Food Deserts in the Southwest: A Case Study of Oklahoma City

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Abstract

This article evaluates access to supermarkets for residents of Oklahoma City with two main goals. The policy-oriented goal is to determine if Oklahoma City experiences a problem common to many metropolitan areas whereby disadvantaged segments of the population have limited access to healthy, affordable food. The methodological goal is to study access incorporating space more explicitly than occurs in most research, using spatial autocorrelation statistics and spatial correlation to identify food deserts. Food deserts are then spatially correlated to clusters of disadvantaged groups that have been found to be underserved by grocery stores. Unlike other cities in the United States, Oklahoma City's inner-city residents often have the best access to supermarkets, especially the Hispanic population and the poor. However, the African-American population experiences food deserts, a finding of many other studies in the United States.

Key words: Food deserts, Socioeconomic inequalities, Cumulative Spatial Opportunity (CSO) index, Spatial autocorrelation, Oklahoma City

1. Introduction

As cities have grown and changed through time, retail firms have had to adjust their location strategies to adapt to the spatial and economic restructuring of cities. American suburbanization forced retail businesses to expand into a succession of suburban rings and along transportation corridors. As suburbanization occurred there was concomitant emptying of the inner city as many retail firms perceived these areas to be less profitable or desirable than the suburbs. In particular, this has been a problem with grocery stores, often leaving inner-city residents with poor access to supermarkets. Poor access reduces shopping opportunities, incurs excessive travel costs to shop via increased gasoline usage or multiple bus fares, can create health risks because of poorer quality food or smaller selection, and often results in higher costs for food purchased at corner markets or convenience stores (Larson, Story, and Nelson, 2009; Odoms-Young, Zenk, and Mason, 2009).

Past research linking access to retail food health or socioeconomic status has produced inconsistent findings. Morland, Diez-Roux, and Wing (2006) found higher rates of obesity, overweight individuals, and hypertension in U.S. Census tracts lacking a supermarket. Poor access to supermarkets and other retail opportunities has been linked with low-income, inner-city, and minority residential areas in the United States (Chung and Myers, Jr., 1999; Gordon et al., 2001; Morland et al., 2002; Zenk et al., 2005; Moore and Diez-Roux, 2006; Morland, Diez-Roux, and Wing, 2006; Powell et al., 2007; Franco et al., 2008; Dai, 2010; Russell and Heidkamp, 2011), though other studies failed to find urban food deserts in Toledo (Eckert and Shetty, 2011) or Chicago (Alwitt and Donley, 1997).

Research has also found that rural residents have poor access to supermarkets (Morton and Blanchard, 2007; Powell et al., 2007) though others have found sufficient access there (Sharkey, Horel, and Dean, 2010). In the United Kingdom, poor food accessibility, if it occurs at all, is generally found only in suburban locations (Clarke, Eyre, and Guy, 2002; Wrigley, 2002), while in Australia and Canada most urban areas have good access to food and competitive food prices (Smoyer-Tomic, Spence, and Amrhein, 2006; Apparicio, Cloutier, and Shearmur, 2007; Latham and Moffat, 2007; Smoyer-Tomic et al., 2008; Ball, Timperio, and Crawford, 2009; Black et al., 2011).

In this context, this article explores supermarket accessibility in 2011 in the Oklahoma City Metropolitan Statistical Area (MSA) to determine how this city fits into the continuum of urban food deserts. Health problems are abundant across Oklahoma, including high rates of heart disease, obesity, and hypertension (Muchmore, 2010), and Oklahoma City is useful as a representative, south/western-U.S. metropolitan area, a region that is under-represented in the literature. Understanding how food accessibility differs for a variety of residents will provide policy makers with information about which neighborhoods (if any) have poor supermarket accessibility. It is hypothesized that grocery store access is worse in the inner city and for historically-disadvantaged populations such as the poor, those without vehicles, the under educated, and various racial and ethnic minorities. Measuring access to healthy food will promote a better understanding of how a lack of access might relate to recurrent health problems and what steps public agencies, private entities, and the citizenry can take to improve overall health levels of residents across the MSA.

2. Background

2.1. Emergence and health impacts of food deserts

Technology has caused a tremendous transformation of the grocery business, as well as most other retail endeavors in the United States, since the late 19th Century. Food procurement, especially in urban areas, evolved from street vendors or public markets to the grocery store due to a variety of technological catalysts including refrigeration, transportation improvements, and increased use of personal automobiles, all of which also contributed to increases in store size. Expansion via chain stores helped shopkeepers keep prices low by buying in bulk, saving on advertising expenses, and earning higher profits due to lower overhead costs (Eisenhauer, 2001).

The mid-20th Century saw the middle class flee the central city, which became less attractive to retailers as low land costs and growing populations in the suburban fringe lured retailers to develop new markets there (Shaffer, 2002). Many small stores closed because they could not compete with larger-format grocery stores (Alwitt and Donley, 1997) that emerged towards the end of the 20th Century (e.g., Wal-Mart Supercenters). This created gaps in access to grocery shopping opportunities in the inner and central cities that are called "grocery gaps" (Shaffer, 2002) or "food deserts" (Wrigley, Warm, and Margetts, 2003). When supermarkets moved to the suburbs, inner-city residents, who generally have poorer mobility, had fewer shopping opportunities. This situation, coupled with low incomes, meant finding healthy food could be problematic and led to poor food choices and increasing health risks (Eisenhauer, 2001). Poor nutrition has been found to contribute to many health problems, including diabetes, heart disease, and a variety of cancers (Steinmetz and Potter, 1996; Franceschi et al., 1998; Fernandez et al., 2000).

In the United States, food deserts have often been found in inner-city areas where there are concentrations of minorities and lower-income residents. Shaffer (2002) linked the limited options for obtaining healthy food in Los Angeles to serious health problems like obesity. Similar results have been found across the United States. In Baltimore, Franco et al. (2008) determined that predominantly black and lower-income neighborhoods had poorer healthy food availability than neighborhoods that were mostly higher-income and white, findings mirrored in New York City by Gordon et al. (2001). Berg and Murdoch (2008) found that low income residents and African-Americans in Dallas had the worst access to grocery stores. In Detroit, the racial makeup of the area, specifically African-American neighborhoods, had more of an impact on access than income levels (Zenk et al., 2005). Chung and Myers (1999) found lower access to chain grocery stores and higher prices in the inner city of Minneapolis-St. Paul. A study of neighborhoods in Maryland, Minnesota, Mississippi, and North Carolina (Morland et al., 2002) found that heavily African-American residential areas had only one-fourth the number of supermarkets in located in predominantly white areas, while a study of over 28,000 zip codes across the United States determined that African-American and Hispanic neighborhoods had only 52 percent and 32 percent as many chain supermarkets as white or non-Hispanic neighborhoods, respectively (Powell et al., 2007).

Furthermore, food deserts are not strictly an urban phenomenon nor experienced only by the poor. Rural residents also experience limited supermarket accessibility (Furey, Strugnell, and McIlveen, 2001; Sharkey and Horel, 2008; Smith and Morton, 2009) as retail opportunities tend to be farther away, public transit is nonexistent, and thus vehicles are necessary for travel. Also, low-income residents are not the only ones experiencing poor food access and malnutrition; those who are disabled, ill, without a car (Hallett, IV and McDermott, 2011), single parents, unemployed, and elderly are disadvantaged (Westlake, 1993). Whether income, race, or a combination of factors is responsible for limiting shopping opportunities, these food deserts serve to isolate the residents both economically and socially, as a much narrower range of business or entertainment opportunities exists nearby (Westlake, 1993; Piacentini, Hibbert, and Al-Dajani, 2001).

Lack of access increases both travel costs and food prices, though research findings have been mixed as to price differentials between minorities and the poor versus white, affluent areas (Winkler, Turrell, and Patterson 2006; Latham and Moffat 2007; Ball, Timperio, and Crawford 2009). Low-income consumers have less to spend so any increase in the cost of a good has severe consequences that can force consumers to sacrifice other necessities, like shelter or clothing. Hence, the study of food availability is a multi-faceted problem involving characteristics of the population, retailers, and geographic characteristics of the study area, topics that are reviewed next.

2.2. Process measures and outcome measures

Living in close proximity to a retail store, medical facility, or community center should make it easier to access that place. Yet, studies have revealed that even when access is improved, consumers still may not take advantage due to prior habits or monetary issues (Wrigley et al., 2002; Wrigley, Warm, and Margetts, 2003). As a consequence, methods have emerged to study this phenomenon from two perspectives, examining both the objective spatial traits of the study area and the subjective behavioral choices of the studied population. Correspondingly, accessibility studies are typically based on either *process measures*, which employ aggregate socioeconomic data and the locations of facilities to evaluate the spatial dimensions, or *outcome measures*, which require surveys of the population to understand the behavioral dimensions (Guy, 1986). Due to the time, cost, and other issues associated with surveys, this research uses process measures to study conditions across the MSA and to represent its entire population as completely as possible using economic and demographic data from the U.S. Census.

In addition to population traits, process measures require some delineation of consumers' distance thresholds for various goods and services in order to determine the set of accessible facilities for each neighborhood. For example, convenience stores attract customers from a shorter distance that do regional malls (Wrigley, Guy, and Lowe, 2002). Approaches that use travel times or simple distances to a facility are the most common (Joseph and Phillips, 1984; Zenk et al., 2005) as are methods that identify the number of opportunities within a specified buffer (Russell and Heidkamp, 2011).

Lacking individual-level survey data, this research examines the entire metropolitan area using a standard threshold distance. A wide range of buffer values has been used in past research on grocery stores (Charreire et al., 2010). Clarke, Eyre, and Guy (2002) used 500-meter buffers around retail food stores in Great Britain. Smoyer-Tomic et al., (2008) employed four different distances (500, 800, 1000, and 1500 meters from census-block centroids) in Edmonton, Canada. Witten, Exeter, and Field (2003) used a 2000-meter buffer for supermarket access in New Zealand. In Dallas, Berg and Murdoch (2008) used a one-mile radius around each supermarket. In contrast, in rural areas a consensus buffer size seems to be ten miles (Morton and Blanchard, 2007; Sharkey and Horel, 2008; McEntee and Agyeman, 2010; Hubley, 2011). Research in the Oklahoma City MSA has determined that a buffer of three miles best delineates the breakpoint between good and poor access (Brown, 2011) though experimentations with other buffer sizes produced similar results. Smoyer-Tomic, Spence, and Amrhein (2006) likewise found few differences between different buffer sizes. Although the three mile buffer chosen for this article is larger than what has been used in other urban studies, the Oklahoma City MSA has large swaths of rural land and one of the largest metropolitan footprints in the United States.

2.3. Measuring access to facilities

In addition to understanding the nature and history of food deserts and determining the distance thresholds that delimit consumer behavior regarding grocery stores, the issue of how to detect, measure, and differentiate unequal access to grocery stores must be resolved. Guy (1986) describes several accessibility measures, including gravity, Gaussian, and the Cumulative Spatial Opportunity (CSO) measures. A trait of all measures is that they produce an index score of accessibility for each location that can be mapped and statistically analyzed while retaining unique features that measure accessibility in different ways. All measures ultimately descend in some way from the gravity model, with distance decay impeding access; models differ based on the specific distance decay function used and the many ways that access to opportunities (here, grocery stores) can be tabulated, measured, or ranked.

A measure directly based on the gravity model is simplest and serves as a benchmark against which more complex methods can be evaluated. Access to retail opportunities for locations across the study area can be measured as:

$$A_i = \Sigma_j S_j * d_{ij}^{\beta} \qquad (1)$$

where A_i is the accessibility index for location i, S_j is the 'size' of the opportunity at location j, d_{ij} is the distance from location i to opportunity j, and β is a distance decay parameter (Guy, 1986). A fuller discussion of the dataset occurs later, but locations i in this study will be Census tracts and opportunities j will be grocery store locations. Often, S_j is set to one and all stores are treated as identical entities (Guy, 1986), an approach adopted here, but it could actually measure size in some way (e.g., square footage, number of establishments in a mall). Overall, however, this model is quite basic.

Gaussian models improve upon simple gravity measures because they allow for non-linear distance decay effects, giving much heavier weights to closer opportunities. Weights decline at a rapid pace the farther out an opportunity j is from location i. A standard Gaussian formulation is:

$$A_i = \Sigma_j S_j * exp\{-½[d_{ij} / d_*]^2\} \qquad (2)$$

where d_* is the distance from point i at which the rate of decline in accessibility has achieved its most rapid rate (the inflection point on the distance decay curve). Beyond d_*, the decline in accessibility becomes more gentle as it approaches the distance axis asymptotically (Guy, 1986). However, the calibration or justification for values of d_* can be as challenging as estimating β in a standard gravity model.

The Cumulative Spatial Opportunity (CSO) method limits analysis to a subset of opportunities. Rather than computing the influence of every opportunity j in the study area on access for each location i, the CSO employs a bandwidth distance D that limits opportunities to only those within a certain distance from location i. The bandwidth D is typically set to some value representing the likely maximum walking or driving distance consumers will travel for the good. Thus, the CSO measure is based only on the distance decay for a smaller number of nearby shopping opportunities to which consumers might travel and is influenced only by the number of opportunities available to location i within the threshold D; this number is expressed as $O_i(D)$. As with all measures, nearer opportunities have higher weights than farther ones. The CSO measure can be expressed as (Guy 1986):

$$A_i = O_i(D)* \{D - [\Sigma_j d_{ij} / O_i(D)]\} \qquad (3)$$

The biggest challenge of the CSO method is that it is sensitive to the bandwidth value D. If the distance is either too large or too small, the numbers of opportunities may be too many or too few, respectively. Past studies provide some guidance in this area, but some examination of the study area is needed to arrive at a satisfactory value of D for this research. As noted earlier, preliminary research has derived a bandwidth or threshold distance of three miles for this study as 75 percent of the Oklahoma City MSA population and over 80 percent of Census tracts have either their first- or second-closest supermarkets within three miles (Brown, 2011). For an extensive review of other buffer distances and methods used, see Charreire et al. (2010).

2.4. Spatial autocorrelation

The goal of this article is to identify spatial associations between the locations of food deserts and historically-disadvantaged populations. While it is tempting to simply correlate CSO scores and socioeconomic variables across tracts, these traits typically exhibit spatial autocorrelation (SAC), a phenomenon in which the value of an individual observation is correlated to its neighbors. This phenomenon underpins the concepts of neighborhood, region, and culture, and is very important in geography. However, SAC violates the assumption of independent observations that is critical to methods like correlation and regression, tools that could detect associations between access and socioeconomic status. A strong correlation between two non-spatial variables may be due to a mutual dependence on an omitted (and possibly un-measurable) variable that captures the spatial characteristics of the study area and not because of a direct, causal link (Haining, 1990). Such spatial characteristics may relate to aggregation and scale effects as well as larger population processes that drive people to segregate into enclaves of similar status. As a result, the effects of autocorrelation must be accounted for in some fashion.

To address this situation, SAC statistics are used. Specifically, Moran's *I* (Getis, 2010) measures SAC for each variable (univariate analysis) and can be used to spatially correlate CSO scores with socioeconomic variables (bivariate analysis). In addition to avoiding problems of overlooking SAC in a dataset, local statistics are calculated for each sub-unit of the study area (here, tracts), which can be mapped and studied both visually and statistically. To facilitate this analysis, the software package *GeoDa* (Anselin, Syabri, and Kho, 2010) is used, which easily calculates the spatial statistics and significance maps shown in the results given later.

Given the large number of food desert definitions (McEntee, 2009), accessibility measures, statistical methods, and available data sources and scales, consensus about the ideal way to study this phenomenon is unlikely to emerge, despite the hopes stated by McEntee and Agyeman (2010) in their assessment of the body of research. However, recent research remains relatively descriptive in both the literal and statistical sense of the word, so this article represents a methodological advance and provides an urban case study similar to recent research focused on Montréal (Apparicio, Cloutier, and Shearmur, 2007).

3. Study Area

Oklahoma ranks last among U.S. states in the percentage of adults who eat five or more servings of fruits and vegetables daily, over one-third of the population is overweight, and in 2004 Oklahoma ranked worst among states in the percentage of households that go hungry. Furthermore, a recent study found that thirty-two of the seventy-seven counties have a food desert (McDermott et al., 2006); as noted earlier, this was the only research found specific to Oklahoma but it was conducted at the county level. Due to this county-level research, more in-depth analysis is needed to understand these variations at a smaller geographical scale. Oklahoma City (Figure 1) is studied due to the lack of previous research done on the MSA and its demographic similarities to the entire United States.

The Oklahoma City MSA has just over 1.3 million people in seven counties (6,300 square miles) in central Oklahoma. It was the fastest-growing city in Oklahoma between 2000 and 2010 and has recently experienced an increasing number of minorities, especially Hispanics (Census 2010). African-Americans and Hispanics comprise 9.9 percent and 9.5 percent of the population, respectively. Though not mutually exclusive, these groups are distinctly segregated, African-Americans being concentrated to the east of the downtown core near the state capital and Hispanics clustered southwest of the downtown area. The MSA is 11.7 percent elderly, has 14.9 percent of its population living in poverty, 12.6 percent of its adult (age twenty-five and over) population lacks a high school diploma, and just 2.1 percent of the population over the age of sixteen does not own a vehicle. Though Oklahoma has a large American Indian population, this group makes up just 3.2 percent of the MSA population (U.S. Census Bureau, 2009, 2010).

No research on supermarket access in Oklahoma City was found. In 2006, each county in Oklahoma was analyzed for food accessibility and food security (McDermott et al., 2006), but no research on food access at the neighborhood level exists. Past research has examined access to public parks and other services in apposition to socioeconomic data. With respect to parks, better access corresponded to Hispanic and low-income tracts, whereas heavily African-American and Asian tracts had less access (Comer and Skraastad-Jurney, 2008). Various services and amenities differed along residential lines. Inner-city residents had good access to employment center, but suburban residents had better access to recreational facilities and health care centers (Knox, 1982).

4. Data Sources

Supermarkets offering fresh fruits and vegetables, fresh meat (e.g. ground beef, pork, and chicken), and a

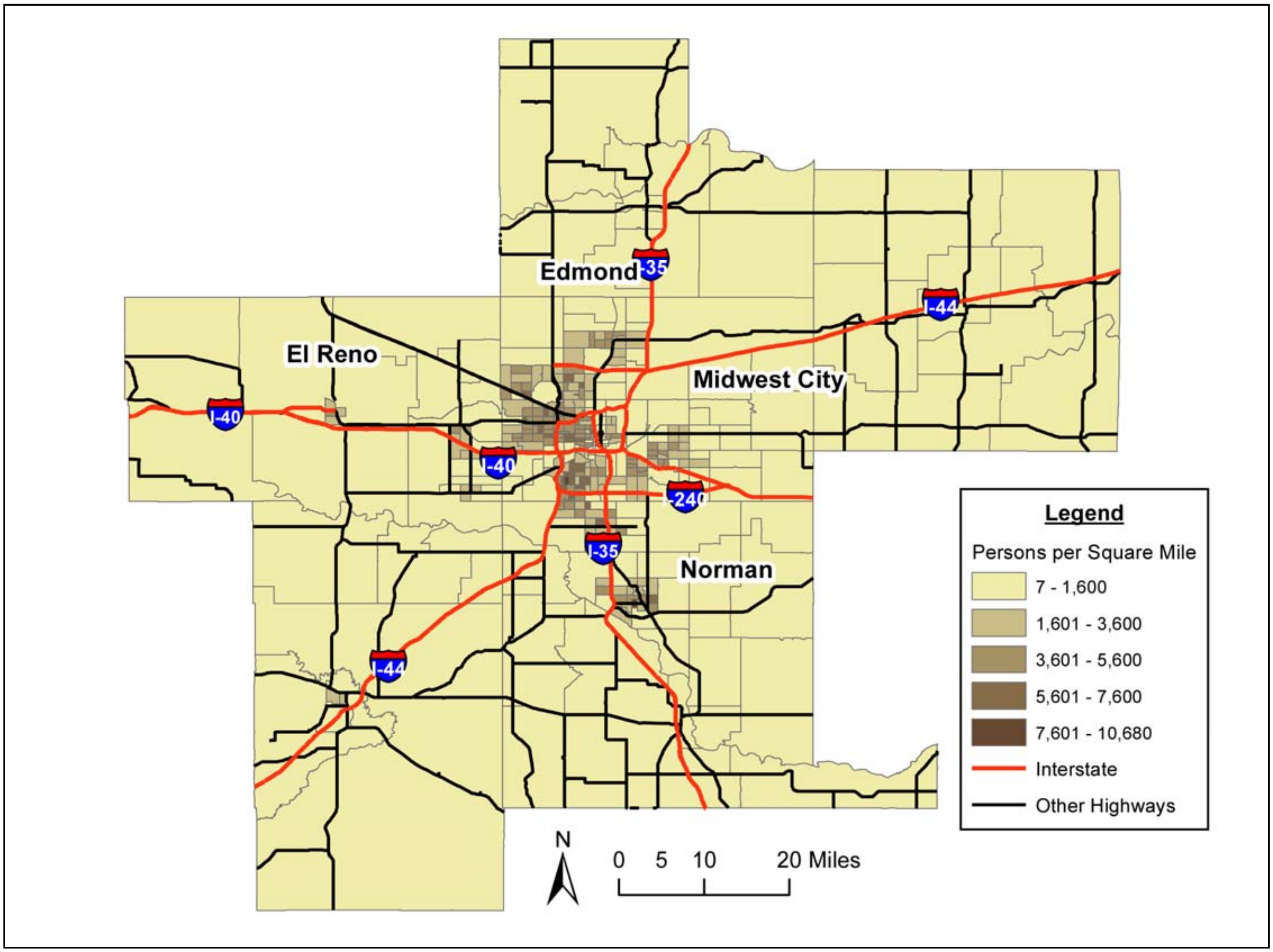

Figure 1. Population densities of Oklahoma City MSA census tracts

wide variety of staple foodstuffs are used in this research due to their greater selection of food and lower prices than smaller retailers like corner markets or convenience stores. Chain stores (e.g. regular Target stores) without a fresh meat selection are excluded due to their smaller selection of food items, as are convenience stores, fast food stores, and specialty food stores (e.g. ethnic, organic, gourmet). Locations of food retailers were determined from the local telephone directory, a common approach (Zenk et al., 2005; Ball, Timperio, and Crawford, 2009; Kelly, Flood, and Yeatman, 2011), and verified with site visits to each supermarket over several months in 2011. In order to mitigate edge effects, supermarkets within twenty miles of the boundary of the MSA were included to account for residents living near the MSA's edge traveling outwards for their food. This resulted in a dataset with 104 supermarkets (Figure 2).

In addition to grocery store locations, socioeconomic and demographic data are needed for the process measure approach adopted here. Census data present several choices of spatial units for analysis: blocks, block groups, or tracts. Census tracts tend to exhibit similar socioeconomic characteristics so this study uses tracts as proxies for true neighborhoods, an extremely common approach in the literature (Zenk et al., 2005; Moore and Diez-Roux, 2006; Franco et al., 2008; Black et al., 2011) although block groups (Sharkey and Horel, 2008; Russell and Heidkamp, 2011; Widener, Metcalf, and Bar-Yam, 2011) and ZIP codes (Alwitt and Donley, 1997; Powell et al., 2007) have been used as well. In Canada, numerous governmental surveys use true neighborhoods for data collection purposes, permitting direct study of neighborhoods there (Smoyer-Tomic, Spence, and Amrhein, 2006; Latham

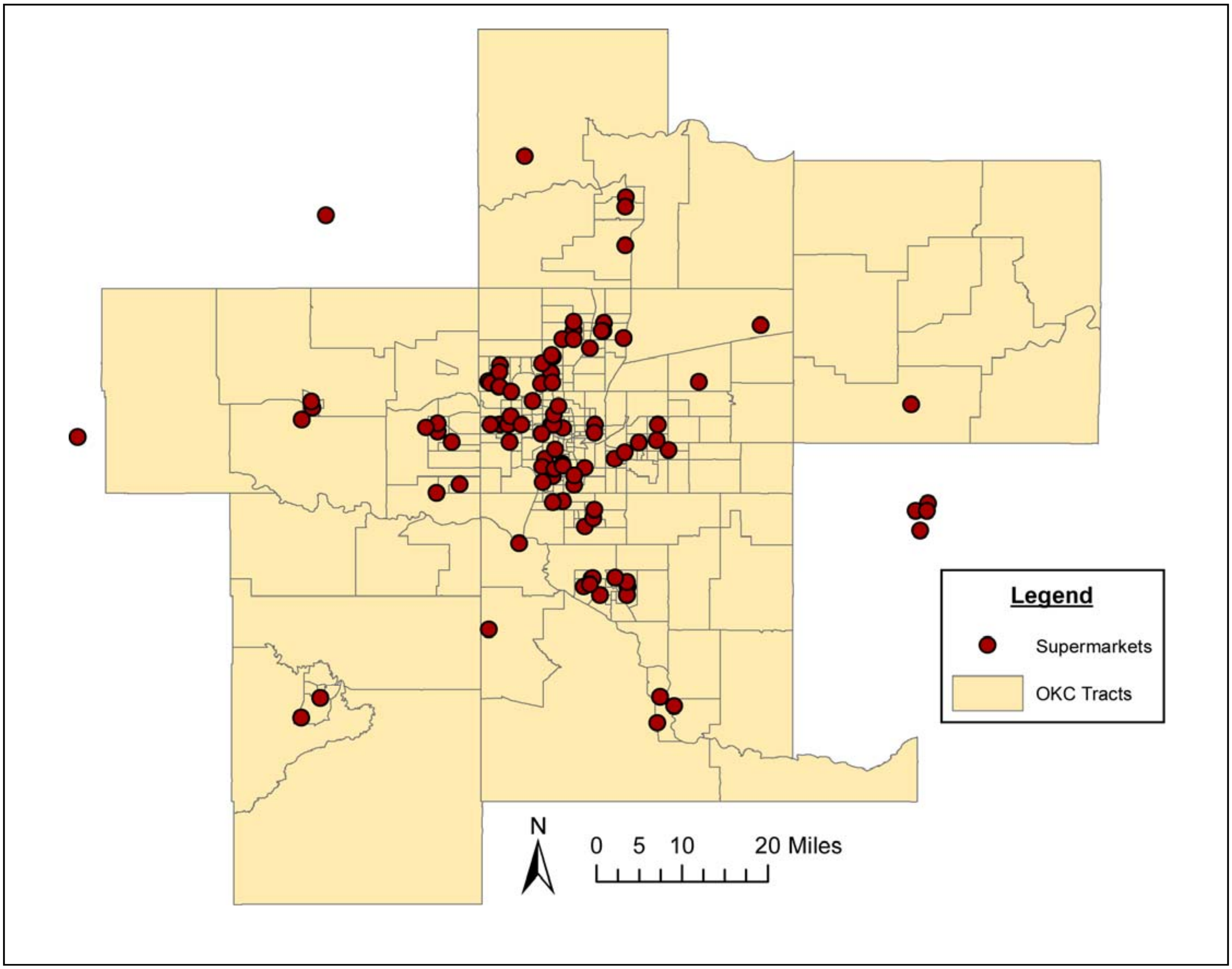

Figure 2. Oklahoma City MSA supermarket locations included in study

and Moffat, 2007; Smoyer-Tomic et al., 2008). The use of spatial aggregates instead of individual households introduces bias (Hewko, Smoyer-Tomic, and Hodgson, 2002), but this is unavoidable given the nature of this research and the greater ease, lower cost, and more complete coverage that Census data provide.

Past research (Beaulac, Kristjansson, and Cummins, 2009; Larson, Story, and Nelson, 2009; Walker, Keane, and Burke, 2010; Kelly, Flood, and Yeatman, 2011) provides guidance on identifying population groups that are most at risk for poor supermarket access. Minority populations usually have poorer access in metropolitan areas so the percentages of African-Americans, American Indians, and Hispanic populations are included. Additionally, income and educational attainment may affect access so these traits are included by using the percentage of residents living in poverty and the percentage of adults age twenty-five and older who lack a high school diploma. Access to healthy food is also important throughout the lifespan and elderly residents are more at risk for living in food deserts, so the percentage of population age sixty-five and older is analyzed. Finally, transportation can be a critical factor in accessing a range of retail options so the percentage of persons age sixteen and older without a personal vehicle is included (Smoyer-Tomic, Spence, and Amrhein, 2006).

In the United States, most socioeconomic data are now collected annually via the American Community Survey (ACS) instead of the decennial Census. Therefore, this article uses tract-level data from the 5-year ACS, which was based on a sample of approximately two million people nationwide and was conducted from January 1, 2005 to December 31, 2009 (Census, 2009). Table 1 lists the ACS variables used in this study. Note that several indicators (education,

Table 1. Variables and definitions from ACS 5-year estimates

Demographic Variable of Interest	Table	Description
Percentage African-American	B02001	Race
Percentage American Indian	B02001	Race
Percentage Hispanic	B03002	Hispanic or Latino by Race
Percentage without Diploma	B08141	Sex by age by educational attainment for the population 25 years and older
Percentage in Poverty	B17001	Poverty in the past 12 months by sex by age
Percentage Elderly	B01001	Sex by age
Percentage without Motor Vehicle	B08141	Means of transportation to work by vehicles available for the population 16 years

Source: U.S. Census Bureau (2009)

poverty, and transportation to work by automobile) are expressed as percentages of the appropriate target sub-population (i.e., adults), not the entire population of the MSA.

Finally, to determine neighborhood-level exposure to supermarkets, ESRI's (2009) ArcGIS 9.3 Network Analyst extension is used to calculate the distances between supermarkets and tract centroids as recommended by Smoyer-Tomic, Spence, and Amrhein (2006) using a road network file for the Oklahoma City MSA (OCGI, 2010). While the MSA encompasses 334 total tracts, one downtown tract (1031.02, comprising about sixteen city blocks near the downtown sports arena complex) has no population and is excluded, leaving 333 populated tracts to use as observations (*n*) in this study.

5. Results

To differentiate areas of the MSA with respect to grocery stores access, patterns of CSO values are mapped and spatially correlated with socioeconomic variables to determine if historically-disadvantaged groups experience poor access and are thus at risk of negative health outcomes to which poor access has been linked. This article serves as both a case study for the Oklahoma City MSA as well as a template for how other metropolitan areas in the United States (and beyond) could be studied. Figure 3 shows the CSO scores with higher values indicating higher access to grocery stores. Access is highest in the central corridor and decreases towards the edges, with pockets of higher access existing in some of the suburbs that have more supermarkets. This is noteworthy because it reveals that the portion of Oklahoma City hypothesized to be underserved, the downtown area, might not suffer from a food desert like occurs in many other U.S. cities. This result, combined with other research in Oklahoma City (Comer and Skraastad-Jurney, 2008), indicates that Oklahoma City may be rather atypical in terms of access levels to grocery stores, doctors, and variations in food prices (Brown, 2011).

As noted earlier, SAC will invalidate the results of simple correlation analyses so an examination of global SAC will indicate whether these concerns are warranted. Global Moran's I values are computed for each of the socioeconomic variables and the CSO measure and are ranked in Table 2 from highest (positive) SAC to lowest. Of note, the bounds of Moran's I are +/-1.0, just like Pearson's correlation coefficient, though the expected value is not exactly zero like Pearson's r but rather is $-1/(n-1)$ (Getis 2010). With 333 observations (tracts), the expected value is -0.0030 under a null hypothesis of no SAC. In comparison to this value, all variables are significant to at least the 0.002 significance level (0.2 percent) using a permutations approach (Anselin, Syabri, and Kho, 2010) with 999 permutations. Hence, all variables exhibit strong positive SAC and simply correlating them with Pearson's r would increase Type I error rates when rejecting null hypotheses (Haining, 1990).

Across the MSA, the Hispanic population is the most concentrated followed by those without high

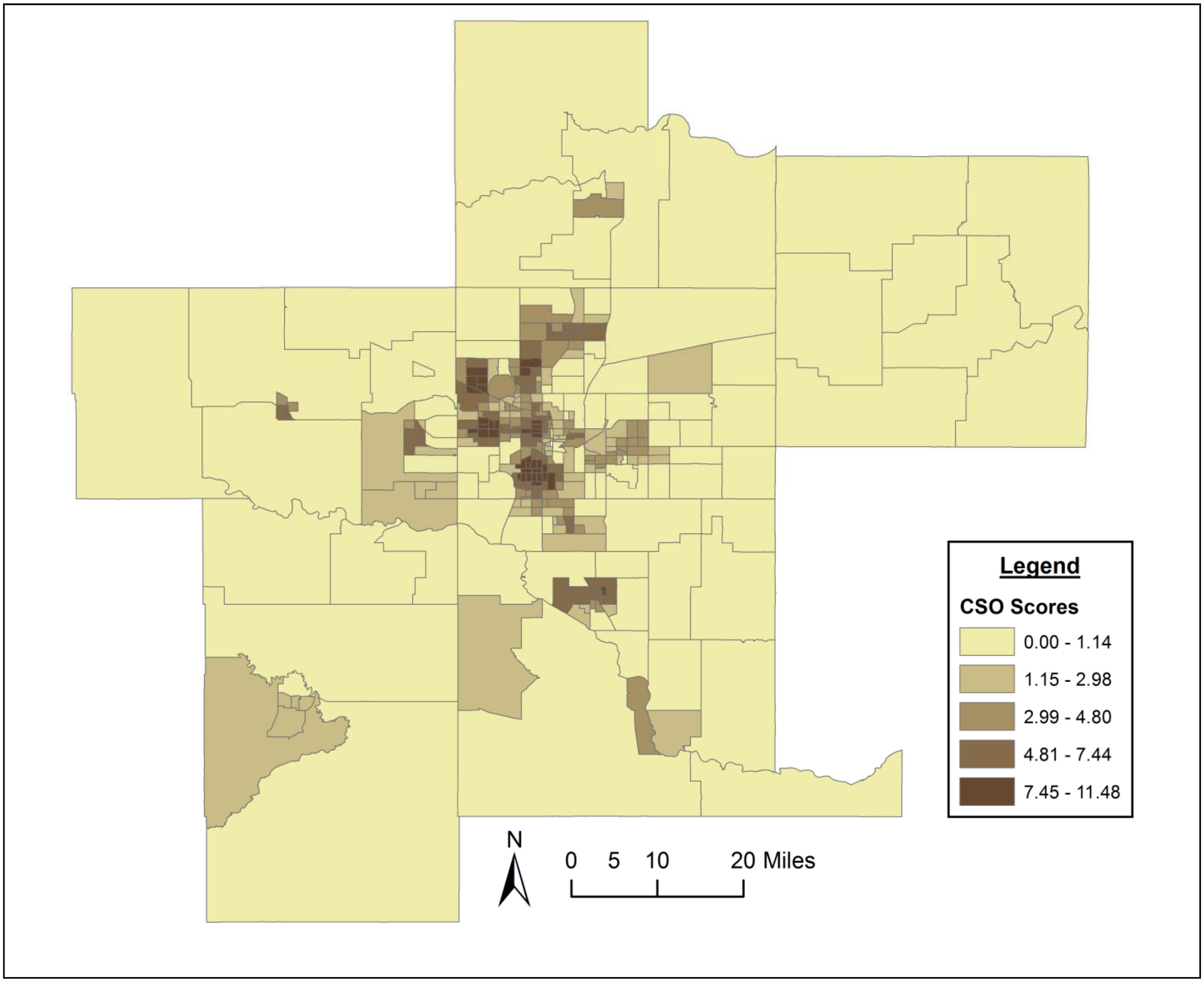

Figure 3. Cumulative Spatial Opportunities (CSO) scores using 3-mile bandwidth

school diplomas and African-Americans. Those living in poverty are moderately clustered, while the elderly, American Indians, and those without vehicles are notably less concentrated though still statistically significant. Finally, there are clearly areas with good or poor access to grocery stores as measured by the clustering of similar CSO scores. Having identified areas of differential access to grocery stores, the main focus of this article turns to who lives in underserved areas and if this matches expectations.

An extension of the univariate Moran's statistic is the bivariate Moran's *I*, which correlates an observation's value of one variable against the average of its neighbors' values of a <u>second</u> variable (i.e., the spatial lag). This approach permits an examination of the relationship between pairs of variables in the presence of SAC, allowing for meaningful interpretations of the strength and direction of the relationships as well as producing significance values for each observation (tract) that can be mapped and examined. Table 3 summarizes these results.

Notably, percent Hispanic and CSO have the strongest spatial association; these were also the two variables that exhibited the most univariate clustering (Table 2). Thus, the Hispanic population experiences good access to grocery stores overall. This may be an unexpected finding, but the Hispanic population, especially in Oklahoma City as well as many other North American cities, has not followed the same historical patterns of migration and settlement as groups like African-Americans or American Indians.

Table 2. Global univariate spatial autocorrelation statistics

Demographic Variable of Interest	Moran's *I*	Significance (p-value)
Percentage Hispanic	0.7468	< 0.001
CSO	0.6157	< 0.001
Percentage without Diploma	0.6099	< 0.001
Percentage African-American	0.5386	< 0.001
Percentage in Poverty	0.3152	< 0.001
Percentage Elderly	0.1625	< 0.001
Percentage American Indian	0.1246	< 0.001
Percentage without Motor Vehicle	0.1129	0.002

Table 3. Global bivariate spatial autocorrelation statistics

CSO vs. Variable of Interest	Moran's *I*	Significance (p-value)
Percentage Hispanic	0.3764	< 0.001
Percentage without Diploma	0.2528	< 0.001
Percentage in Poverty	0.1732	< 0.001
Percentage without Motor Vehicle	0.1028	0.002
Percentage Elderly	0.0277	0.118
Percentage American Indian	0.0103	0.298
Percentage African-American	-0.0959	< 0.001

Hispanics are relative latecomers to cities outside the Sunbelt, so any "flight" of retail in past decades had long since happened and Hispanic immigrants arrived to already-changed retail landscapes. Rather than settling in the inner-city, Hispanics are somewhat outside this area and therefore, retail opportunities still exist.

The other positive and significant correlations with CSO are for the percentages of the population without a high school diploma, those living in poverty, and those without vehicles, though these are relatively small in magnitude with bivariate *I* values of 0.25, 0,17, and 0.10 respectively. Thus, conditions are not as bleak for inner-city residents in Oklahoma City as in other cities because many high-need areas have good grocery store access.

At the other extreme, African-Americans stand out with the only negative SAC result detected in this study, either univariate or bivariate. Most importantly, this reveals that Oklahoma City is not entirely unique in terms of equitable access to healthy food for its historically-disadvantaged populations. This is somewhat surprising, since the African-American population is concentrated just to the east of the downtown area, but this concentration is farther east of the largest agglomeration of high CSO scores and has very little overlap.

These results are useful, but global statistics only tell part of the story. Most importantly, they do not permit an examination of specific locations where food deserts exist for various population groups. As such, another valuable analysis tool is the significance map based on local statistics, showing each tract with a local Moran's I_i value that is significant at the 0.05 level or below. The value of local statistics is that they permit the identification and mapping of four combinations of SAC. Positive SAC can manifest itself as either "high-high" patterns (hot spots) in which significantly larger than expected values of both variables are spatially contiguous, or "low-low" patterns (cold spots) where significantly lower than expected values co-locate. Likewise, negative SAC can appear as either "low-high" or "high-low" juxtapositions (Anselin, Syabri, and Kho 2010). For consistency, the relative value of a tract's CSO score is listed before the hyphen and the spatial lag of that tract's neighbors' values of each socioeconomic variable is listed after the hyphen in the legends for Figures 4-7.

The strongest bivariate spatial association is for percent Hispanic and CSO and the strong spatial association between these two variables is clearly evident on Figure 4. Both the dark black (high-high) and gray (low-low) tracts exhibit positive SAC. The core of the Hispanic population cluster southwest of downtown overlaps strongly with tracts having high CSO scores (a hotspot) while the northeast portion of the MSA has both a very small Hispanic presence and poor access to grocery stores (a cold spot). A few small pockets of negative SAC can also be seen; these tend

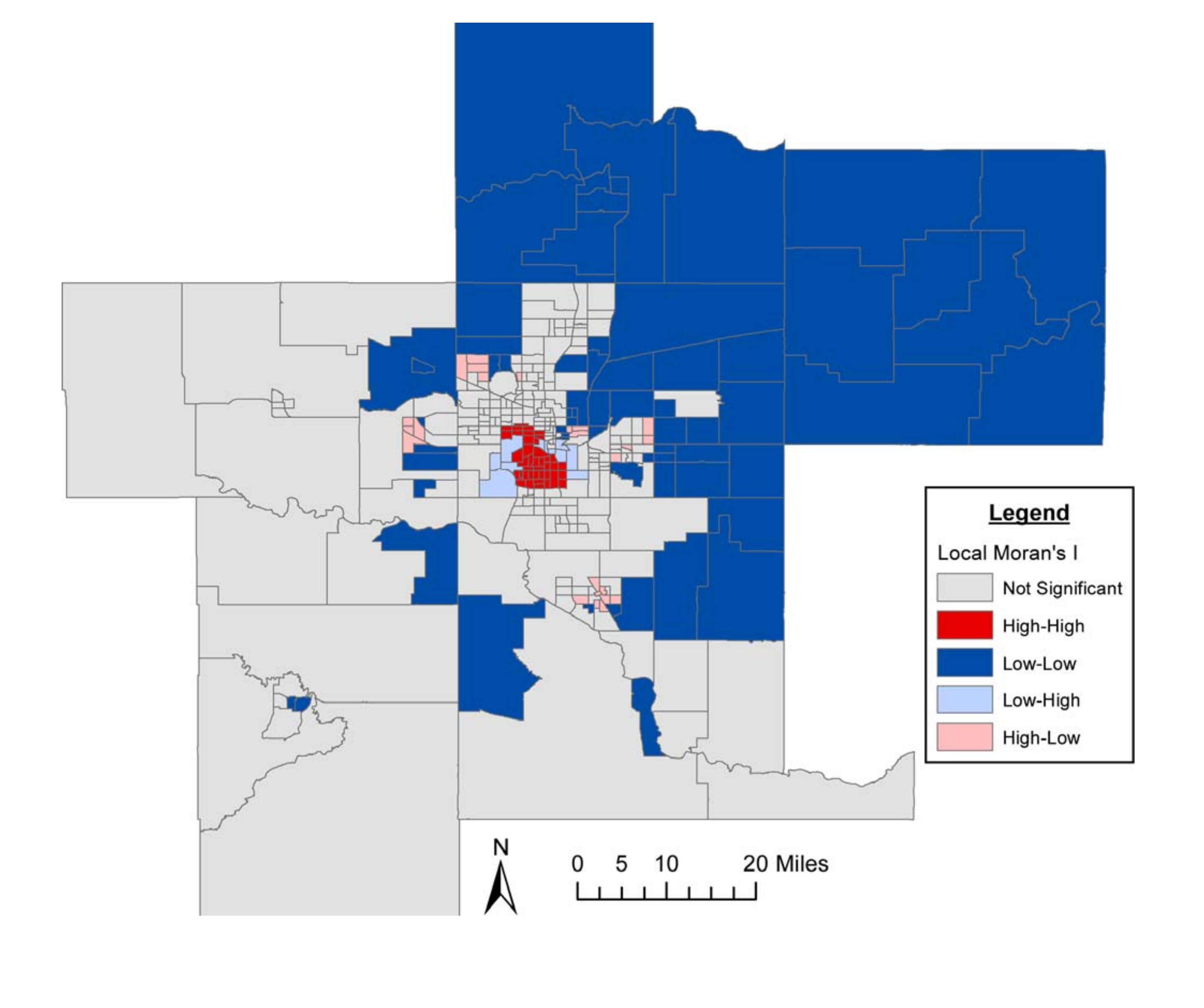

Figure 4. CSO and percentage Hispanic cluster map

to be on the fringes of hot or cold spots where two variables' values are in transition and there is a juxtaposition of high and low values.

The next highest bivariate Moran's *I* value is for the percentage of the population without a high school diploma (Figure 5). Of note, the hot spot on this map almost perfectly matches that shown on Figure 4 because the socioeconomic characteristics themselves correlate; locations with large concentrations of Hispanics, poverty, low educational attainment, and poor access to private transportation are all likely to co-locate. However, several negative autocorrelation areas with high access and low percentages of persons without diplomas are quite noticeable. Edmond to the north and Norman to the south stand out as both are home to large state universities (the University of Central Oklahoma is in Edmond while the University of Oklahoma is in Norman). The other form of negative SAC noticeably surrounds the hot spot; areas of poor access adjacent to the Hispanic cluster also have high percentages of persons without diplomas. Again, this reveals that the corridor of good grocery store access is quite narrow, and while it runs through the Hispanic cluster of Oklahoma City it misses concentrations of other groups in the MSA.

Another positive SAC result is for percentage living in poverty (Figure 6). Not surprisingly, the Hispanic dominated area southwest of downtown Oklahoma City is apparent here as well due to the

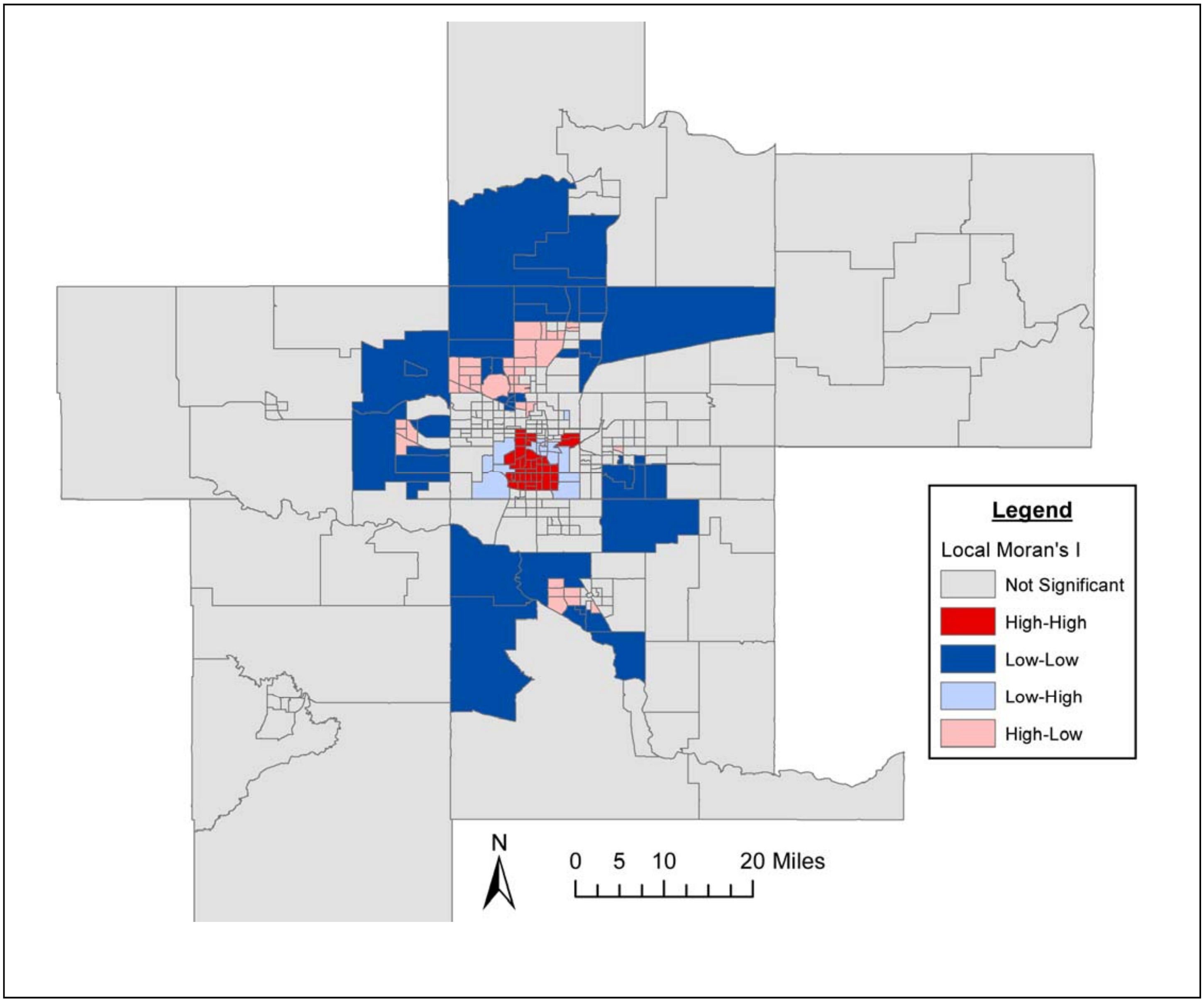

Figure 5. CSO and percentage without diploma cluster map

aforementioned links between Hispanic origin, low educational attainment, and poverty. Again, however, this area is congruent with an area evincing good access to grocery stores, resulting in a hot spot. Surrounding this hot spot is a low-high zone of poor access to grocery stores for tracts with high levels of poverty.

As noted earlier, the lone result that matched expectations derived from the literature is that African -Americans experience poor grocery store access. However, the global Moran's *I* value of -0.09 is not large and is significant mostly due to the large sample size (333 tracts). An examination of the local statistic's pattern (Figure 7) reveals a problem area that is just east of downtown consisting of many tracts with significantly low access (CSO) scores and high African -American percentages. Thus, in Oklahoma City the African-American population is the one group clearly experiencing food deserts.

Thus, Oklahoma City resembles other U.S. cities in terms of poor access for African-Americans. However, other groups sometimes found to be underserved in other studies – the poor, the elderly, the less educated, and Hispanics – generally enjoy good access in the MSA. On the whole, Oklahoma City is unique in its patterns of grocery store access compared to most other U.S. cities and is more similar to cities in Canada and the United Kingdom.

6. Conclusion

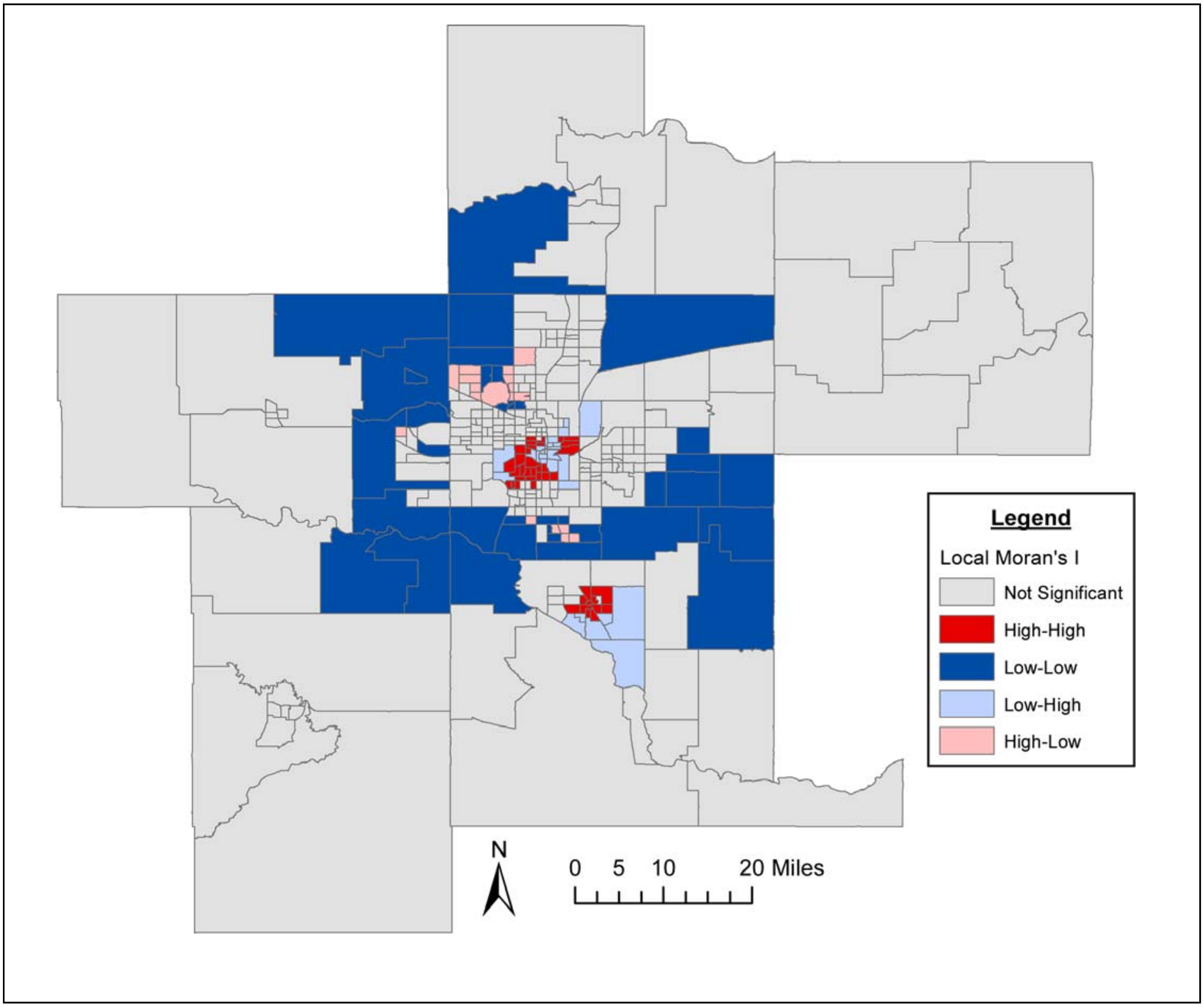

Figure 6. CSO and percentage living in poverty cluster map

This study contributes to the literature by examining neighborhood access to grocery stores using the CSO measure, which improves on simpler distance decay methods by limiting possible shopping options to a fixed distance threshold. Guidance from the literature and evidence from the Oklahoma City MSA resulted in a choice of three miles for this distance. Using the CSO in conjunction with various socioeconomic indicators representing historically-disadvantaged groups found relatively good grocery store access for the majority of residents across the MSA, in particular refuting the hypothesis that the inner city would exhibit food deserts in high-need areas.

This finding contrasts with many past studies of food deserts (for reviews, see Beaulac, Kristjansson, and Cummins, 2009; Larson, Story, and Nelson, 2009; Walker, Keane, and Burke, 2010; Kelly, Flood, and Yeatman, 2011). Bivariate spatial autocorrelation techniques did reveal that African-Americans have poorer access, a finding common across most studies of American cities. Whether this pattern occurred due to African-Americans moving into existing food deserts or whether the stores left at some point after these neighborhoods were established would require a detailed historical examination of the study area. Such study is beyond the scope of this article but would be an informative supplement to this research.

Overall, this article employed numerous methods previously documented in the literature, specifically in

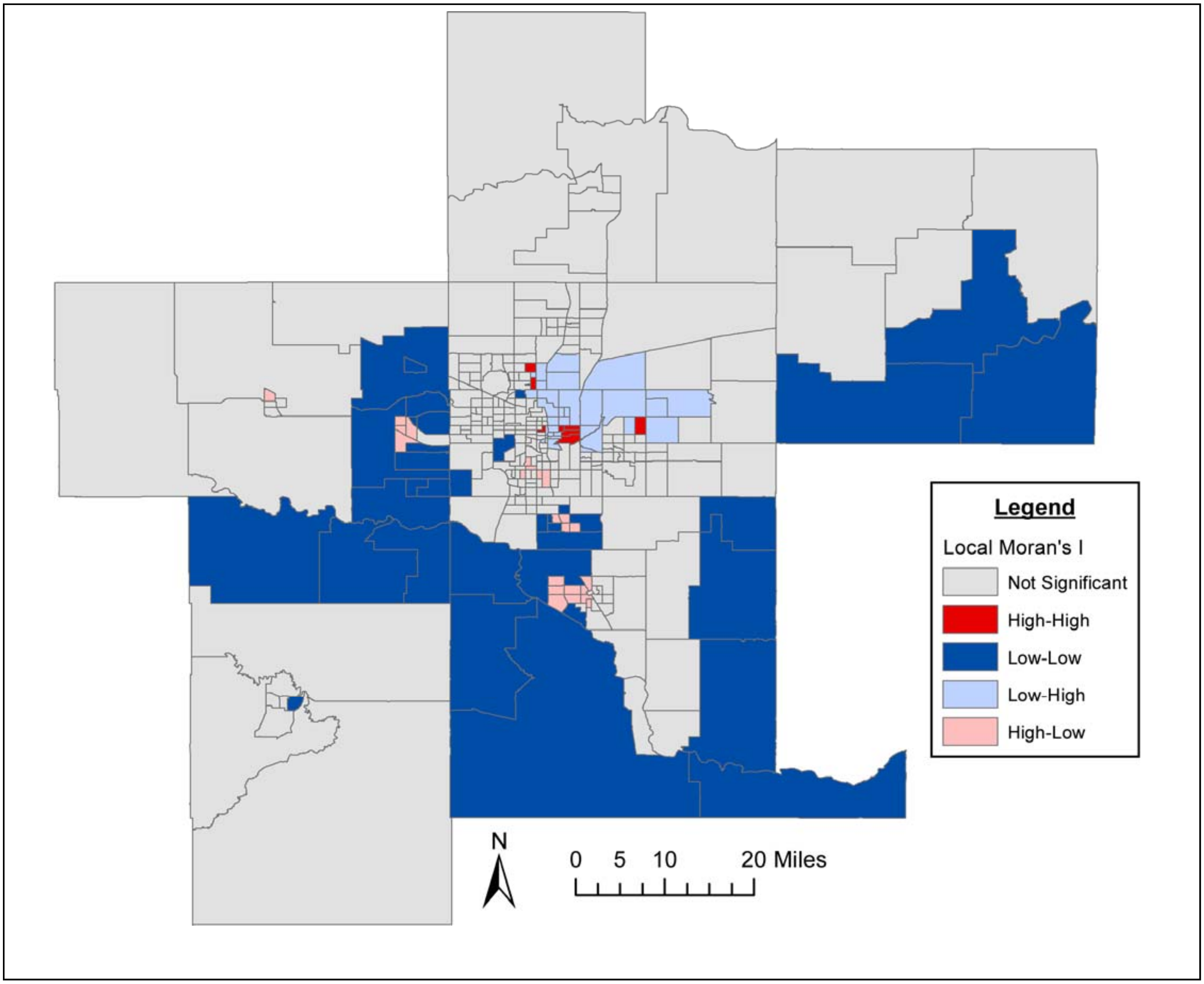

Figure 7. CSO and percentage African-American cluster map

terms of a process approach, access measures, the use of distance buffers, and network analysis to determine distances between consumers and retail opportunities. However, most past research has limited analysis to simple visual or descriptive methods. This article employed spatial autocorrelation techniques to more fully explore and explain the grocery retail landscape of the Oklahoma City MSA. Advanced spatial autocorrelation techniques can uncover finer levels of potential poor accessibility for different socioeconomic and demographic groups with statistically-valid methods. Such results can guide policy decisions, urban redevelopment schemes, and even retail marketing with a goal of providing healthy food options for the entire population of an MSA that could subsequently ameliorate the obesity and malnutrition epidemics in progress in the United States.

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