NIH Public Access
Author Manuscript
Health Place. Author manuscript; available in PMC 2014 September 01.

Published in final edited form as:
Health Place. 2013 September ; 23: . doi:10.1016/j.healthplace.2013.07.002.

Spatial patterning of supermarkets and fast food outlets with respect to neighborhood characteristics

Archana P. Lamichhane[a,b], **Joshua Warren**[c], **Robin Puett**[a,d,e], **Dwayne E. Porter**[d], **Matteo Bottai**[a], **Elizabeth J. Mayer-Davis, PhD**[b], and **Angela D. Liese, PhD**[a,*]

[a]Department of Epidemiology and Biostatistics, Arnold School of Public Health, University of South Carolina, Columbia, SC, USA

[b]Department of Nutrition, Gillings School of Global Public Health, University of North Carolina at Chapel Hill, Chapel Hill, NC, USA

[c]Department of Biostatistics, Gillings School of Global Public Health, University of North Carolina at Chapel Hill, Chapel Hill, NC, USA

[d]Department of Environmental Health Sciences, Arnold School of Public Health, University of South Carolina, Columbia, SC, USA

[e]South Carolina Cancer Prevention and Control Program, Arnold School of Public Health, University of South Carolina, Columbia, SC, USA

Abstract

A large body of literature has reported differences in exposure to environments supporting either healthy (e.g. supermarkets) or unhealthy (e.g. fast food outlets) dietary choices by neighborhood characteristics. We explored the associations of both supermarkets and fast food outlets availability with neighborhood characteristics, and clustering of these two outlet types in a largely rural state. Compared to block groups without a supermarket, those with a supermarket had a significantly higher income, higher housing value, larger population with high school education and above, lower minority population and lower population living below poverty even after controlling for urbanicity and population density of census block groups. Surprisingly, a similar relationship was found for block groups with and without fast food outlets. This was due to spatial co-occurrence and clustering of fast food outlets around supermarket locations. Hence, future studies exploring the associations of food environment with diet or diet-related health outcome should concurrently examine all aspects of food environment (healthy and unhealthy).

Keywords

spatial patterning; spatial clustering; supermarket; fast food outlet; neighborhood characteristics

[*]Address for correspondence: Angela D. Liese, PhD, Department of Epidemiology and Biostatistics, Arnold School of Public Health, University of South Carolina, 921 Assembly Street, Columbia, SC 29208, Phone: 803-777-9414; Fax: (803) 777-2504; liese@mailbox.sc.edu.

1. Introduction

Despite the importance of diet in maintaining good health as well as in the management of various diseases, a large proportion of individuals fail to meet the dietary guidelines. The diet of children and adolescent is quite poor due to excess intake of fat, sugar, snacks, soda and fast food (Nielsen et al., 2002; Troiano et al., 2000) and lower than recommended intake of fruit, vegetables and fiber (Guenther et al., 2006; Neumark-Sztainer et al., 2002; Nicklas and Johnson, 2004; Striegel-Moore et al., 2006). Various studies have noted socio-economic or racial differences in dietary intake (Giskes et al., 2002; Goodwin et al., 2006; Shimakawa et al., 1994) and burden of diet-related diseases (Freid et al., 2003). A national study in the United States reported that non-Hispanic black youth, youth from rural non-metropolitan areas and youth from the southern US were 2.3, 2.1 and 1.9 times more likely to have lower-quality diets when compared to non-Hispanic white youth, youth from metropolitan and the Northeast US, respectively (Goodwin et al., 2006). Similarly, another national level study also suggested that a difference in food accessibility and availability is a major determinant of morbidity and mortality in metro and non-metro areas (Ahern et al., 2011). Furthermore, evidence indicates that rural children are more overweight or obese compared to urban children, with the highest likelihood of overweight/obesity in the rural South compared to other parts of the country (Liu et al., 2007; Liu et al., 2008; Liu et al., 2012). However, very little is known about the underlying causes for these differences.

Recently, increased attention has been given to contextual factors such as individual's neighborhood of residence as a factor contributing to disparities in dietary intake and health outcomes through availability or lack of health promoting resources. Majority of the evidence comes from studies performed in the northern United States encompassing largely metropolitan urban and sub-urban neighborhoods. These studies suggest that residents of poor and minority neighborhoods have lower access to environments supporting healthy dietary choices and greater access to environments supporting unhealthy dietary choices than affluent and white neighborhoods. For instance, fewer supermarkets were located in or near black compared to white neighborhoods (Morland et al., 2002; Morland and Filomena, 2007; Powell et al., 2007; Zenk et al., 2005), and low-income compared to the wealthiest neighborhoods (Moore and Diez-Roux, 2006; Powell et al., 2007). In terms of fast food outlets, studies suggested that low-income or predominantly black neighborhoods had higher densities of fast food outlets (Block et al., 2004; Cummins et al., 2005; Kwate, 2008; Kwate et al., 2009; Reidpath et al., 2002), compared to higher income or predominantly white neighborhoods. However, a recent study from a six-county rural region of Texas has reported that the most deprived neighborhoods with the greatest proportion of minority residents had better spatial access to supermarkets and grocery stores (Sharkey and Horel, 2008) and also fast food outlets and opportunities (Sharkey et al., 2011) compared to the least deprived neighborhoods.

Given these contrasting regional findings regarding spatial food retail access by neighborhood socioeconomic status, and inconsistencies in the association of availability of healthy food items in rural communities of South Carolina (Liese et al., 2007) compared to rural communities in the Northeast (Hosler et al., 2006; Hubley, 2011), there is a need for studies that encompass large rural environments. Particularly, it has been suggested that rural residents may face several barriers for physical access to food stores due to long travel distance, lack of transportation and limited financial resources (Sharkey et al., 2010). Furthermore, rural southern states have faced a higher burden of diet-related diseases such as obesity, diabetes and heart disease as compared to other regions of the nation, and have been identified as the stroke and diabetes belt (Barker et al., 2011; Lanska and Kuller, 1995).

Most of the existing studies relating neighborhood characteristics (e.g., median household income of block-group or census-tract) to distribution of food outlets, have focused on only one outlet type, either outlets supporting healthy dietary choices such as supermarkets (Moore and Diez-Roux, 2006; Morland et al., 2002; Powell et al., 2007) or outlets supporting unhealthy dietary choices such as fast food outlets. (Block et al., 2004; Cummins et al., 2005; Kwate et al., 2009; Reidpath et al., 2002) The exception are a few studies from New Zealand (Pearce et al., 2007), Canada (Smoyer-Tomic et al., 2008), and rural counties in Texas, USA (Sharkey et al., 2011; Sharkey and Horel, 2008). However, none of the studies have extensively explored the spatial clustering of food outlets supporting healthy dietary choices with outlets supporting unhealthy dietary choices.

The purpose of this study was to explore the availability of both supermarkets and fast food outlets in relation to neighborhood characteristics using spatial statistical methods in the entire State of South Carolina, a largely rural state from the Southeastern US with a high proportion of minority residents. Furthermore, we tested for the degree of spatial clustering of food outlets providing healthy and unhealthy food options using bivariate K function method (Dixon, 2013).

2. Methods

2.1. Study Area

This study included the entire State of South Carolina, a rural state with higher than 30% of minority populations. We included 2,857 census block groups, which are the smallest geographic units (approximate population of 1,500) for which census data on social and economic measures is available. Previous researches on built food environment have also used block groups as unit of analysis (Gordon et al., 2011; Hill et al., 2012; Sharkey et al., 2009).

2.2. Neighborhood-level Covariates

Demographic and socioeconomic data were obtained from the United States Census Bureau 2000 (Summary File 1 and Summary File 3) at the census block-group level for the State of South Carolina (Bureau of the Census, 2001a; Bureau of the Census, 2001b). The data obtained for this study included demographic measures such as total population, race/ethnicity-specific population and population density. Socio-economic measures included median household income, median value of housing, population with high school education and above, and population living below the federally defined poverty level. These variables were used to derive several categorical variables for the analysis. The measure reflecting race composition of block groups was determined based on the proportion of various race/ethnic groups of the specific block-group. A block-group was identified as “Predominantly white” if the proportion of white population in the tract was more than 80% (Morland and Filomena, 2007). Similarly a block-group or census-tract was “Predominantly black” if the black population was more than 80%, and “Mixed” if the proportion of both race/ethnic group was 80% or less (Morland and Filomena, 2007). Similarly, the measure reflecting the poverty status of the neighborhood was determined based on the proportion of population living below the federally defined poverty line. A block-group or census-tract was identified as “Poor” if the tract has ≥ 20% of the population living below poverty and “Not poor” otherwise (Krieger et al., 2003). For variables such as median household income, median value of housing, and percent population with high school and above education, tertiles of variables were created with the highest tertile representing higher socio-economic status and higher proportion of population with high school education and above.

Variable representing urbanicity-level of neighborhoods such as 2000 Rural-Urban Commuting Area Codes (RUCA) are only available at the census-tract levels from the Economic Research Service (ERS)/ United States Department of Agriculture (USDA) (USDA/ERS, 2005). Hence for this study, block groups were assigned RUCA code of their respective census tracts. We used a four-tier consolidation of the RUCA system: 1) Urban core, 2) Sub-urban, 3) Large rural town, and 3) Small town/ isolated rural (Washington State Department of Health, 2009).

2.3. Built Food Environment Measures

For this study food outlets such as supermarkets (proxies of environment supporting healthy dietary choices) and fast food outlets (proxies of environment supporting unhealthy dietary choices) were selected (Gordon et al., 2011). Supermarkets in this study were defined as a large corporate owned franchised food stores selling groceries including fresh produce and meat, as distinguished from grocery stores and smaller non-corporate owned food stores (Morland et al., 2002; Morland et al., 2006) and included Bi-lo, Publix, Bloom, Earth Fare, Food Lion etc. Fast food outlets were defined as nationally or internationally known franchised limited service restaurants that sell inexpensive, quickly served foods such as hamburgers, pizza and fried chicken (Jeffery et al., 2006; Wang et al., 2007) with payment made prior to receiving food and expedited food service with limited or no wait staff (Block et al., 2004; Burdette and Whitaker, 2004; Hurvitz et al., 2009) and included Bojangles', Burger King, Chick-Fil-A, McDonald's etc.

Data on food outlets including geocodes were obtained from two sources including 1) the Licensed Food Service Facilities Database (LFSFD) from South Carolina Department of Health and Environmental Control (SCDHEC) (obtained in August 2008) and 2) InfoUSA Inc. (obtained in February 2009). After performing substantial data cleaning to remove typological errors and duplicate entries, we identified supermarkets and fast food outlets from both data sources based on the name of the facilities and merged them into a new analysis dataset. We identified a total of 686 supermarkets and 2,624 fast food outlets in the State of South Carolina.

The geocoded locations of the food outlets were used to determine the specific block-group of each outlet. The function "counts point in polygons" available in ArcGIS 9.3 software (ESRI, 2008) was then used to count the number of supermarkets and fast food outlets in each census block group. Census block groups were identified to have supermarket availability if they contained at least one supermarket. Similarly, census block groups were identified to have fast food availability if they contained at least one fast food outlet.

2.4. Statistical Analysis

2.4.1. Neighborhood Characteristics and Food Outlet Availability—We evaluated neighborhood differences in the availability of supermarket and fast food outlets by comparing census block groups with and without supermarkets, and with and without fast food outlets, in terms of socio-economic and demographic characteristics (Smoyer-Tomic et al., 2008) using a t-test. We then performed additional analyses to evaluate the block group differences in terms of supermarket and fast food outlet availability combinations (block groups with both supermarket and fast food outlet availability, with only supermarket, with only fast food outlets, and with no outlets). These analyses were performed using SAS version 9.2 (SAS Institute Inc., Cary, NC, 2008).

As a sensitivity analysis, we repeated block group level analyses as above including an eight county region (Calhoun, Chester, Clarendon, Fairfield, Kershaw, Lancaster, Orangeburg, Richland) for which we had a contemporaneous, validated database listing all existing supermarkets and fast food outlets from a field census. Analysis results from validated and non-validated datasets were then compared to determine if the associations of neighborhood characteristics with supermarket and fast food availability would have differed, if we would have used ground-verified dataset.

"Spatial autocorrelation" is one of the common issues among studies using neighborhood defined boundaries such as census tracts or census block groups as the unit of analysis (Sharkey et al., 2009; Zenk et al., 2005). Because nearby census block groups tend to have more similar characteristics than more distant ones, the use of ordinary least square regression (to explore the associations of neighborhood characteristics to outcomes of interest) can result in biased parameter estimates through the violation of independence assumption. Hence, we used global Moran's I statistics to identify spatial autocorrelation between census block groups in terms of supermarket/fast food outlets availability and five demographic and socio-economic variables. Because we found strong spatial autocorrelation among block groups in terms of these characteristics (data not shown); we thereafter utilized spatial logistic regression analysis to examine the associations of the availability (presence vs. absence) of supermarkets and fast food outlets with socio-economic and demographic characteristics of block groups, controlling for urbanicity of census block groups.

We introduced a spatial effect into the logistic regression model which allowed for neighboring locations to have similar probabilities of observing the same outcome, based solely on their spatial locations. The full Bayesian model, detailed by Banerjee et al. (Banerjee et al., 2006), is given as

$$Y(\boldsymbol{s}_i) \overset{ind}{\sim} \text{Bern}\{p(\boldsymbol{s}_i)\}, \ \log\left\{\frac{p(\boldsymbol{s}_i)}{1-p(\boldsymbol{s}_i)}\right\} = \mathrm{x}_i^T\beta + \theta(\boldsymbol{s}_i)$$

where the Y (s_i) represents the outcome variable (i.e. availability of supermarket and fast food outlets in block groups represented as "Yes" or "No"), x_i^T vector represents block group level predictors (i.e. demographic and socio-economic characteristics, and urbanicity level) and β represents the vector of regression coefficients (i.e. intercept term and slope parameters associated with the predictors) that relate the predictors to the probability of observing the outcome of interest. The $\theta(\boldsymbol{s}_i)$ term represents the purely spatial component of the model and is allowed to be similar to its neighboring values through the use of a spatially referenced prior distribution.

The spatial effects are given the intrinsic conditionally autoregressive (ICAR) (Besag, 1974) prior distribution such that

$$\theta(\boldsymbol{s}_i)|\theta_{-i} \sim \text{N}\left(\sum_j \frac{w_{ij}}{w_{i+}}\theta(\boldsymbol{s}_j), \frac{\sigma^2}{w_{i+}}\right)$$

where θ_{-i} is the vector of $\theta(\boldsymbol{s}_j)$ parameters with $\theta(\boldsymbol{s}_i)$ excluded, w_{ij} is equal to one if locations i and j are neighbors (touching borders) and zero otherwise, w_{i+} is the number of neighbors of location $\boldsymbol{s}_i$, and σ^2 controls the variance of the effects. Locations are not considered to be neighbors of themselves, resulting in $w_{ii} = 0$ for all i.

We fitted this model using the *CARBayes* package available in R statistical software (R Development Core Team, 2012).

2.4.2. Spatial Co-occurrence/ Clustering of Supermarkets and Fast Food Outlets—

We evaluated the spatial clustering of fast food around supermarket locations using "bivariate K function" analysis techniques (Cuthbert and Anderson, 2002). We quantified the degree of clustering of fast food outlets around supermarket locations at various distances ranging from 0 to 1.25 miles. The bivariate K function, an extension of the usual univariate K function (Ripley, 1976; Ripley, 1977) is useful for assessing the spatial relationship between two point processes occurring in the same spatial domain. The theoretical bivariate K function is given as

$$K_{ij}(h)=(\lambda_j)^{-1}E(\#\text{of type} j \text{events within distance} h \text{of an arbitrary type} i \text{event})$$

where λ_j is the intensity of process j (i.e. number of fast food locations "j" per unit area) (Dixon, 2013).

We used the proposed estimator of the bivariate K function with edge correction introduced by Lotwick and Silverman (Lotwick and Silverman, 1982) which is given as:

$$\hat{\mathrm{K}}_{ij}(h)=\left(\hat{\lambda}_i\hat{\lambda}_j A\right)^{-1}\sum_k\sum_l\frac{I\{d(i_k,j_l)<h\}}{w(i_k,j_l)}$$

where $\hat{\lambda}_i = n_i/A$, n_i is the number of supermarket locations, A is the area of the region of interest i.e. South Carolina, $I\{d(i_k, j_l) < h\}$ is an indicator function taking value one if $d(i_k, j_l) < h$ and zero otherwise, $d(i_k, j_l)$ is the Euclidean distance between the k^{th} supermarket location and the l^{th} fast food outlet, and $w(j_k, j_l)$ is the proportion of the circumference of the circle centered at the k^{th} supermarket location with radius $d(i_k, j_l)$ which falls within the region of interest.

We used the *Splancs* package found in R statistical software (R Development Core Team, 2012) to estimate the bivariate K function such that

$$\hat{\mathrm{K}}^*{}_{ij}(h)=\frac{\hat{\lambda}_j\hat{\mathrm{K}}_{ij}(h)+\hat{\lambda}_i\hat{\mathrm{K}}_{ij}(h)}{\hat{\lambda}_j+\hat{\lambda}_i}.$$

We also pursued evaluation of the spatial co-occurrence of supermarkets and fast food outlets using various descriptive and multivariable analyses techniques. First, we calculated distance to the nearest fast food outlet from each supermarket location. Second, we created network buffers of various radius (0.3 mile, 0.5 mile and 1 mile) around supermarket locations (Austin et al., 2005; Day and Pearce, 2011), and then calculated the number of fast food outlets within these buffers. Both of these analyses were performed in ArcGIS 9.3 (ESRI, 2008). Third, we performed spatial logistic regression analyses to assess the likelihood of supermarket availability in block groups which had fast food outlets and vice versa using the *CARBayes* package available in R statistical software (R Development Core Team, 2012).

3. Results

3.1. Neighborhood Characteristics and Food Outlet Availability

Block groups with supermarket showed significantly higher household income, higher housing value, higher proportion of population with high school education and above, lower minority population, and lower proportion of population living below federally defined poverty, compared to block groups without supermarkets (Table 1). Similar associations for block group characteristics were observed for block groups with and without fast food outlet (Table1).

Comparison of the block group level characteristics by supermarket and fast food outlet availability combination showed that block groups with both supermarkets and fast food outlets had the highest median household income, highest proportion of population with high school education and above, lowest proportion of population living below poverty and lowest proportion of minority population, compared to block groups with one or more supermarket or fast food outlet or none (p-value for all <0.05) (Figure 1). Thus, neighborhoods with better socioeconomic characteristics were more likely to have both supermarkets and fast food outlets.

Our sensitivity analyses using a validated food outlet dataset from an eight county region showed extremely similar results as described above using non-validated food outlets dataset for the entire state of South Carolina. For instance, block groups with supermarkets and fast food outlets had lower minority population and had higher socio-economic status compared to block groups without these outlets (data not shown).

The direction of associations between block group characteristics and supermarket or fast food availability observed in descriptive analyses held true even in spatial logistic regression analysis which accounted for spatial autocorrelation and further adjusted for urbanicity of census block groups in the model (Table 2). For instance, compared to the block groups in the highest tertile of median housing value, the block groups in the lowest tertile had 60% lower odds and block groups in the medium tertile had 40% lower odds of having a supermarket even after adjusting for urbanicity-level of census block groups. Similarly, block groups with a predominantly black population had a 60% lower odds of having supermarkets compared to block groups with predominantly white populations. Further adjustment for the population density of the block groups did not attenuate the associations between neighborhood characteristics and supermarket availability (data not shown). Surprisingly, similar significant associations were observed for fast food outlet availability odds by neighborhood characteristics (Table 2).

3.2. Spatial Co-occurrence/Clustering of Supermarkets and Fast Food Outlets

Figure 2 shows the locations of supermarket and fast food outlets in the state of the South Carolina. The map shows that large proportions of supermarkets have fast food locations at close proximity and this holds true for both rural area such as Newberry, SC and urban area such as Charleston, SC. Statistical analysis to test clustering of fast food outlets around supermarket locations are displayed in Figure 3 (A and B). The figure displays estimated bivariate K function at multiple distances (miles) along with expected k function value and 95% confidence intervals (CIs) (Figure 3A). The expected value and CIs results are based on 1,000 simulations under the assumption of spatial independence of the two point processes, fast food and supermarket locations, and are represented by dotted and dashed lines, respectively. The observed value is represented by solid line and falls above the 95% CIs. When compared with the expected value and CIs under the assumption of spatial independence between the two processes (Figure 3B), it is clear that the observed estimates (Figure 3A) are very extreme. This indicates strong spatial clustering of fast food and supermarket locations and suggests that there are many more fast food locations within a specified distance from an arbitrary supermarket location than expected under independence.

The extent of spatial co-occurrence of fast food outlets around supermarket locations is presented in table 1, 2 and 3. Block groups with at least one supermarket had a significantly higher number of fast food outlets compared to those block groups without supermarket (Mean fast food outlets= 2.7 vs. 0.5, p-value <0.0001) (Table 1). Similarly, block groups with at least one fast food outlet had a significantly higher number of supermarkets compared to the block groups without fast food (Mean supermarkets= 0.6 vs. 0.1, p-value <0.0001) (Table 1). The co-occurrences of supermarket and fast food outlet was also supported by the findings that out of 529 block groups with supermarkets, 73% had at least one fast food outlet (median=3 and max=19) (data not shown). Further evaluation for co-occurrences of supermarket and fast food outlet in block groups with spatial logit models showed that the odds of supermarket availability were significantly higher in block groups with fast food availability or vice versa (OR=9.9; 95% CI: 7.9,12.4) even after adjusting for urbanicity-level of census block groups (Table 2).

The proximity analysis showed that the median distance to the nearest fast food outlet from the supermarket locations was 0.1 mile (data not shown). Further distance based analysis showed that about 75% of supermarkets had at least one fast food outlet (median=3 and max=16) within 0.3 mile from their location, 78% had at least one fast food outlet within one-half mile (median=4 and max=17) and 85% had at least one fast food outlet within one mile (median=6 and max=24) (Table 3).

4. Discussion

The results of this study indicate that the availability of supermarkets and fast food outlets differ by neighborhood socio-economic and demographic characteristics. The results regarding the increased availability of supermarkets in affluent and low minority neighborhoods are consistent with the previous studies from the United States (Morland et al., 2002; Morland and Filomena 2007; Powell et al., 2007; Zenk et al., 2005) and Australia (Burns and Inglis, 2007), which reported more supermarkets located in or near white compared to black, or affluent compared to low-income/deprived neighborhoods. The similar findings regarding the increased availability of fast food outlet in affluent and low minority neighborhoods in our study, however, is in contrast with the previous findings from the United States (Block et al., 2004; Kwate 2008; Kwate et al., 2009), Australia (Burns and Inglis 2007; MacDonald et al., 2007; Reidpath et al., 2002), England and Scotland (Cummins et al., 2005; MacDonald et al., 2007; Reidpath et al., 2002), Canada (Hemphill et al., 2008; Smoyer-Tomic et al., 2008) and New Zealand (Pearce et al., 2007), which determined low-income/deprived and minority neighborhoods always had higher prevalence of fast food outlets compared to white and affluent neighborhoods.

The majority of the existing studies exploring fast food outlets and neighborhood characteristics from the United States have explored mostly urban metropolitan areas compared to more rural environment in our study. Block et al. (Block et al., 2004) restricted their analysis so as to get uniform homogeneous urban neighborhoods in the Orleans Parish, which had a large proportion of poor and black residents. Hence, the observed associations of higher density of fast food outlet in poor and black neighborhoods compared to affluent and white neighborhood can be due to the unique characteristics of the region itself. Similarly, Kwate et al. (Kwate 2008; Kwate et al., 2009) also included urban neighborhoods in New York which are racially segregated. The racial segregation has been considered to affect population and economic characteristics, physical infrastructure, and social processes, which in turn work together to increase the likelihood of disproportionate burden of fast food restaurants in black neighborhoods in urban environments (Kwate 2008). Our study is different from these existing studies because it spans a large proportion of rural area. Furthermore, our study included a minority population mostly living in racially mixed neighborhood, hence less racially segregated neighborhoods compared to urban neighborhoods in New York.

Our study findings regarding the similar patterning of the supermarkets and fast food outlets by neighborhood characteristics, however, is consistent with the study from New Zealand (Pearce et al., 2007), which also found that geographic accessibility to supermarkets was patterned by deprivation in a similar way as to fast-food outlets. Evaluation of the associations of neighborhood characteristics with supermarket and fast food availability combination further confirmed the similar patterning by showing neighborhoods with better socio-economic characteristics were more likely to have both supermarket and fast food outlets in their neighborhoods.

Evaluation of spatial clustering of supermarket and fast food outlets using bivariate K function test confirmed the extreme clustering of fast food outlets around supermarket locations in our study area encompassing rural environment from the Southeastern US. Furthermore, descriptive analyses to evaluate the extent of spatial co-occurrence of supermarket and fast food outlets in our study also supported the co-occurrence of environments supporting both healthy and unhealthy dietary choices in geographic space, by showing a large proportion of supermarkets with fast food outlets within close proximity.

The main reasons for similar patterning of supermarkets and fast food outlets by neighborhood characteristics, observed in our study, hence can be explained by the spatial clustering of supermarkets and fast food outlets. The clustering of both healthy and unhealthy food outlets can be typical to rural states including South Carolina, which lack specific land-use zoning and are typified by clustering of retail locations around arterial roads with high traffic volume (personal communication with Mr. Wayne Shuler, chief urban planner in Columbia, SC). Being a large rural state, the towns in South Carolina have two distinctive zones: limited/neighborhood zones which are restricted to personal service and small retail services, and general commercial zones which are less restrictive and can support the establishment of large food retailers such as grocery stores and supermarkets. Furthermore, the site selection of these large food retailers is strongly guided by greater consumer base and buying power of the community (Hartford Food System, 2006). Hence, the establishments of supermarkets can be expected in wealthier neighborhoods with a large population base. Food retailers such as fast food outlets also need a large consumer base to survive (Demrican, 2002). In this situation, both food retailers may favor same geographic space for locating their outlets, particularly in rural state such as South Carolina.

Our study has several limitations. First, our study like several published studies used defined geographic units such as census block groups as a unit of analysis. This container-based approach to calculate availability/accessibility faces a major issue named Modifiable Arial Unit Problem (MAUP) (Zhang et al., 2011), i.e. the geographic relationships of neighborhood characteristics with food outlets availability could change depending upon whether census tracts vs. block groups vs. buffers are used to define availability of outlets. The additional sensitivity analysis in our study with census tracts as a unit of analysis showed similar direction of associations of neighborhood characteristics with availability of supermarket and fast food outlets (data not shown) as our major study findings at census block group level. Hence, this strengthens our study findings and suggests that MAUP may not be a major issue in our study setting. Another major concern in previous epidemiologic studies exploring the health impact of food environment has been the validity of the food outlets data from secondary data sources, which has been considered as a methodological obstacle in these studies (Lytle, 2009; Oakes et al., 2009). However, our recent validation work in the State of South Carolina has shown better sensitivity and positive predicted values for both supermarkets/grocery stores (sensitivity-86% and positive predicted values-86%) and limited service restaurants category (sensitivity-93% and positive predicted values-93%), when the combination of SCDHEC and InfoUSA datasets were used (Liese et al., 2010). Hence, consideration of both data sources in our study would have minimized the count error. Furthermore, the similarity of results for the associations of neighborhood characteristics with food outlets availability using both validated and non-validated food outlet datasets confirmed the robustness and validity of our findings. Our study included only franchised grocery and fast food outlets because of higher chances of misclassification of other small stores (i.e., convenience stress providing unhealthful food classified as small grocery stores providing healthful food by database). Furthermore, the findings of Sharkey et al. in rural Texas counties showed that consideration of only fast food restaurants as the only traditional source of fast-food entrees can underestimate neighborhood exposure to fast food (Sharkey et al., 2011). Hence, future studies using ground-verified data including all franchised and local food outlets, and careful consideration of traditional and non-traditional sources of healthy or unhealthy food options can potentially minimize the misclassification and underestimation issues.

There are several strengths of this study that is noteworthy. First, this study is among a few studies that have explored the associations of neighborhood characteristics with outlet types offering both healthy and unhealthy food options. We used advanced spatial analysis techniques in a Bayesian framework to address spatial autocorrelation and further adjust for spatially correlated and uncorrelated heterogeneity to improve model fit and calculate unbiased estimates of associations. Further, our study included a region encompassing a large rural environment. To our knowledge, this is the first study that extensively explored spatial clustering of fast food outlets around supermarket locations.

5. Conclusions

In summary, our study found that the availability of supermarkets and fast food outlets differed significantly by neighborhood characteristics; neighborhoods with supermarkets and with fast food outlets were significantly higher in socio-economic status and had a lower minority population compared to neighborhoods without these food outlets. We found significant spatial clustering of fast food outlets around supermarket locations in the state of South Carolina. Our results thus suggest that future studies exploring the associations of food environment with diet or diet-related health outcomes should concurrently examine all aspects of the food environment (healthy and unhealthy) in order to disentangle the various contextual drivers of dietary intake and health outcomes. This two-fold approach is an important aspect to consider in South Carolina and other rural states, which lack specific land-use zoning and are typified by co-occurrences/clustering of retail locations in geographic space. In these contexts, separately evaluating the influence of healthy and unhealthy food outlets could lead to spurious findings.

Acknowledgments

Thanks to James Hibbert for his contributions in GIS work.

This project was supported by R21CA132133 from the National Cancer Institute. The content is solely the responsibility of the authors and does not necessarily represent the official views of the National Cancer Institute or the National Institutes of Health.

References

Ahern M, Brown C, Dukas S. A national study of the association between food environments and county-level health outcomes. Journal of Rural Health. 2011; 27:367–379. [PubMed: 21967380]

Austin SB, Melly SJ, Sanchez BN, Patel A, Buka S, Gortmaker SL. Clustering of Fast-Food Restaurants Around Schools: A Novel Application of Spatial Statistics to the Study of Food Environments. American Journal of Public Health. 2005; 95:1575–1581. [PubMed: 16118369]

Banerjee, S.; Carlin, B.; Gelfand, A. Hierarchical Modeling and Analysis for Spatial Data. Florida: Chapman & Hall; 2006.

Barker LE, Kirtland KA, Gregg EW, Geiss LS, Thompson TJ. Geographic distribution of diagnosed diabetes in the U.S.: a diabetes belt. American Journal of Preventive Medicine. 2011; 40:434–439. [PubMed: 21406277]

Besag J. Spatial interaction and the statistical analysis of lattice systems. Journal of the Royal Statistical Society. 1974; 36:192–236.

Block JP, Scribner RA, DeSalvo KB. Fast food, race/ethnicity, and income A geographic analysis. American Journal of Preventive Medicine. 2004; 27:211–217. [PubMed: 15450633]

Burdette HL, Whitaker RC. Neighborhood playgrounds, fast food restaurants, and crime: relationships to overweight in low-income preschool children. Preventive Medicine. 2004; 38:57–63. [PubMed: 14672642]

Bureau of the Census. US Department of Commerce. Census 2000 Summary File 1 (SF1). Washington: Bureau of the Census; 2001.

Bureau of the Census. US Department of Commerce. Census 2000 Summary File 3 (SF3). Washington: Bureau of the Census; 2001.

Burns CM, Inglis AD. Measuring food access in Melbourne: access to healthy and fast foods by car, bus and foot in an urban municipality in Melbourne. Health & Place. 2007; 13:877–885. [PubMed: 17470408]

Cummins SCJ, McKay L, MacIntyre S. McDonald's Restaurants and Neighborhood Deprivation in Scotland and England. American Journal of Preventive Medicine. 2005; 29:308–310. [PubMed: 16242594]

Cuthbert A, Anderson W. Using spatial statistics to examine the pattern of urban land development in Halifax-Dartmouth. The Professional Geographer. 2002; 54:521–532.

Day PL, Pearce J. Obesity-promoting food environments and the spatial clustering of food outlets around schools. American Journal of Preventive Medicine. 2011; 40:113–121. [PubMed: 21238858]

Demrican, ML. Site selection in fast food industry; International Symposium of GIS; 2002. 9-23-2002.

Dixon PM. Ripley's K Function. Encyclopedia of Environmetrics. 2013

Environmental Systems Research Institute (ESRI). ArcGIS 9.3. Redlands, CA: 2008.

Freid, VM.; Prager, K.; MacKay, AP.; Xia, H. National Center for Health Statistics. Hyattsville, MD: 2003. Chartbook on Trends in the Health of Americans. 2003.

Giskes K, Turrell G, Patterson C, Newman B. Socio-economic differences in fruit and vegetable consumption among Australian adolescents and adults. Public Health Nutr. 2002; 5:663–669. [PubMed: 12372160]

Goodwin DK, Knol LK, Eddy JM, Fitzhugh EC, Kendrick O, Donohue RE. Sociodemographic correlates of overall quality of dietary intake of US adolescents. Nutrition Research. 2006; 26:105–110.

Gordon C, Purciel-Hill M, Ghai NR, Kaufman L, Graham R, Van WG. Measuring food deserts in New York City's low-income neighborhoods. Health & Place. 2011; 17:696–700. [PubMed: 21256070]

Guenther PM, Dodd KW, Reedy J, Krebs-Smith SM. Most Americans Eat Much Less than Recommended Amounts of Fruits and Vegetables. Journal of the American Dietetic Association. 2006; 106:1371–1379. [PubMed: 16963342]

Hartford Food System, September. Connecticut's Supermarkets: Can New Strategies Address the Geographic Gaps? 2006 [http://www.hartfordfood.org/pubs/supermarkets.pdf].

Hemphill E, Raine K, Spence JC, Smoyer-Tomic KE. Exploring obesogenic food environments in Edmonton, Canada: the association between socioeconomic factors and fast-food outlet access. American Journal of Health Promotion. 2008; 22:426–432. [PubMed: 18677883]

Hill JL, Chau C, Luebbering CR, Kolivras KK, Zoellner J. Does availability of physical activity and food outlets differ by race and income? Findings from an enumeration study in a health disparate region. International Journal of Behavioral Nutrition and Physical Activity. 2012; 9:105. [PubMed: 22954386]

Hosler AS, Varadarajulu D, Ronsani AE, Fredrick BL, Fisher BD. Low-Fat Milk and High-Fiber Bread Availability in Food Stores in Urban and Rural Communities. Journal of Public Health Management & Practice. 2006; 12:556–562. [PubMed: 17041304]

Hubley TA. Assessing the proximity of healthy food options and food deserts in a rural area in Maine. Applied Geography. 2011; 31:1224–1231.

Hurvitz PM, Moudon AV, Rehm CD, Streichert LC, Drewnowski A. Arterial roads and area socioeconomic status are predictors of fast food restaurant density in King County, WA. International Journal of Behavioral Nutrition and Physical Activity. 2009; 6

Jeffery RW, Baxter J, McGuire M, Linde J. Are fast food restaurants an environmental risk factor for obesity. International Journal of Behavioral Nutrition and Physical Activity. 2006; 3

Krieger N, Chen JT, Waterman PD, Soobader MJ, Subramanian SV, Carson R. Choosing area based socioeconomic measures to monitor social inequalities in low birth weight and childhood lead poisoning: The Public Health Disparities Geocoding Project (US). Journal of Epidemiology and Community Health. 2003; 57:186–199. [PubMed: 12594195]

Kwate NO. Fried chicken and fresh apples: racial segregation as a fundamental cause of fast food density in black neighborhoods. Health & Place. 2008; 14:32–44. [PubMed: 17576089]

Kwate NO, Yau CY, Loh JM, Williams D. Inequality in obesigenic environments: fast food density in New York City. Health & Place. 2009; 15:364–373. [PubMed: 18722151]

Lanska DJ, Kuller LH. The geography of stroke mortality in the United States and the concept of a stroke belt. Stroke. 1995; 26:1145–1149. [PubMed: 7604404]

Liese AD, Colabianchi N, Lamichhane AP, Barnes TL, Hibbert JD, Porter DE, Nichols MD, Lawson AB. Validation of 3 food outlet databases: completeness and geospatial accuracy in rural and urban food environments. American Journal of Epidemiology. 2010; 172:1324–1333. [PubMed: 20961970]

Liese AD, Weis KE, Pluto D, Smith E, Lawson A. Food Store Types, Availability, and Cost of Foods in a Rural Environment. Journal of the American Dietetic Association. 2007; 107:1916–1923. [PubMed: 17964311]

Liu J, Bennett K, Harun N, Zheng X, Probst J, Pate R. Overweight and Physical Inactivity among Rural Children Aged 10–17: A National and State Portrait. South Carolina Rural Health Research Center. 2007

Liu J, Bennett KJ, Harun N, Probst JC. Urban-rural differences in overweight status and physical inactivity among US children aged 10–17 years. Journal of Rural Health. 2008; 24:407–415. [PubMed: 19007396]

Liu JH, Jones SJ, Sun H, Probst JC, Merchant AT, Cavicchia P. Diet, physical activity, and sedentary behaviors as risk factors for childhood obesity: an urban and rural comparison. Child Obes. 2012; 8:440–448. [PubMed: 23061499]

Lotwick H, Silverman B. Methods of analysing spatial processes of several types of points. Journal of Royal Statistical Society (Series B). 1982; 44:406–413.

Lytle LA. Measuring the food environment: state of the science. American Journal of Preventive Medicine. 2009; 36:S134–S144. [PubMed: 19285204]

Macdonald L, Cummins S, MacIntyre S. Neighbourhood fast food environment and area deprivation-substitution or concentration? Appetite. 2007; 49:251–254. [PubMed: 17189662]

Moore LV, Diez-Roux AV. Associations of Neighborhood Characteristics With the Location and Type of Food Stores. American Journal of Public Health. 2006; 96:325–331. [PubMed: 16380567]

Morland K, Filomena S. Disparities in the availability of fruits and vegetables between racially segregated urban neighbourhoods. Public Health Nutrition. 2007; 10:1481–1489. [PubMed: 17582241]

Morland K, Roux AD, Wing S. Supermarkets, Other Food Stores, and Obesity The Atherosclerosis Risk in Communities Study. American Journal of Preventive Medicine. 2006; 30:333–339. [PubMed: 16530621]

Morland K, Wing S, Roux AD, Poole C. Neighborhood characteristics associated with the location of food stores and food service places. American Journal of Preventive Medicine. 2002; 22:23–29. [PubMed: 11777675]

Neumark-Sztainer D, Story M, Hannan PJ, Croll J. Overweight Status and Eating Patterns Among Adolescents: Where Do Youths Stand in Comparison With the Healthy People 2010 Objectives? American Journal of Public Health. 2002; 92:844–851. [PubMed: 11988458]

Nicklas T, Johnson R. Position of the American Dietetic Association: Dietary guidance for healthy children ages 2 to 11 years. Journal of American Dietetic Association. 2004; 104:660–677.

Nielsen SJ, Siega-Riz AM, Popkin BM. Trends in Energy Intake in US between 1977 and 1996: Similar Shifts Seen across Age Groups. Obesity Research. 2002; 10:370–378. [PubMed: 12006636]

Oakes JM, Masse LC, Messer LC. Work group III: Methodologic issues in research on the food and physical activity environments: addressing data complexity. American Journal of Preventive Medicine. 2009; 36:S177–S181. [PubMed: 19285211]

Pearce J, Blakely T, Witten K, Bartie P. Neighborhood Deprivation and Access to Fast-Food Retailing A National Study. American Journal of Preventive Medicine. 2007; 32:375–382. [PubMed: 17478262]

Powell LM, Slater S, Mirtcheva D, Bao Y, Chaloupka FJ. Food store availability and neighborhood characteristics in the United States. Preventive Medicine. 2007; 44:189–195. [PubMed: 16997358]

Reidpath DD, Burns C, Garrard J, Mahoney M, Townsend M. An ecological study of the relationship between social and environmental determinants of obesity. Health & Place. 2002; 8:141–145. [PubMed: 11943585]

Ripley B. The second-order analysis of stationary point processes. Journal of Applied Probability. 1976; 13:255–266.

Ripley B. Modelling Spatial Patterns. Journal of Royal Statistical Society (Series B). 1977; 39:172–212.

Sharkey JR, Horel S. Neighborhood socioeconomic deprivation and minority composition are associated with better potential spatial access to the ground-truthed food environment in a large rural area. Journal of Nutrition. 2008; 138:620–627. [PubMed: 18287376]

Sharkey JR, Horel S, Dean WR. Neighborhood deprivation, vehicle ownership, and potential spatial access to a variety of fruits and vegetables in a large rural area in Texas. International Journal of Health Geographics. 2010; 9:26. [PubMed: 20500853]

Sharkey JR, Horel S, Han D, Huber JC Jr. Association between neighborhood need and spatial access to food stores and fast food restaurants in neighborhoods of colonias. International Journal of Health Geographics. 2009; 8:9. [PubMed: 19220879]

Sharkey JR, Johnson CM, Dean WR, Horel SA. Focusing on fast food restaurants alone underestimates the relationship between neighborhood deprivation and exposure to fast food in a large rural area. Nutrition Journal. 2011; 10:10. [PubMed: 21266055]

Shimakawa T, Sorlie P, Carpenter MA, Dennis B, Tell GS, Watson R, Williams OD. Dietary intake patterns and sociodemographic factors in the atherosclerosis risk in communities study. ARIC Study Investigators. Preventive Medicine. 1994; 23:769–780. [PubMed: 7855109]

Smoyer-Tomic KE, Spence JC, Raine KD, Amrhein C, Cameron N, Yasenovskiy V, Cutumisu N, Hemphill E, Healy J. The association between neighborhood socioeconomic status and exposure to supermarkets and fast food outlets. Health & Place. 2008; 14:740–754. [PubMed: 18234537]

Striegel-Moore RH, Thompson DR, Affenito SG, Franko DL, Barton BA, Schreiber GB, Daniels SR, Schmidt M, Crawford PB. Fruit and vegetable intake: Few adolescent girls meet national guidelines. Preventive Medicine. 2006; 42:223–228. [PubMed: 16406116]

Troiano RP, Briefel RR, Carroll MD, Bialostosky K. Energy and fat intakes of children and adolescents in the United States: data from the National Health and Nutrition Examination Surveys. Am J Clin Nutr. 2000; 72:1343S–1353S. [PubMed: 11063476]

USDA/ ERS. USDA/ERS; 2000. Rural-Urban Commuting Area Codes. [http://www.ers.usda.gov/Data/RuralUrbanCommutingAreaCodes/2000/_].

Wang MC, Kim S, Gonzalez AA, MacLeod KE, Winkleby MA. Socioeconomic and food-related physical characteristics of the neighbourhood environment are associated with body mass index. Journal of Epidemiology and Community Health. 2007; 61:491–498. [PubMed: 17496257]

Washington State Department of Health. Guidelines for Using Rural-Urban Classification Systems for Public Health Assessment. 2009. [http://www.doh.wa.gov/Data/guidelines/RuralUrban2.htm_].

Zenk SN, Schulz AJ, Israel BA, James SA, Bao S, Wilson ML. Neighborhood Racial Composition, Neighborhood Poverty, and the Spatial Accessibility of Supermarkets in Metropolitan Detroit. American Journal of Public Health. 2005; 95:660–667. [PubMed: 15798127]

Zhang X, Lu H, Holt JB. Modeling spatial accessibility to parks: a national study. International Journal of Health Geographics. 2011; 10:31. [PubMed: 21554690]

- Block groups with supermarkets had a significantly higher SES than without supermarket.
- Similar relationship was observed for block groups with or without fast food outlets.
- Similar patterning of the supermarkets and fast food outlets by neighborhood characteristics.
- Spatial co-occurrence of supermarkets and fast food outlets in geographic space.

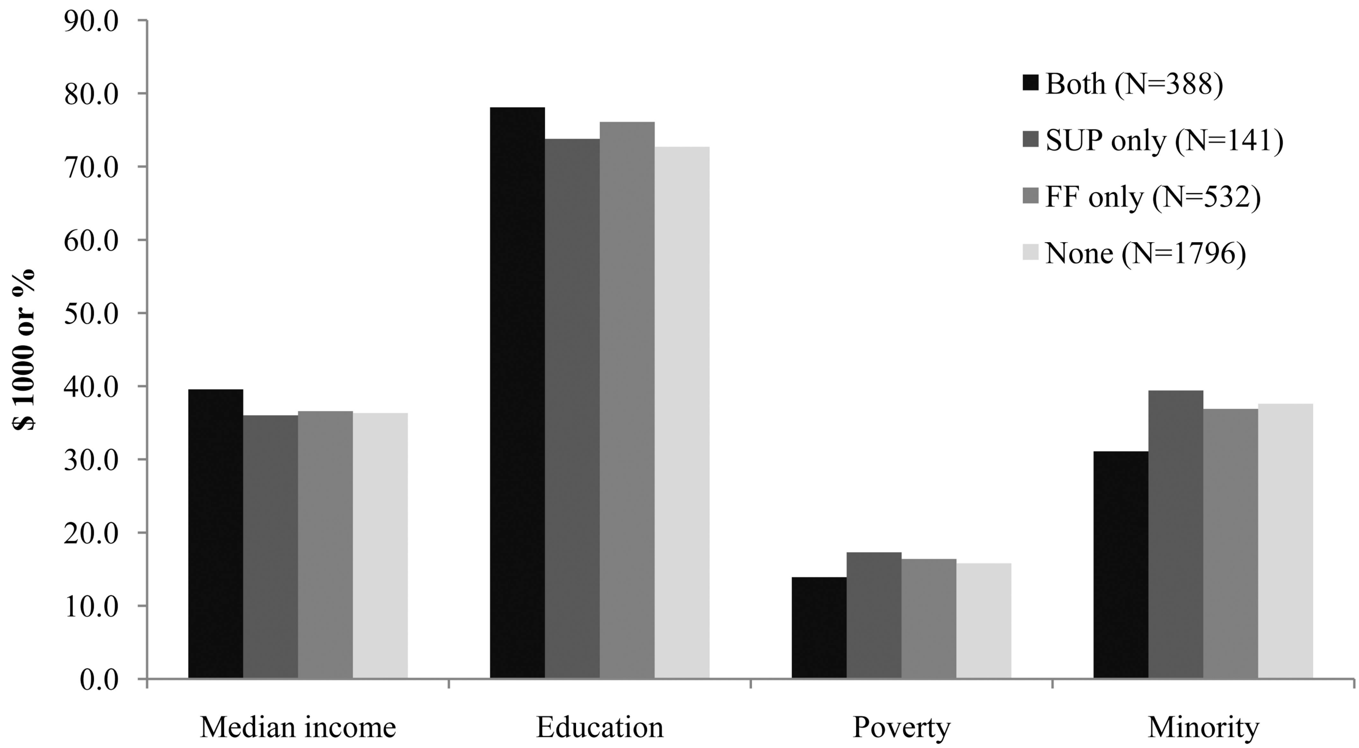


Figure 1.
Demographic and socio-economic characteristics of census block groups by combination of supermarket and fast food outlet availability.

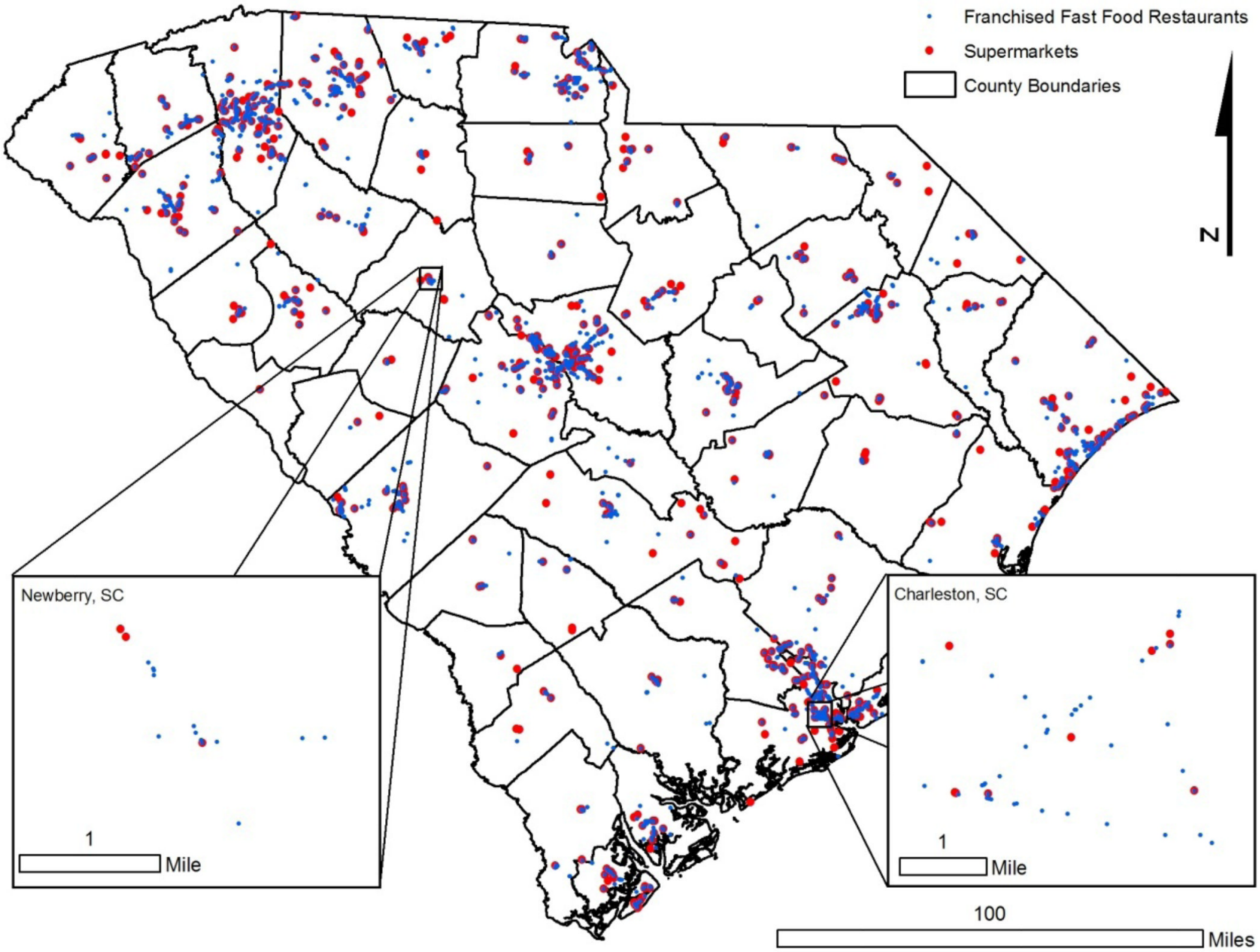
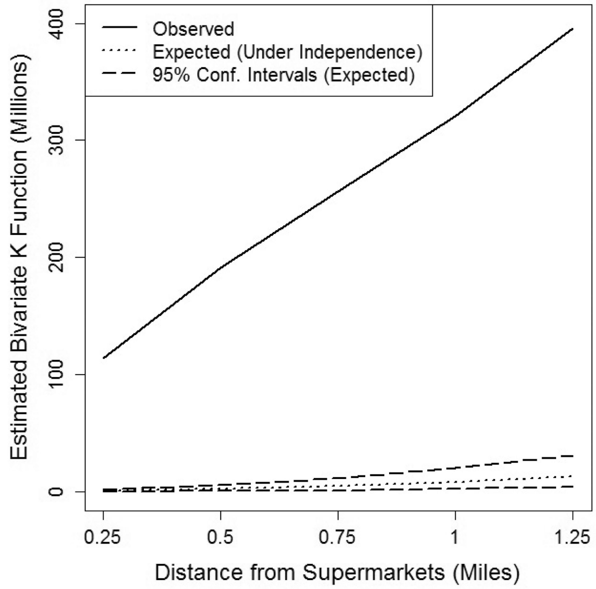


Figure 2.
Distribution of supermarket and fast food outlets in the State of South Carolina.

A)



B)

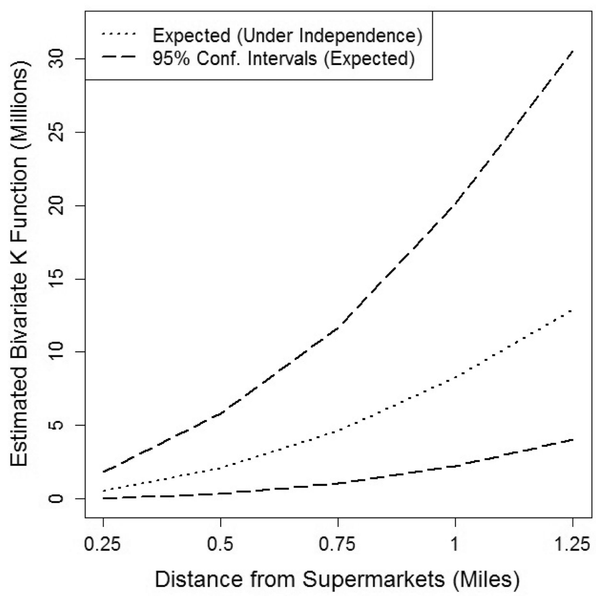


Figure 3.

Clustering of fast food outlets around supermarket locations in the state of South Carolina: A) results from bivariate K function analysis using study data, and B) results from bivariate K function analysis under the hypothesis of independence between the spatial processes.

Table 1

Neighborhood characteristics by supermarket and fast food availability categories.

Neighborhood characteristics	Supermarket availability			Fast food outlet availability		
	Yes	No	p-value	Yes	No	p-value
No. of block groups, N (%)	529 (18.5%)	2328 (81.5%)	-	920 (32.2%)	1937 (67.8%)	-
Area (sq mile)	7.0 (12.5)	11.7 (19.1)	-	6.4 (12.2)	12.9 (20.0)	-
Population density (person/sq mi)	1,057 (1,202)	1,249 (1,947)	-	1,247 (1,659)	1,198 (1,911)	-
Number of supermarket	1.3 (0.6)	-	-	0.6 (0.8)	0.08 (0.3)	<0.0001
Number of fast food outlet	2.7 (3.1)	0.5 (1.3)	<0.0001	2.85 (2.6)	-	-
Median household income ($)	38,611 (15,911)	36,374 (15,346)	0.0027	37,830 (15,657)	36,293 (15,365)	0.0131
Median value of housing ($)	98,455 (60,997)	87,555 (72,773)	0.0004	96,867 (62,724)	86,108 (74,173)	<0.0001
Population with high school education and above (%)	77.0 (13.4)	73.5 (14.0)	<0.0001	76.9 (14.1)	72.8 (13.7)	<0.0001
Minority population (%)	33.3 (24.6)	37.5 (28.3)	0.0007	34.5 (25.4)	37.8 (28.6)	0.0019
Population below poverty (%)	14.8 (11.2)	16.0 (12.0)	0.0431	15.4 (12.4)	16.0 (11.6)	0.2502
Urbanicity (%)						
Urban	50.8	45.9		59.1	40.9	
Sub-urban	15.3	19.9		14.2	21.3	
Large town	21.7	22.3		17.7	24.4	
Small town/rural	12.1	11.9	0.0687	8.9	13.4	<0.0001
Race composition (%)						
Predominantly white	39.5	36.5		38.3	36.5	
Predominantly black	4.5	9.5		5.8	10.0	
Racially mixed	56.0	53.9	0.0010	56.0	53.5	0.0009
Poverty status of area (%)						
Not poor	75.0	70.8		73.5	70.7	
Poor	25.0	29.2	0.0500	26.5	29.3	0.1208

Note: Values reported are Mean (SD) unless mentioned.

Table 2

Associations of neighborhood characteristics with supermarket and fast food availability while accounting for spatial dependencies (N=2,857).

Block group characteristics	Supermarket* OR (95%CI)	Fast food outlet* OR (95%CI)
Median household income ($)		
Low	0.8 (0.6,1.0)	1.1 (0.8, 1.4)
Medium	0.8 (0.6,1.1)	0.9 (0.7, 1.2)
High	1.0	1.0
Median value of housing ($)		
Low	0.4 (0.3,0.6)	0.5 (0.4, 0.6)
Medium	0.6 (0.5, 0.8)	0.7 (0.6, 0.9)
High	1.0	1.0
Population with high school and above education (%)		
Low	0.5 (0.4,0.7)	0.5 (0.4, 0.7)
Medium	0.6 (0.5,0.8)	0.6 (0.5, 0.8)
High	1.0	1.0
Racial composition		
Racially mixed	1.0 (0.8, 1.2)	1.3 (1.1, 1.6)
Predominantly black	0.4 (0.3,0.7)	0.6 (0.4,1.0)
Predominantly white	1.0	1.0
Poverty status		
Poor	0.8 (0.6, 1.0)	1.1 (0.9,1.4)
Not poor	1.0	1.0
Fast food availability		
Yes	9.9 (7.9, 12.4)	-
No	1.0	-
Supermarket availability		
Yes	-	10.0 (7.9, 12.6)
No	-	1.0

*Model adjusted for urbanicity-level of census block groups.

Table 3

Availability of fast food outlets within various buffers around supermarket locations.

Radius of buffers around supermarket locations (mile)	Supermarkets with fast food outlets (%)	Median number of fast food outlets
0.3	75	3 (minimum=1, maximum=16)
0.5	78	4 (minimum=1, maximum=17)
1.0	85	6 (minimum=1, maximum=24)