776
10301	3	1,552	16.7%	259.184
10301	4	2,035	16.7%	339.845
10302	1	874	18.1%	158.194
10302	2	4,183	18.1%	757.123
10302	3	5,619	18.1%	1017.039
10302	4	4,763	18.1%	862.103
10401	1	2,056	9.0%	185.04
10401	2	1,107	9.0%	99.63
10401	3	856	9.0%	77.04
10401	4	1,697	9.0%	152.73
10401	5	944	9.0%	84.96

Tract	Block Group	Population	Food Insecurity	Demand (P_k)
10402	1	975	8.4%	81.9
10402	2	1,166	8.4%	97.944
10402	3	2,885	8.4%	242.34
10403	1	2,152	18.1%	389.512
10403	2	3,413	18.1%	617.753
10403	3	2,603	18.1%	471.143
10501	1	1,798	7.2%	129.456
10501	2	2,056	7.2%	148.032
10501	3	2,513	7.2%	180.936
10503	1	805	12.7%	102.235
10503	2	3,545	12.7%	450.215
10503	3	4,501	12.7%	571.627
10504	1	1,070	7.9%	84.53
10504	2	2,631	7.9%	207.849
10504	3	1,191	7.9%	94.089
10504	4	1,478	7.9%	116.762
10504	5	942	7.9%	74.418
10506	1	5,735	11.8%	676.73
10506	2	3,635	11.8%	428.93
10506	3	1,909	11.8%	225.262
10507	1	1,192	11.3%	134.696
10507	2	5,974	11.3%	675.062
10507	3	1,920	11.3%	216.96
10508	1	1,383	10.2%	141.066
10508	2	1,425	10.2%	145.35
10508	3	692	10.2%	70.584
10508	4	3,270	10.2%	333.54
10509	1	2,573	11.1%	285.603
10509	2	2,475	11.1%	274.725
10509	3	3,697	11.1%	410.367
10510	1	1,566	4.2%	65.772
10510	2	1,197	4.2%	50.274
10510	3	2,189	4.2%	91.938
10600	1	2,199	27.9%	613.521
10600	2	2,175	27.9%	606.825
10600	3	816	27.9%	227.664
10600	4	1,658	27.9%	462.582
10701	1	1,875	39.4%	738.75

Tract	Block Group	Population	Food Insecurity	Demand (P_k)
10701	2	2,707	39.4%	1066.558
10701	3	1,227	39.4%	483.438
10701	4	1,730	39.4%	681.62
10702	1	1,656	22.4%	370.944
10702	2	1,380	22.4%	309.12
10702	3	1,242	22.4%	278.208
10702	4	1,605	22.4%	359.52
11001	1	3,041	8.3%	252.403
11001	2	3,330	8.3%	276.39
11001	3	2,692	8.3%	223.436
11001	4	948	8.3%	78.684
11002	1	2,682	21.3%	571.266
11002	2	1,606	21.3%	342.078
11002	3	952	21.3%	202.776
11003	1	1,286	7.0%	90.02
11003	2	2,363	7.0%	165.41
11003	3	1,496	7.0%	104.72
11004	1	1,182	13.6%	160.752
11004	2	862	13.6%	117.232
11004	3	1,228	13.6%	167.008
11101	1	1,401	42.4%	594.024
11101	2	3,336	42.4%	1414.464
11101	3	1,435	42.4%	608.44
11101	4	1,749	42.4%	741.576
11102	1	3,690	10.4%	383.76
11102	2	2,695	10.4%	280.28
11102	3	1,165	10.4%	121.16
11103	1	1,423	14.4%	204.912
11103	2	1,305	14.4%	187.92
11103	3	1,190	14.4%	171.36
11200	1	2,081	28.0%	582.68
11300	1	769	52.6%	404.494
11300	2	1,239	52.6%	651.714
11300	3	1,372	52.6%	721.672
11300	4	4,672	52.6%	2457.472
11300	5	0	52.6%	0
11300	6	618	52.6%	325.068

Table 10: Pantry Hours Open Full Table

Agency Name	Hours Open	Details
7hills Homeless Center	37.5	Monday-Friday 8am-4pm
American Agape Foundation	3.9	15th of every month- hours differ (estimated with trendline)
Banford House -Mount Comfort Church of Christ	2	Wednesday 9-11:00 am
Bread of Life	5	Wednesday & Thursday 9-11:30 am
Cooperative Emergency Outreach (CEO)	6	Monday, Wednesday, Friday 1-3pm
Daily Bread	5	Wednesday & Thursday 9-11:30 am
Farmington SAWC	1.5	Private
Fayetteville Christian School	5	Monday-Friday 5-6:00 pm
Fayetteville School District (Outback)	4.1	Private (estimated with trendline)
Fayetteville Senior Center	9.8	Private (estimated with trendline)
FBC West Fork	18	Tuesday, Wednesday, Thursday 9:00 am-3:00 pm: Apointments Only
Feed the 479	8.5	Monday-Wednesday 5-7:00 pm & Thursday 9:30-11:30am, every 3rd Sat 9-11am
First United Presbyterian Church Fayetteville	3.9	Not provided (estimated with trendline)
Genesis Church	9.5	Tuesday & Wednesday 11-3pm for groceries. Thursdays 5:30 to go dinner.
Grace Place	11	Tuesday 9:00 am-12:00 pm & 6-8:00 pm; Thursday & Saturday 9:00 am-12:00 pm
Harmon UMC	0.4	Every 3rd Wednesday 9:30-11am
Jane B. Gearhart Full Circle Food Pantry	11	Monday 11am-3pm, Wednesday 3pm-6pm, & Thursday 10am-2pm
Life Ministries	6	Tuesday and Thursday 9:00 am-12:00 pm
LifeSource	11.5	Monday 8:30-11:30 am & 6-7:00 pm; Wednesday 8:30-11:30 am; Thursday 8:30-11:30 am & 5:30-7:00 pm
Marshallese Enra Food Pantry	8	Wednesday 9am-5pm
Returning Home, Inc.	3.9	Private (estimated with trendline)
Saint Raphael Catholic Church	2	Tuesday and Thursday 5:45-6:45 pm
Samaritan Community Center	5	Tuesday and Thursday 10:00 am-12:30 pm

Agency Name	Hours Open	Details
Second Mile Ministries	5	Monday & Wednesday 9:00am-11:30 am
Sonora Baptist Church	3.9	Wednesday & Sunday (estimated with trendline)
Soul Food Pantry	6	Tuesday 10:00am-2:00pm, 5:00-7:00pm
Spirit of Truth COGIC Food Pantry Ministry	2	Saturday's 9-11:00 am
Springdale 7th Adventist Church	1	Wednesday 5-6:00pm
Springdale Christian Church	3	Sunday 9:00 am-12:00 pm
St. James Missionary Baptist Church	2	Tuesday 11:00 am-1:00 pm
St. Joseph Tontitown Food Pantry	1.5	Monday 5:30-7:00 pm
St. Paul's Episcopal Church	5.5	Tuesday and Thursday 9-11:45 am
St. Thomas Episcopal Church	0.5	Every third Friday 5:00 pm
The Salvation Army - Fayetteville	5.5	Monday & Wednesday 1:00pm (estimated with trendline)
Trinity United Methodist	2.5	Wednesday 4-6:30pm
Washington Regional Faith in Action	42.5	By appointment. Monday – Friday 8:00 a.m. – 4:30 p.m.
West Ridge Church	2	Monday 11:30 am-1:30 pm
Winslow Community Meals, Inc.	7.5	Monday-Friday 11:30am-1:00 pm