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Use of GIS Spatial Analysis to Identify Food Deserts in the State of Alabama

By Virginia P. Sisiopiku[*]
Natalia Barbour[†]

Availability and accessibility to fresh foods plays an essential role in public health and individual wellbeing. Unfortunately, a significant amount of the US population today has limited access to supermarkets, farmers markets or other sources of healthy, nutritious and affordable whole food diet options. This phenomenon is known as "food deserts". Current literature suggests that there is a link between food deserts and high obesity and poverty rates. Identifying the exact location of food deserts, and analyzing contributing factors and social demographics can help to minimize the negative social effects of food deserts. This study investigated the extent of the food desert problem in Alabama and its potential repercussions on the health and wellbeing of Alabamians. Data were obtained from the United States Department of Agriculture (USDA) and analyzed using Geographic Information Systems (GIS) analysis tools. A base GIS map layer for county level analysis was obtained from census.gov. The base layer was joined with pertinent data and maps were created in ArcGIS software to display graphically the intensity of select variables. Moran's statistics were implemented to determine hot and cold spots and statistical significance. The analysis results identified counties in the state of Alabama with the greater need for accessibility to fresh foods. The study findings are very useful for urban planning purposes and for prioritizing efforts to minimize the negative social effects of food deserts in the future. Implementation of initiatives that educate local residents about the importance of making healthy food choices, location of stores providing fresh foods in areas of need, and improvement of local residents' accessibility to such establishments should be considered as a priority.

Introduction

It has been long recognized that healthy lifestyle and good eating habits protect society from diseases, prevent obesity and help extend life expectancy. Earlier studies confirm that the consumption of fresh, non-processed foods is

[*]Associate Professor, University of Alabama at Birmingham, USA.
[†]Graduate Research Assistant, University of Alabama at Birmingham, USA.

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an essential factor in maintaining good health. However, millions of US residents live in areas that have limited access to supermarkets, farmers markets or other sources of healthy, nutritious and affordable whole food diet options. This phenomenon is known as "food deserts".

The concept of "food deserts" applies to urban neighborhoods and rural towns without ready access to fresh, healthy, and affordable foods. These communities either have no access to food or may be served only by fast food restaurants and convenience stores that offer few healthy, affordable food options" [United States Department of Agriculture, undated].

The USDA's Economic Research Service estimates that 23.5 million people in the US live in food deserts, more than half of which come from low-income families [United States Department of Agriculture, undated]. It has also been established that the lowest income households pay proportionally more for food than higher income households [Hendrickson *et al.*, 2006]. A combination of higher food prices and inaccessibility to fresh produce is likely to contribute to higher rates of diseases, obesity and mortality among people living in poverty.

Since the food choices that people make are determined by what is available in their close proximity and given that accessibility is an important factor in forming eating habits, individuals living in areas with significant number of convenience stores are more likely to adopt high calorie, low nutrients diets [Morland *et al.*, 2002-1]. Moreover, disadvantaged population segments are less likely to own a car, thus often depend on walking or transit use in order to meet their travel needs, including grocery shopping.

Background

Preliminary studies in the US confirm that the problem of food deserts touches the southern regions of the country the most. Figure 1 shows the percentage of people with no car and no access to supermarket. According to Figure 1, states where five percent or more of their population has no car and no supermarket within a mile are Louisiana, Alabama, Mississippi, Georgia, Kentucky, West Virginia, Virginia, North Carolina and South Carolina, nearly all of which are located in the South. Thus a pressing need exists in these states to understand better the extent of the food accessibility problem and take measures to address it.

At the national level, a 2013 study by the Center for Disease Control that analyzed the prevalence of self-reported obesity among U.S. adults shows a similar pattern. There are six states with high obesity rates and high percentage of population without a car and supermarket within one mile namely Louisiana, Alabama, Mississippi, Kentucky, West Virginia and South Carolina. Obesity indicators are important as earlier studies have linked obesity to other health conditions such as high-blood pressure, heart disease, diabetes and even cancer [Ghadirian *et al., 2009,* WCRF/AICR, 1997, and Hu *et al.*, 2011].

Figure 1. *No Car and no Supermarket within a Mile. (Reprinted from Gallagher M. (2001). "USDA Defines Food Deserts", Nutrition Digest, American Nutrition Association: 36(3)*

The state of Alabama is in the top tier of states with respect to high obesity rates. According to recent data, Alabama is now the fifth most obese state in the entire country [Levi *et. al*., 2013]. The adult obesity rate is 33%, up from 28.4% in 2003 and triple the 11.2% in 1990. Also, Alabama is ranked number one among all the states with regards to hypertension rates and third with regards to diabetes [Levi et. al., 2013].

To reverse these trends and prevent the rates of obesity and diseases from increasing further in Alabama, it is crucial to identify the areas where these phenomena are the most prevalent within the state and examine the factors that possibly have an influence on the situation. Identifying important contributing factors can help in better understanding the roots of the problem and thus recommend proper countermeasures to address the issue in an effective manner.

The objective of this paper is to study the magnitude of the food desert problem in the state of Alabama. Geographic Information Systems (GIS) analysis is employed to identifying the locations that experience the food desert phenomenon across the state of Alabama. Such information is very useful for urban planning purposes and for prioritizing efforts to minimize the negative social effects of food deserts.

Methodology

In order to analyze the extent of the food deserts phenomenon in Alabama, data regarding risk factors and demographics were gathered. The 2010 county

level data were obtained from the United States Department of Agriculture (USDA) (Economic Research Service, undated) and divided in the following categories:

- Access and Proximity to Grocery Store
- Store Availability
- Restaurant Availability and Expenditures
- Food Assistance
- Food Prices and Taxes
- Local Foods
- Health and Physical Activity
- Socioeconomic characteristics

Access and Proximity to Grocery Store data, in general, describe population access to food stores. Store Availability data provide information on the number and type of stores per particular number of people (usually 1,000 population). Restaurant Availability and Expenditures records include details on the type and location of restaurants as well as their number per 1,000 people. Food Assistance figures contain variables such as Supplemental Nutrition Assistance Program (SNAP) participants, School Breakfast Program participants or household food insecurity data. The Prices/Taxes category has data on the general food sales taxes and ratios of different products in particular county over the national average price. Local Foods files provide information on farmers' markets distributions or agro tourism operations. Health and Physical Activity data give obesity rates in each county (among adults and children), diabetes rates and supply of recreation and fitness facilities. Socioeconomic characteristics files were also used as they provide information on poverty rates, children in poverty and give percentages of white, black, Hispanic, etc. by county.

The literature review has suggested that the poverty, obesity, accessibility and price should be all taken into consideration while analyzing food deserts occurrence. Thus the following variables were selected for analysis in this study:

- No access to the store and no car available (%)
- Low income and low access to the store (%)
- Grocery stores number per population of 1,000 (number/1,000 pop)
- Convenience stores number per population of 1,000 (number/ 1,000 pop)
- Fast food restaurants number per population of 1,000 (number/ 1,000 pop)
- Poverty rate (%)
- Obese adults (%)
- Low-income obese preschool children (%)

- Low fat milk price over the national average price (ratio)
- Soda price over the national average price (ratio)
- White population (%)
- Black population (%)

The base layer for each map for county level analysis was obtained from census.gov. So as to achieve systematic maps, each study variable was divided into three ranges: low, medium and high for display purposes. Depending on whether one was interested in high or low occurrence of a particular variable, the high/low range was set to be approximately to 30% (or less) of the total range for the variable. The base layer was then joined with the Alabama data file and different variables and their incidence were displayed on maps created in ArcGIS software.

In addition to simple observation of trends, statistical tools available through ArcGIS were implemented in the analysis. The core layer of the analysis referred to areas with the low accessibility to stores. External variables were introduced in these areas for pattern observation. Hot/Cold spots were considered to determine whether or not any form of clustering was present. Moreover, Moran's statistics were applied to measuring autocorrelation based on locations and values simultaneously. The above methodology allowed examination of multiple variables in the zones of low food accessibility.

GIS and Statistical Analysis and Results

A base layer map for the state of Alabama (county level) was used along with data from the USDA (also county level). To identify the counties in which there is a high/low occurrence of certain phenomenon, each variable was first displayed on a separate map. For example, Figures 2 and 3 help to identify the counties within the state of Alabama where the food deserts incidents occur on the basis of a. the percentage of households with no car & low access to the store, and b. the percentage of households with low income and low access to the store, respectively. It can be seen that the most disadvantaged Alabama counties with respect to food accessibility are the ones that appear in the high bracket on both maps and those are Greene, Wilcox, Monroe, Crenshaw, Lowndes, Bullock and Macon counties.

Similar analyses were performed for all study risk factors and the following observations were made:

- The adult obesity rates reach almost 50% in some counties and are higher than preschool children obesity rates which reach up to 27% in some areas. Based on the data, five Alabama counties have both high adult and high preschool children obesity occurrences, namely Greene, Marengo, Wilcox, Bullock, and Chilton counties.

Figure 2. *Households with no Car and Low Access to the Store (%), 2010*

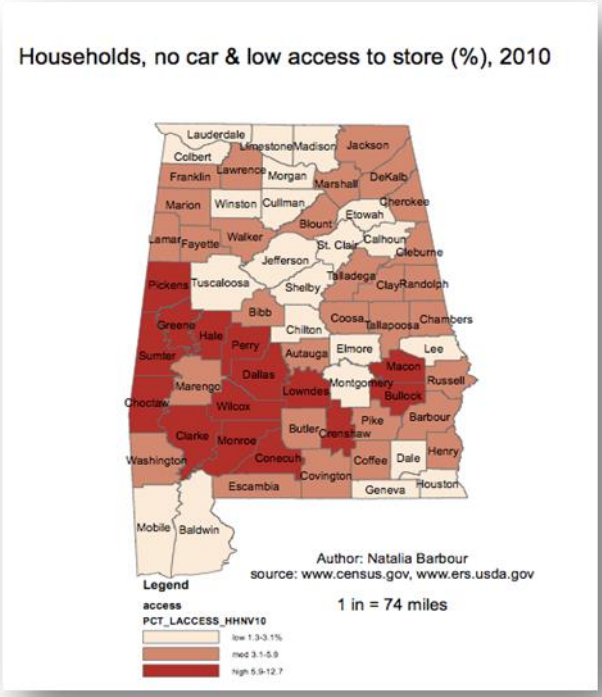
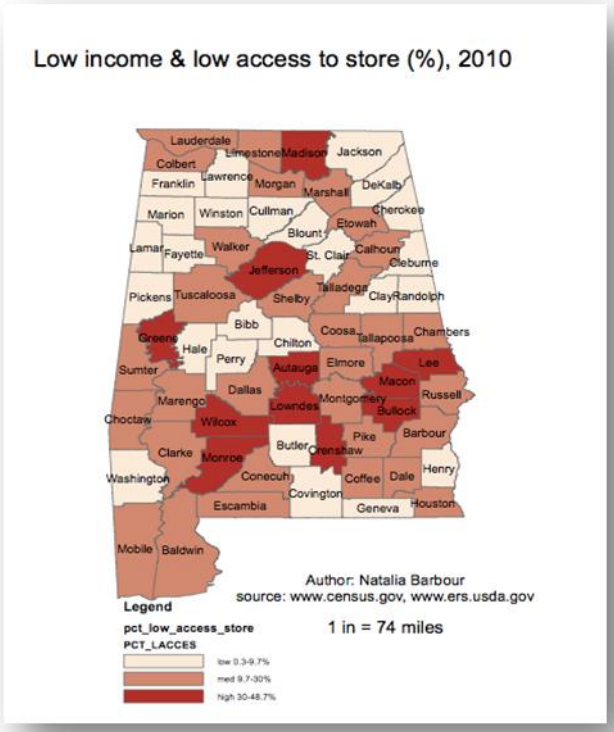


Figure 3. *Low Income and Low Access to the Store (%), 2010*



- With regards to food accessibility, the areas with the lowest number of grocery stores are located in the mid-west section of the state in close proximity to each other. On the other hand, convenience stores locations appear to be more random. Moreover, the entire state of Alabama has substantial number of fast food restaurants with only 13 out of 67 counties having less than 0.37 fast food restaurants per 1,000 of population.
- Low fat milk price are found higher than the national average price in 19 out of 67 counties with only 4 Alabama counties showing low fat milk price lower than the national average. While comparing the price of low fat milk and soda it appears that the high range ratio for milk is 1-1.14 versus 0.99-1.00 for soda. This implies that the soda price does not exceed the national average anywhere in the state of Alabama, which in turn makes it an attractive choice for the consumer.
- Socioeconomic factors, such as poverty rate and percentage of racial minorities, are not randomly dispersed around the state.

The next part of the analysis implemented statistical tools built in the ArcGis software in order to define whether there are any clustering tendencies. This analysis used cluster and outlier analysis (Anselin Local Moran's I Spatial Statistics) and measured potential spatial autocorrelation (Global Moran's I Spatial Statistics). Very small p-value indicates that it is highly unlikely that the observed spatial pattern is the result of random processes. The output feature class for cluster of high values (HH) and low values (LL) was statistically significant at the 5% level (p=0.05). As an example, the results from the statistical analysis for households with no car and low access to a grocery store are shown in Figures 4 and 5.

According to the spatial autocorrelation report (Figure 4), there is less than 1% chance that the cluster pattern is the result of random chance. The clustered counties with the highest number of households with no car and no access to store are shown on Figure 5.

The results for the low-income and low access to the store cluster also are significant at the 90% confidence level. In other words, there is less than 10% chance that the clustered pattern happened due to chance (Figure 6). The counties with high values of low-income and low access to the store are shown in Figure 7.

In a similar manner other variables were analyzed. The hot and low spots were examined for occurrence of other risk factors and the summary results are displayed in Table 1. Using the capabilities of GIS mapping and a thorough and systematic examination of factors related to poverty, obesity, accessibility and price across the state of Alabama led to the identification of many significant county clusters (Table 1). Cross category comparison can identify counties with the highest amount of coexisting risk factors.

Figure 4. *Spatial Autocorrelation Analysis on Households with no Car and Low Access to Store, 2010*

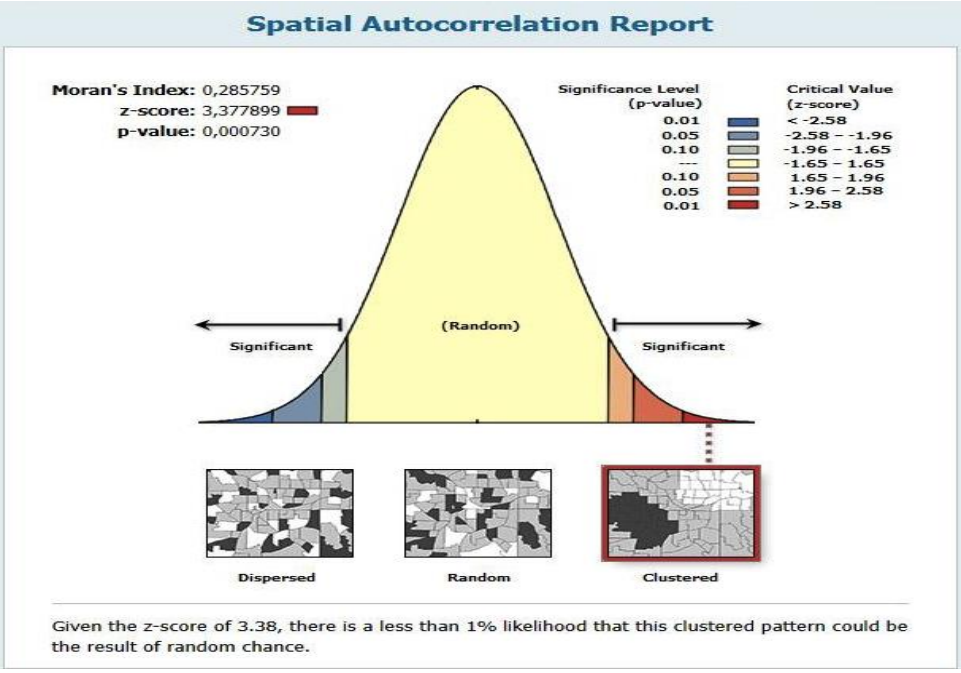


Figure 5. *Cluster Analysis on Households with no Car and Low Access to Store, 2010*

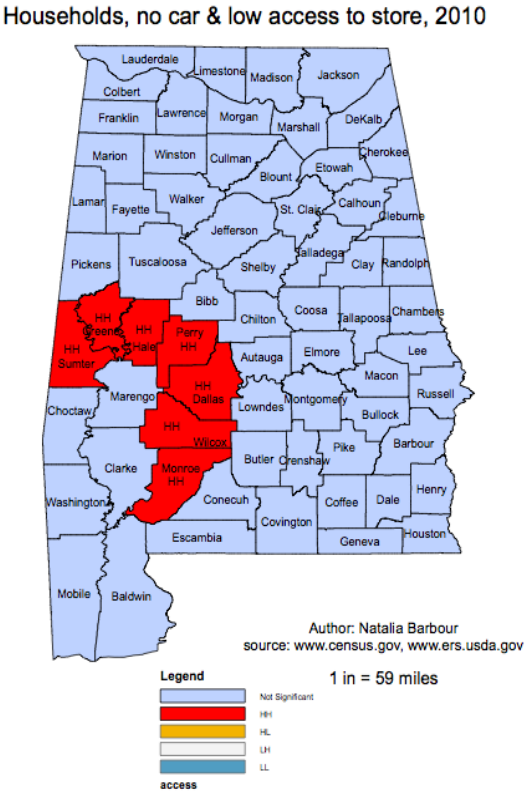


Figure 6. *Spatial Autocorrelation Analysis on Households with Low-income and Low Access to Store, 2010*

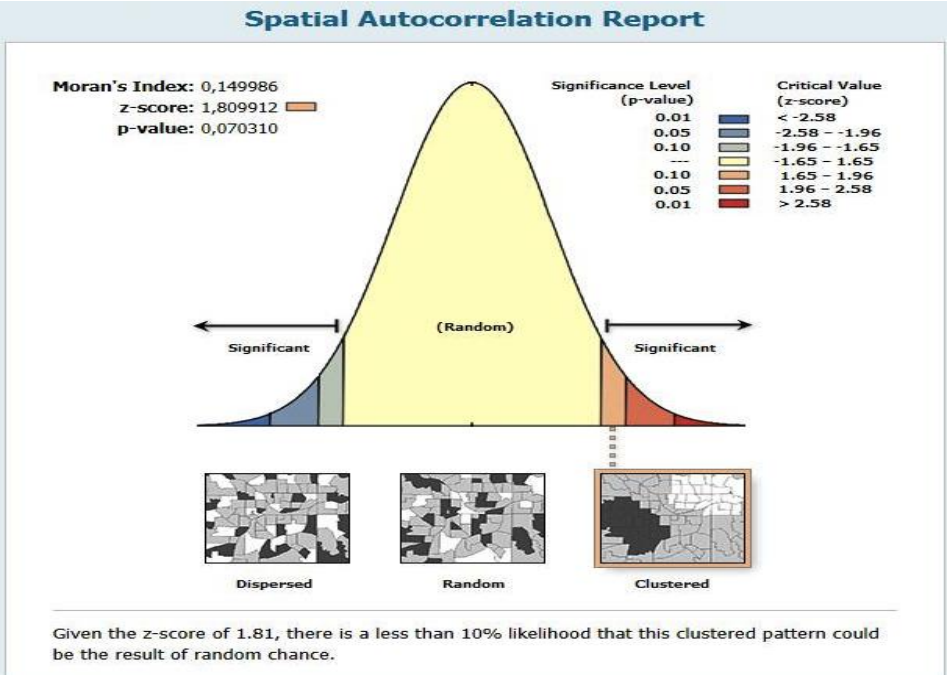
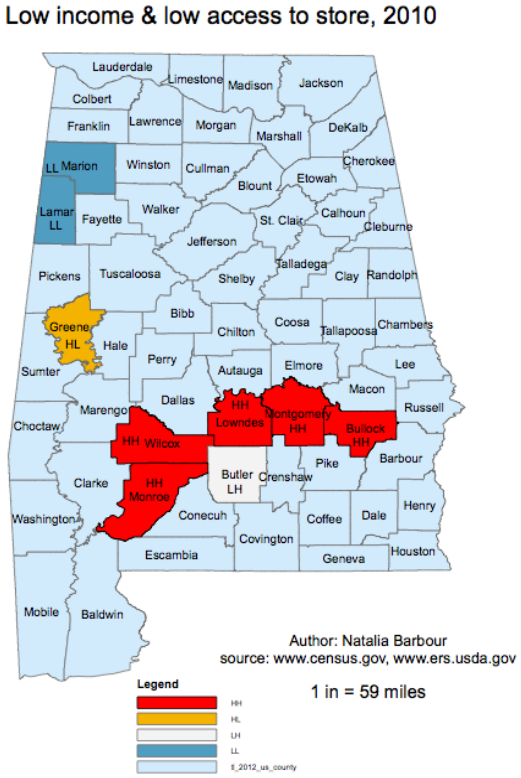


Figure 7. *Cluster Analysis on Low-income Population with Low Access to Store, 2010*



Discussion

The findings of the study show that the most disadvantaged Alabama counties with regards to car and food accessibility are Sumter, Greene, Hale, Perry, Dallas, Wilcox and Monroe and the chance of this spatial autocorrelation being random of less than 1%. Counties with the lowest income and the lowest access to grocery stores are Greene, Wilcox, Monroe, Lowndes, Montgomery, and Bullock (less than 10% chance of the pattern being formed due to chance). Combining these two categories into one gives a good idea about the current locations of the food deserts in Alabama and identifies Sumter, Greene, Hale, Perry, Dallas, Wilcox, Monroe Lowndes, Montgomery, and Bullock as the counties with the highest prevalence of food deserts. Based on the results of the analysis the most disadvantaged counties are Greene, Wilcox and Monroe as their residents only have limited access to a car but also are low-income households with low supermarket availability.

The literature review suggests that the highest obesity rates occur in areas with the most limited access to grocery stores. This has been also confirmed in the state of Alabama through the analysis performed in this study. Custer analysis maps determining hot spots for obesity with the probability of clusters less than 1% are almost identical to hot spots for counties with regards to low car and store accessibility. According to 2010 data, the most obese counties were found to be Sumter, Greene, Hale, Dallas and Wilcox. Low-income preschool children obesity rates (with less than 10% chance that the spatial autocorrelation pattern is random) were identified as high in Greene, Wilcox, Franklin, Marshall and DeKalb counties. Again, Greene and Wilcox counties were areas that appear to need the most urgent attention.

The statistical results for the number of grocery and convenience store and fast food restaurants amount per 1,000 population were not significant and their distributions did not exhibit any clustering propensities. Low-fat milk and soda price distributions, on the other hand, have shown very strong clustering tendencies in Alabama with counties experiencing low-fat milk price above the national average mostly in the southern parts of the state and soda price oscillating around countrywide mean.

The literature also pointed to poverty as a contributing factor in food deserts occurrence and the analysis confirmed that this also holds true in the state of Alabama. The highest rates of poverty were observed in Sumter, Geene, Perry, Dallas, Wilcox, Monroe, and Bullock with less than 1% probability that this clustering is due to chance. Apart from Bullock, all of the above counties were also found significant for the no car and low access to store. Bullock county was one of the significant areas for the low income and low access to store. It is also interesting to note that four counties experiencing poverty and low car ownership, low income and compromised accessibility to grocery stores (namely Sumter, Geene, Wilcox, Monroe) were also found significant for adult obesity.

Table 1. *Summary Results*

VARIABLE	p-VALUE	SIGNIFICANT HH COUNTIES
No access to the store and no car available (%)	p=0.0007	Sumter, Greene, Hale, Perry, Dallas, Wilcox and Monroe
Low income and low access to the store (%)	p=0.070	Greene, Wilcox, Monroe, Lowndes, Montgomery, and Bullock
Obese adults (%)	p=0.0002	Sumter, Greene, Hale, Dallas and Wilcox
Low-income obese preschool children (%)	p=0.069	Greene, Wilcox, Franklin, Marshall and DeKalb
Grocery stores number per population of 1,000 pop	p=0.368	Not significant
Convenience stores number per population of 1,000 pop	p=0.180	Not significant
Fast food restaurants number per population of 1,000 pop	p=0.246	Not significant
Low fat milk price over the national average price (ratio)	p=0.000	Choctaw, Washington, Marengo, Clarke, Monroe, Conecuh, Escambia, Geneva, Houston, Dale, Barbour, Henry, Russell
Soda price over the national average price (ratio)	p=0.000	Clarke, Mobile, Baldwin, Escambia, Geneva, Dale, Henry, Geneva, Henry, Houston
Poverty rate (%)	p=0.000	Sumter, Geene, Perry, Dallas, Wilcox, Monroe, and Bullock
White people (%)	p=0.000	Marion, Winston, Cullman, Blount, Cherokee
Black people (%)	p=0.000	Sumter, Greene, Hale, Perry, Dallas, Wilcox, Lowndes, Montgomery, Macon, Bullock

Moreover, there is a clear division between White and Black neighborhoods in the state of Alabama and is common for counties to be predominately inhabited by a single race group. As far as race is concerned, the study pointed out that those counties that are hot spots for percent of black residents exhibit less than 1% chance that this pattern being random. Moreover, these are the same counties which are found significant for household with no car and low access to store, low income and low access to store, high obesity and poverty rates. It can be concluded that the problem of food deserts in Alabama affects African Americans disproportionally more than Whites, thus creating another layer of disparities that needs to be addressed in a fair, equitable, and effective way.

Conclusions and Recommendations

Taking all factors into consideration the study results demonstrate that the most affected counties in the state of Alabama in terms of low access to store, high obesity and poverty rates are Sumter, Geene, Wilcox, Monroe, and Bullock. Observation of the findings shows that the counties in greater need are located in rural areas in the so called "black belt". It should be noted, however, that other counties may also have pockets where food deserts are an important issue that requires attention. For example, the Jefferson County was not one of the counties that surfaced as those of greater need. Still, detailed analysis of the Birmingham region in Jefferson County in the study by Gallagher [2010] showed that Birmingham experiences food deserts and food imbalance conditions that impact quality and length of life, especially for the urban poor.

Since the most disadvantaged counties have been determined, actions should be taken in addressing the issue of food deserts in Alabama. It is recommended that educational outreach programs be implemented in schools and work places in the affected counties to promote healthy eating habits. Such programs would inform about the benefits of healthy diet and social and economic consequences of diets high in processed foods and encourage participants to alter their eating patterns and seek healthier alternatives.

It is also recommended that the disadvantaged counties are studied more closely using zip code data analysis. Such analysis will help identify the exact locations where a grocery story carrying healthy options can be placed to address current and future needs. Moreover, additional risk factors (e.g., family size, education level, etc.) can be mapped and analyzed in the future. It is further recommended that additional analysis be undertaken in order to identify the exact locations of food deserts, especially in urban areas in Alabama, where the county wide analysis may be too aggregated to show a complete picture. However, such analysis will require more detailed information such as zip code data which may be difficult to obtain.

In addition to placing more grocery stores that carry fresh foods in close proximity to disadvantaged neighborhoods, modifying the assortment of current convenience stores is suggested. Encouraging the retailors to offer fresh produce at their local stores could positively affect public health at these locales. Also, because food can also be obtained from vending machines, modifying the choices that vending machines offer would provide additional opportunities to residents for making a healthy food selection. Finally, imposing local taxes on unhealthy foods options can be used as a disincentive for people to buy those foods on a regular basis.

Another way to address the "food deserts" issue in Alabama is to promote the idea of local community gardens where fresh produce is grown by local residents. This way, communities in need could get access to some fruits and vegetables at relatively low cost close to home. While there is no cure-all solution that can eliminate the food desert phenomenon and its health related consequences, studies show that sustainable local farming and urban gardening can improve access to healthy and nutritious food options where the needs are

greatest. A study by Lim and Kishnani [2010] suggests that Singapore's public housing estates are suitable for rooftop farming and if implemented nationwide, such a scheme could result in a 700% increase in domestic vegetable production, satisfying 35.5% of demand (Lim and Kishnani, 2010).

This paper documented the extent of the "food desert" phenomenon in the state of Alabama and offered recommendations for action. The county level analysis confirmed the existence of food inaccessibility among certain residents and identified significant contributing risk factors. The project findings are supported by statistical analysis and make an excellent starting point for further analysis.

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