Characteristics of Potential Spatial Access to a Variety of Fruits and Vegetables in a Large Rural Area

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ABSTRACT

Supermarkets are considered by many researchers as the sole retail source of fruits and vegetables for consumer choice. There has been limited study of all types of food stores as potential opportunities for purchase of fresh and processed (canned and frozen) fruits and vegetables, especially in rural areas. In this paper, data from the Brazos Valley Food Environment Project (BVFEP) are combined with 2000 U.S. census data to examine neighborhood access to fruits and vegetables. BVFEP data include identification and geocoding of food stores in six rural counties in Texas, using ground-truthed methods and on-site assessment of the availability and variety of fresh and processed (canned, frozen, and 100% juice) fruits and vegetables in all food stores, using an observational survey. Specifically, two criteria of access – proximity and coverage – will be used to describe the potential access to a variety of fruits and vegetables by residents of the six study counties.

INTRODUCTION

Nutrition-related chronic health conditions, such as diabetes and obesity, pose a tremendous economic and social burden to individuals, families, communities, and society.[1] Adequate consumption of nutritious foods, such as fruits and vegetables, is essential for overall good nutritional health, and the prevention and management of nutrition-related health conditions, such as obesity, diabetes, cardiovascular disease, and some cancers.[2-10] Although the consumption of fruits and vegetables is recommended, they are often not easily accessible.[11] Results from the 1999-2000 National Health and Nutrition Examination Survey (NHANES) indicate that a large proportion of American children and adults do not meet the recommendations for fruit and vegetable intake.[12] An analysis of NHANES III data revealed that fewer servings of fruits and vegetables was associated with being black (compared with whites), poor or low-income, and having a limited educational attainment.[13] Additional studies found low fruit and vegetable consumption among rural populations, especially among low-income and minority subgroups.[14, 15] For the most part, interventions to improve fruit and vegetable intake or treat obesity, especially among at-risk populations, have relied on individual-based behavior change, and with limited success.[16, 17] Consequently, ecological approaches to behavior change and health recognize that there is a dynamic interaction between the individual and the physical environment.[18, 19]

Social-ecological approaches to food choice and healthful eating have recognized that local food environments, which are a primary source for nutrient intakes, may have an effect upon health and well-being, as well as adherence to dietary recommendations, through food cost and availability.[20-23] The conceptual model in Figure 1, which is based on work in access to

healthcare,[24, 25] provides a framework for food access and shows that access to healthful food is the result of the relationship between the food environment and potential consumers, and suggests that food choice and healthful eating are influenced by the shopping opportunities that are available (potential access) and the shopping opportunities that are utilized (realized access). In this paper, the food environment is limited to traditional, convenience, and non-traditional food stores, which retail a general line of food products.[26-29] Characteristics of the food environment include the number, type, size, and location of food stores; availability of food categories (e.g., fresh fruit); variety of different items within a category (e.g., different types of fresh fruit); price and quality of food items; and availability of other services (e.g., banking, pharmacy, movie rental). Characteristics of potential consumers include neighborhood of residence, availability of a vehicle, public transportation, financial resources (type, amount, and timing), home environment (food storage, meal preparation area, and refrigeration), food preferences, meal preparation knowledge and skills, household size, employment, and health. Barriers or facilitators associated with the food environment and/or consumer influence the selection of food purchase opportunity at a given time. For example, limited household refrigeration may require a consumer to make frequent, costly trips for perishable food items; or purchase less healthy food items from a retail store closer to home.[11, 30, 31] Proximity to food stores may influence food choice through food cost and availability.[20-23, 32, 33]

Geographic or spatial access from the home to the food environment (i.e., food resources) remains a major focus of research to understand access to a variety of healthy foods and to eliminate disparities in nutrition-related health conditions.[28, 34] There are several

measures that have been used to describe different dimensions of accessibility to food stores. The approach most prevalent in the literature is a measure of proximity or distance (straight-line or network) to the nearest food store.[27, 35-37] Other dimensions include coverage (number of food stores within a specified distance or buffer area),[23, 35] food/price variety (average distance to the three closest different chain-name supermarkets),[35] and density (proportion or ratio of food stores per county, census tract, or census block group).[20, 38]

Physical access is a major problem for people in deprived communities; those without cars, the elderly, and people on low incomes.[39-43] U.S. studies have documented better-quality diets for individuals who reside in closer proximity of supermarkets;[44] there are fewer supermarkets and a greater proportion of convenience stores in poor areas[36, 45-48] The influence of neighborhood inequalities in physical access to food stores (primarily large supermarkets) has been studied in the U.S., U.K., Europe, Canada, Australia, and New Zealand, and with mixed results. In some studies, poor or minority areas (neighborhoods) provided little or no access to supermarkets (larger selections of healthy foods);[20, 36, 37, 42, 45, 47, 49-54] other studies found little or no difference between deprived and affluent areas in access to supermarkets,[35, 50, 55-59] or better access from deprived neighborhoods.[60-63] There is strong evidence that residents of rural areas are affected by poor access to supermarkets and health food items.[27, 51, 64-68] In the only U.S. study of neighborhood deprivation, minority composition, and proximity to food stores in a rural area, investigators found that more socioeconomically-deprived neighborhoods (defined by census block group) had better potential access compared with other neighborhoods; however, the distance to the nearest supermarket was still beyond usual walking distance.[27]

The determination of potential spatial access relies on identifying store types and locations and geospatially measuring the distance between two points.[28] The methods used to define and measure spatial accessibility can greatly influence the results, especially in rural areas.[27, 28, 69] Because of misrepresentation of access that can result from the use of secondary data as a source of store types and locations and use of geographic centroid for the center of the neighborhood (census block group or census tract),[27] it has been recommended that ground-truthed methodology be used to identify food stores through direct observation and collect on-site Global Positioning System (GPS) data, especially in rural areas.[28]

The preponderance of published work on food access defined the food environment primarily as supermarkets and occasionally included grocery stores.[35-37, 43, 44, 56, 63, 66, 70] However, this definition of the food environment ignores changing market factors that extend beyond supermarkets.[28] Traditional food stores, such as supermarkets and grocery stores, are facing increased competition from supercenters, conveniences and other non-traditional food stores.[71, 72] Non-traditional formats, such as drug stores, mass merchandisers, and dollar stores, have perfected "channel blurring" with the rapid expansion of food items to their customary non-food format.[73, 74] Over the past 10 years, non-traditional food stores have increased the variety of shopping and food options with the introduction of refrigerated and frozen sections to their stores and lower food prices to consumers, all at the expense of traditional supermarkets and grocery stores.[72-74] While the opportunities for lower priced food items, especially for low-income families, have multiplied, these increased opportunities do not necessarily provide improved opportunities for healthier alternatives.[68] Rural areas are most

affected by these changing market forces, where distance and transportation become even more of a factor.[75-77]

In a broader sense, accessibility could be defined as potential access to healthier foods, with availability (food items present and ready for purchase) having a greater influence on food choice and consumption.[68] Little is known about the influence of changing market factors, such as the expansion of food offerings by mass merchandisers and dollar stores, on access to healthy foods, especially in rural areas. Although dietary recommendations for fruits and vegetables include fresh, canned, frozen, and 100% juice,[78] studies, for the most part, have limited their investigations to the availability of fresh fruits and vegetables, which ignore the nutrient benefits of canned and frozen fruits and vegetables.[58, 79-82]

Nutritional and health disparities faced by low-income families in rural areas make understanding the effects of changing market factors on access to a variety of fruits and vegetables especially critical. In order for rural families to be food secure and have access to fruit and vegetables, food resources need to be accessible (located near neighborhoods, especially low-income or rural areas, or with transportation available) and available (include a variety of fruits and vegetables in local stores. Potential access to fruits and vegetables is based on the characteristics of food stores that are potentially available to a consumer; these characteristics include number and type of food store, location, geographic distribution, distance to neighborhoods where people reside, availability of fruit, availability of vegetables, variety of fruit, and variety of vegetables. In this paper, data from the Brazos Valley Food Environment Project (BVFEP) are combined with 2000 U.S. census data to examine neighborhood access to fruits and vegetables. BVFEP data include identification and geocoding

of food stores in six rural counties in Texas, using ground-truthed methods,[27] and on-site assessment of the availability and variety of fresh and processed (canned, frozen, and 100% juice) fruits and vegetables in all food stores, using an observational survey.[68] Specifically, two criteria of access – proximity and coverage – will be used to describe the potential access to a variety of fruits and vegetables by residents of the six study counties in the following ways:

1) describe the availability of fresh and processed fruit and vegetables in traditional, convenience, and non-traditional food stores;
2) determine network-based potential access to fresh and processed fruits and vegetables using proximity and coverage criteria for access; and
3) examine the relationship of between neighborhood inequalities (e.g., socioeconomic deprivation and minority composition) and access to fresh and processed fruits and vegetables.

METHODS

Geographic setting

The study used data from the 2006-2007 Brazos Valley Food Environment Project (BVFEP), which was approved by the Institutional Review Board at Texas A&M University, and the decennial 2000 U.S. Census Summary File 3 (SF-3) for six rural counties in the Central Texas Brazos Valley region. These counties, which consist of 101 census block groups (CBGs), are considered rural based on population density (persons/m^2).[83, 84] The six counties included five urban clusters (i.e., population > 2,500), several smaller towns (population 156-1,555), and

many unincorporated areas.[27] The five urban clusters, which comprise all or parts of 26 CBG, were located in five of the six counties; the populations for the five urban clusters were 3,181, 3,569, 5,132, 6,296, and 11,952.[85] The rural region covered a land area of 4,466 m^2 and included a population of 119,654 people.[84] Regular public transportation services, such as fixed route, commuter, or taxi services, were not available in the study area.[86, 87]

Neighborhood characteristics

The CBG, which is the smallest unit of census geography for which the detailed "long-form" social and economic data from the census are tabulated, was selected to define a neighborhood.[27] Socioeconomic characteristics were extracted from the SF-3 for all 101 CBG in the rural study area to describe socioeconomic deprivation, minority composition, and population density.[27] Deprivation represented unemployment (persons age 16 y and older in the labor force who were unemployed and actively seeking work), poverty (persons with incomes below the federal poverty level), low education attainment (persons age 25 y and older, with less than a 10^{th}-grade education), household crowding (occupied households with more than one person per room), public assistance (households receiving public assistance), vehicle availability (occupied housing with no vehicle available), and telephone service (occupied housing with no telephone service). Established procedures were used to merge the SF-3 data for the six rural counties, conduct iterated principal factor analysis, and construct a standardized index of neighborhood socioeconomic deprivation.[27, 88-91] Based on the distribution of scores for index, a three-category variable for overall neighborhood socioeconomic deprivation: low deprivation (highest overall socioeconomics and lowest quartile of deprivation scores), middle deprivation (middle two quartiles), and high deprivation

(lowest overall socioeconomics and highest quartile of deprivation scores).[27] Figure 2 shows the spatial distribution of deprivation and minority composition for the study area CBGs. Two additional characteristics were extracted from the SF-3: percent of households with a female head and sum and percent of residents over the age of 60 years.

Food store data

The BVFEP used ground-truthed methods in a two-stage approach to determine the access to and availability of fruit and vegetables to residents of the 101 CBG in six rural counties in the Brazos Valley of Texas. In the first stage, trained observers systematically drove all highways (Interstate, U.S., and State), farm-to-market roads, and city or town streets/roads within the study area. All traditional (supercenters, supermarkets, and grocery stores), convenience (convenience stores and food marts), and non-traditional (dollar stores, mass merchandisers, and pharmacies) food stores were enumerated through direct observation and on-site determination of geographic coordinates using a Bluetooth Wide Area Augmentation System (WAAS)-enabled portable Global Positioning System (GPS) receiver and the World Geodetic System 1984 datum.[27, 28] WAAS-enabled GPS has been shown to be significantly more accurate than typical, non-WAAS GPS [92], with positional accuracy of <3 meters.[93] In the second stage, an observational survey instrument was developed, tested, and administered in all food stores by trained observers to determine the availability and selection of fruits and vegetables.[68]

Measurement of fruit and vegetable availability

The availability of fruits and vegetables was separately determined from an observational survey of the presence and variety of fresh and processed fruits and vegetables.[30, 68] Processed

fruits and vegetables included canned, frozen, and juice.[81] Healthier processed fruit included fruit canned in natural juice, fruit canned in light syrup, frozen fruit without added sugar, and 100% fruit juice. Healthier processed vegetables included vegetables canned and frozen without a sauce and 100% vegetable juice. Variety was operationalized as the number of different food items within a fruit or vegetable category (e.g., number of different fresh fruits).

Overall fruit score. Separate scores were constructed from a total of different fruit for fresh fruit (0 = none, 1 = 1-3, and 2 = ≥ 4); canned fruit in natural juice (0 = none, 1 = 1-4, and 2 = ≥ 5); canned fruit in light syrup (0 = none, 1 = 1-4, and 2 = ≥ 5); frozen fruit (0 = none, 1 = 1-4, and 2 = ≥ 5); and 100% fruit juice (0 = none, 1 = any). A summary score for overall fruit was created by summing the category scores for fresh fruit, canned fruit in natural juice, canned fruit in light syrup, frozen fruit, and 100% fruit juice. Overall fruit scores range from 0 (worst availability of fruit) to 9 (best availability of fruit). Because the overall fruit score was highly skewed, a three-category variable was constructed for level of overall fruit availability: poor availability (fruit score: 0-1), medium availability (fruit score: 2-3), and good availability (fruit score: 4-9).

Overall vegetable score. The overall vegetable availability score combines variety and the presence of a dark green vegetable (e.g., broccoli, collard greens, kale, spinach, or turnip greens).[78] Separate scores were constructed from a total of different vegetables for fresh vegetables (0 = none, 1 = 1-4 and no dark green, 2 = ≥5 and no dark green or 1-4 and a dark green, 3 = ≥5 and a dark green); canned vegetables (0 = none, 1 = 1-4 and no dark green, 2 = ≥5 and no dark green or 1-4 and a dark green, 3 = ≥5 and a dark green); frozen vegetables (0 = none, 1 = 1-4, and 2 = ≥ 5); and 100% vegetable juice (0 = none, 1 = any). Overall vegetable

scores range from 0 (worst availability of vegetables) to 9 (best availability of vegetables). A four-category variable was constructed for level of overall vegetable availability: no availability (vegetable score: 0), poor availability (vegetable score: 1-2), medium availability (vegetable score: 3-4), and good availability (vegetable score: 5-9).

Potential Spatial Access

Neighborhoods were characterized by CBG, which represent the smallest geographic unit of the census from which detailed "long form" social and economic data are tabulated.[94, 95] The population-weighted centroid for each of the 101 CBG was calculated using the ArcGIS Desktop tool Mean Center (Version 9.2, Environmental Systems Research Institute). This tool constructs the CBG mean center based on the mean-weighted x and y values of the block population centroids.[27] Two criteria of spatial access were calculated from the population-weighted centroid (population center) of each CBG:[27, 96] 1) proximity, and 2) coverage.[35] *Proximity*: ESRI's Network Analyst extension in ArcInfo 9.2 was used to calculate the shortest network distance along the road network between two sets of paired point data: neighborhood (population-weighted CBG centroid) and the nearest corresponding food store within the six-county study area. Separate distances were calculated from each CBG to the nearest supercenter, supermarket, grocery store, convenience store, mass merchandiser, dollar store, and pharmacy in miles. *Coverage*: Network Analyst computed the total number of each type of food store within one mile, three miles, five, and 10 miles, using the shortest network distance from the population-weighted center of each CBG. Since the study area is not a large, highly dense urban area as much of the limited literature describes (e.g., Chicago, Detroit, Montreal,

Los Angeles),[32, 35, 36] coverage distances were selected that represented a long walk (1 mile) and reachable by car (within 3, 5, and 10 miles) within the study area. Proximity measured the shortest distance needed to travel to a specific type of food store, while variety indicates the number of opportunities. More opportunities equates to greater accessibility.[69] Proximity and coverage measures were calculated for supermarkets (including supercenter), grocery stores, good selection of fresh fruits or vegetables, and good selection of fresh or processed fruits or vegetables.

Statistical analysis

Release 9 of Stata Statistical Software was used for all statistical analyses; $p < 0.05$ was considered statistically significant. Descriptive statistics were estimated for availability of fresh and processed fruit and vegetables by type of food store. Tests for trend were estimated across categories of increasing deprivation using *nptrend*, which performs the nonparametric test for trend across ordered groups.[97] Because nearby neighborhoods are more likely to have similar access characteristics than distant ones, we examined spatial nature of the data using spatial autocorrelation measures – i.e. how neighborhoods are spatially correlated in terms of access to different food stores. Moran's I statistics, one of the most commonly used measures of global spatial autocorrelation, were obtained for both distance and coverage methods of access measures. Spatial weight matrix was constructed based on binary connectivity (adjacency), and expected I, variance, and z-scores were obtained to assess significance of the correlation in Geoda.[98] Moran's I values range between -1 and 1, with values near 1 indicating highly positive spatial autocorrelation of similar access characteristics.

Finally, three multivariate regression models were fitted to determine the relationship of neighborhood deprivation to potential spatial access to a good variety of fruits and vegetables, controlling for population density: 1) proximity, 2) 3-mile coverage, and 3) 5-mile coverage. The multivariate model approach was chosen instead of four separate multiple regression models (one for each outcome variable) for two reasons: 1) the four outcome variables are correlated with each other and the multivariate regression accounts for this correlation when testing hypotheses about the predictor variables; and 2) the final collection of models is easier to interpret if the same predictor variables are identified.

RESULTS

Neighborhood characteristics and food stores

There were five urban clusters, one in each of five counties. As a group, the urban clusters consisted of 25.7% of CBGs (*n* = 26), 25.2% of the population for the six-county study area, and 59.3% of high deprivation neighborhoods (data not shown). The distribution of neighborhood socioeconomic characteristics shows high levels of neighborhood need in the study area, which are presented as mean, standard deviation, and median for the overall study area and by level of deprivation (see Table 1). With the exception of seniors (individuals aged >60 years), the percent of all socioeconomic characteristics increased significantly with increasing levels of deprivation. In data not shown, almost 20% of residents had a poverty-level income and 11% of households were without access to a vehicle in 25% of neighborhoods. Table 1 also shows the distribution of proximity and coverage measures to traditional, convenience, and food stores. Residents in one-half of the neighborhoods had to travel at least 9.2 miles to reach the nearest

supermarket or 5.2 miles to reach the nearest grocery store. Residents in urban clusters had to travel a mean distance of 1.2±1.3 miles (median = 0.82 miles) to the nearest supercenter or supermarket, 1.1±1.3 miles (median = 0.79 miles) to the nearest grocery store. For 25% of the neighborhoods, the nearest supermarket was at a distance of more than 15 miles. Coverage showed a median of no supermarkets and one traditional food store (supercenter, supermarket, and grocery store) within five network miles of a neighborhood center. In data not shown, 22 of the 26 urban cluster neighborhoods had access to at least one supermarket within one mile; 48 CBG (47.5%) did not have access to a supermarket within 10 miles. Forty percent (*n* = 47,838) of the total population resided in these 48 CBG. Sixty-nine of the neighborhoods did not have access to a supermarket or grocery store within one mile; 56 did not have access within three miles; and 41 neighborhoods still did not have access to supermarket or grocery store within five miles. Figure 2 shows the spatial distribution of neighborhood socioeconomic deprivation, minority composition, and placement of supermarkets and grocery stores in the study area.

Availability of fruit and vegetables

Observational surveys were completed in 185 food stores in the six rural counties. Only one convenience store refused to participate. Table 2 shows percentage of each type of food store that offered fresh or processed fruit or vegetables. As a group, convenience stores provided less availability of fruits and vegetables than traditional or non-traditional food stores. Almost 100% of non-traditional food stores (i.e., dollar stores, mass merchandisers, and pharmacies) offered processed, not fresh, fruits and vegetables. A greater percentage of convenience stores offered processed vegetables rather than processed fruit. Scores for the number of fresh and

processed fruits and vegetables are shown by food store type in Table 3. The data show that variety of fresh or processed fruits and vegetables was better in supermarkets compared with grocery stores, and in dollar stores compared with convenience stores. Table 4 shows summary scores for availability and variety of fruits and vegetables, which include fresh and processed fruit or vegetables. Vegetable scores differed between supermarkets and grocery stores; fruit scores differed among convenience stores, dollar stores, and mass merchandisers. Table 5 shows the level of availability and variety of fruit and vegetables. Overall poor availability of fruits and no availability of vegetables were found exclusively in convenience stores. Good selection of fruits or vegetables could be found among six of the seven types of food stores.

Potential spatial access to fruit and vegetables

Table 6 shows the neighborhood access to fresh and processed fruits and vegetables, using network measures of proximity to the nearest shopping opportunity with good availability (variety) of fruits or vegetables and coverage (number) of shopping opportunities with good availability of fruit or vegetables within one, three, five, and ten network miles of the population weighted centroid of each CBG. Overall, residents had to travel a shorter distance for good availability of fresh fruits compared with fresh vegetables. Mean and median distance apparently disappeared when fresh and processed types were combined. Access, regardless of criterion, was better for a good variety of fresh and processed fruits or vegetables than for a good variety of fresh alone. Figures 3 and 4 show the spatial distribution of potential access to good varieties of fresh fruits and vegetables. Access improved when fresh and processed fruit or vegetables were combined into overall fruits or vegetables (see Figures 5 and 6). As shown in Table 6, access improved with increased level of deprivation; proximity to the nearest location

for best fruit or vegetables decreased with level of deprivation. Not only did distance become closer, but the number of shopping opportunities increased. In more than one-half of the neighborhoods (data not shown), there were no places within three miles for a good selection of fresh fruit (60%, *n* = 61) or combined fresh and processed fruit (56%, *n* = 57). At a five-mile distance, 52.5% (*n* = 53) neighborhoods were without access to fresh fruit and 40.6% (*n* = 41) to fresh or processed fruit. Even at 10 miles, there were 33 (32.7%) neighborhoods (32,759 residents; 27.4% of total population) without access to a good selection of fresh fruit and 16 (15.8%) neighborhoods (13,688 resident; 11.4%) without access to fresh or processed fruit. For 64 (63.4%) neighborhoods, there was no access to a good selection of fresh vegetables and no access to a good selection of fresh or processed vegetables in 55 (54.5%) neighborhoods within three miles. At a distance of five miles, 57 (56.4%) neighborhoods still did not have access to a good selection of fresh vegetables and 37 (36.6%) did not have access to a good selection of fresh or processed vegetables. At 10 miles, 38 (37.6%) neighborhoods (36,471 residents; 30.5% of total population) remained without access to a good selection of fresh vegetables and 12 (11.9%) neighborhoods (9,730 residents; 8.1%) without access to fresh or processed vegetables. Figures 3-6 show that residents of the five urban clusters have better access to a good variety of fresh and overall fruits or vegetables than residents elsewhere in the study area.

Spatial autocorrelation

Moran's I and z-scores for minimum distance, and 3-, 5-, and 10-mile coverage methods are presented in Table 7. Overall we found evidence of positive spatial autocorrelation among nearby neighborhoods. Data indicate that distance values may be more clustered for fresh fruit compared with overall fruit, and with fresh vegetables compared with overall vegetables. Based

on the Moran's I values for coverage, the inference of similar clustering in space for all coverage distances could be made.

Multivariate Models for Access

Multivariate linear regression models were used to examine the relationship between neighborhood socioeconomic deprivation and access to good availability of fruits or vegetables, controlling for population density. Table 8 shows that, adjusting for population density, residents in neighborhoods with high deprivation, compared with neighborhoods of low deprivation, had to travel a significantly shorter distance to the nearest opportunity for good availability of fresh and processed fruit or vegetables. Population density (not shown) was significant; the greater the population density, the better the access to the nearest fruit or vegetable opportunity. A similar relationship for 3-mile coverage is shown in Table 9 and for 5-mile coverage in Table 10. High deprivation neighborhoods were associated with a greater number of shopping opportunities for fruits or vegetables. As with the prior analysis, increasing population density was similarly associated with greater coverage.

DISCUSSION

Geographic access to retail resources for healthy foods remains a major focus of research that examines the influence of where people live with their ability to consume a healthful diet; little of this work has focused on rural areas, where the burdens of nutrition-related health conditions and food insecurity are great.[1, 27, 66, 67, 80, 99-106] Physical access to food stores has been shown to be a major problem for people in deprived communities; those without cars, the

elderly, people on low incomes, and residents of rural areas.[27, 39-43, 51, 64-68] However, methods used to define and measure spatial accessibility can significantly affect the results and influence policy and programs.[28] Key challenges to the accurate measurement of potential spatial access to healthy foods in rural areas include: 1) definition of food stores, 2) definition of healthy foods, and 3) calculation of access measures.[27, 28]

This paper extends our understanding of spatial access to fruits and vegetables from rural neighborhoods by examining two dimensions of access: 1) proximity or distance to the nearest shopping opportunity for a good variety of fruits or vegetables, and 2) coverage or the number of food shopping opportunities within a specified distance of the neighborhood. Analyses revealed that almost 83% of neighborhoods in the study area were not located within one mile of a supermarket; 77%-80% were not within one mile of a food store that marketed a good variety of fresh fruits or vegetables; and when processed fruits or vegetables were included, 75% of neighborhoods were without food shopping opportunity a within one mile. This is especially problematic, given that there was no public transportation; many households were without access to a vehicle, had limited financial resources, or were occupied by seniors or a female head. There were four methodological improvements that warrant mention: 1) all food store data were collected using ground-truthed methods; 2) food stores included supercenters, supermarkets, grocery stores, convenience stores, mass merchandisers, dollar stores, and pharmacies; 3) availability and variety of fruits and vegetables were determined through an on-site observational survey and included fresh, canned, frozen, and 100% juice; and 4) all distances were calculated from the population-weighted centroid of a CBG (not the geographic center), using road networks.[27, 28, 68]

Potential spatial access, whether network distance to the nearest location or the number of multiple locations within a specified network distance, required paired point data (from population-weighted CBG centroid and corresponding food store within the study area). Three different approaches to define the corresponding food store with fruits or vegetables – supermarket as a proxy, fresh fruits or vegetables, and overall fruits and vegetables which included fresh and processed – provided three different pictures of rural proximity and coverage. Supermarkets were located at the farthest distance from neighborhoods and provided lowest coverage; convenience stores were in closest proximity and provided highest coverage. Shopping opportunities for a good variety of fresh fruits or vegetables were closer than supermarkets, but required access and resources for a car for residents of more than 75% of neighborhoods (*n* = 78-81 CBG; more than 92,000 residents) located at a distance of greater than one mile. The inclusion of healthier processed fruits or vegetables reduced the number of neighborhoods without one food shopping opportunity within one mile to 75-76 (74.2% - 75.2%; more than 90,000 residents).

A difference in travel patterns among rural populations have been observed between rural resident who live in-town compared with those who live in open-country.[107, 108] In the present study area, 25% of the population reside in the 25% of CBG that are located in five urban clusters, which have at least one supermarket within one mile and the greatest coverage of multiple shopping opportunities for fresh or processed fruits or vegetables. Although it is expected that most rural residents would have their own vehicle,[108] limitations of income and home environment may require the need for more frequent trips for food purchase, especially for the majority of residents who do not reside in one of the urban clusters. For these families,

distance becomes a barrier for purchase of fruits or vegetables. More than 50% of CBG did not have a shopping opportunity for fresh fruits or vegetables within five miles; more than 32% of CBG had to travel farther than 10 miles. With the inclusion of processed fruits or vegetables, more than 36% of neighborhoods had to travel more than five miles to reach location that provided a good variety of fruits or vegetables.

This paper responded to the methodological challenges that have been identified in measuring potential access to food stores in rural areas.[28] The measurement of the food environment recognized the emergence of new and changing store formats. Supermarkets and grocery stores are no longer the only shopping opportunities for fruits or vegetables. Restricting shopping opportunities to supermarkets would understate the access to fruits or vegetables. Access was described in distance to the nearest food opportunity and cumulative opportunities or variety of opportunities within a specific geographic area.[35] Utilization of data on availability of fresh or processed fruits or vegetables in the measurements provided robust meaning to concept of potential access in this large rural area.

Access to a good variety of healthy foods, such as fruits and vegetables, can play a pivotal role in the nutritional health of rural families. Many of these families live in socioeconomically-deprived neighborhoods; many are have a low household income, are unemployed, older, or lack access to a vehicle. The lack of public transportation or not being able to afford transportation further marginalizes a large population and limits their options for food resources. [41, 51, 66, 109] Indeed, it is difficult to initiate or maintain healthful eating habits without access to healthy foods. Knowing more about the level of access to shopping opportunities for healthy foods is essential for combining environmental approaches with

traditional health interventions to make it easier for individuals to make healthier food choices.[110] The preparation for policy change to strengthen food assistance programs or program delivery activities, or interventions to improve nutritional health should include an understanding of rural areas – where people live and where they shop for food. Additionally, it is important to understand not only the distance that people must travel to the nearest store to make a purchase, but also how much diversity in stores they have in order to compare price, quality, and selection. Future research should examine how spatial access, whether from home or work, to the food environment influences the utilization of food stores, and the strategies used by low-income rural families in this area to obtain food for the household.

Table 1. Neighborhood characteristics and spatial accessibility to traditional, convenience, and non-traditional food stores by neighborhood socioeconomic deprivation, using measures of proximity and coverage[a]

	All Deprivation (*n* = 101)	Low Deprivation (*n* = 26)	Medium Deprivation (*n* = 48)	High Deprivation (*n* = 27)
NEIGHBORHOOD CHARACTERISTICS				
Socioeconomic characteristics, %				
Unemployment[e]	2.8±1.9 (2.4)	2.3±1.5 (2.2)	2.7±1.8 (2.3)	3.5±2.1 (3.3)[b]
Income <100% FPL[e]	16.0±9.6 (14.0)	10.0±4.4 (9.8)	13.3±4.6 (13.9)	26.5±11.5 (24.8)[d]
Low education[e]	15.2±7.2 (14.2)	9.9±3.7 (9.7)	15.0±5.7 (14.8)	20.6±8.2 (19.2)[d]
Crowded households[e]	5.7±5.1 (1.5)	3.2±2.7 (3.3)	4.8±3.8 (4.5)	9.8±6.3 (8.5)[d]
Public assistance[e]	2.9±3.0 (2.2)	1.5±1.8 (1.2)	2.8±2.8 (2.2)	4.7±3.7 (3.8)[d]
No vehicle available[e]	8.9±7.9 (6.6)	3.7±2.7 (3.7)	6.8±3.9 (6.5)	17.5±9.9 (14.9)[d]
No telephone service[e]	4.9±3.9 (4.2)	3.2±2.4 (3.4)	4.4±3.0 (4.1)	7.4±5.1 (5.6)[d]
Minority composition	29.1±20.0 (24.6)	10.0±5.1 (8.9)	26.2±10.2 (24.7)	52.8±19.0 (46.9)[d]
Population density	353.7±755 (24.7)	153.5±672.6 (14.5)	235.8±613.4 (20.8)	756±918 (238.3)[d]
Female-headed households	27.5±12.8 (24.1)	22.8±17.4 (19.3)	23.9±7.5 (22.9)	38.6±8.1 (39.85)[d]
Residents >60 y	21.5±6.6 (21.4)	22.3±8.2 (21.9)	22.2±5.2 (22.3)	19.4±6.8 (19.6)

SPATIAL ACCESSIBILITY				
Proximity, mi				
Nearest supermarket	9.9±8.5 (9.2)	11.4±8.8 (10.8)	12.1±8.0 (11.2)	4.7±6.8 (1.2)[b]
Nearest grocery	7.0±6.3 (5.2)	9.4±6.8 (9.0)	8.2±5.8 (8.0)	2.5±4.3 (0.90)[b]
Nearest convenience store	3.1±2.5 (2.8)	3.7±2.7 (3.0)	3.8±2.3 (3.6)	1.2±2.0 (0.45)[b]
Nearest non-traditional food store[f]	8.0±6.5 (8.3)	9.5±6.8 (9.7)	9.2±6.0 (9.6)	4.3±6.0 (1.3)c
Coverage – 1 mi				
Supermarket	0.32±0.58 (0)	0.23±0.59 (0)	0.12±0.39 (0)	0.74±0.66 (1)[b]
Traditional food stores[g]	0.45±0.75 (0)	0.27±0.67 (0)	0.25±0.70 (0)	1.0±0.68 (1)[b]
Convenience stores	1.9±2.9 (0)	1.3±2.8 (0)	0.79±1.8 (0)	4.5±3.0 (4)[b]
Nearest non-traditional food store[f]	0.55±1.0 (0)	0.58±1.4 (0)	0.27±0.71 (0)	1.0±1.0 (1)[c]
Coverage – 3 mi				
Supermarket	0.67±1.0 (0)	0.58±1.1 (0)	0.29±0.74 (0)	1.4±1.1 (1)[b]
Traditional food stores[g]	0.89±1.1 (0)	0.61±1.1 (0)	0.54±0.99 (0)	1.8±0.97 (2)[b]

Convenience stores	5.3±7.2 (2)	4.7±7.5 (1)	2.8±4.9 (1)	10.4±7.8 (8)[b]
Nearest non-traditional food store[f]	1.1±1.7 (0)	1.0±1.8 (0)	0.52±1.2 (0)	2.3±1.8 (2)[c]
Coverage – 5 mi				
Supermarket	0.83±1.1 (0)	0.81±1.2 (0)	0.5±0.87 (0)	1.4±1.1 (1)[b]
Traditional food stores[g]	1.2±1.1 (1)	0.92±1.3 (0)	0.94±1.1 (1)	1.8±0.97 (2)[b]
Convenience stores	7.3±8.1 (4)	7.5±9.4 (2.5)	4.9±6.1 (3)	11.2±8.6 (9)[c]
Nearest non-traditional food store[f]	1.4±1.8 (0)	1.4±2.1 (0)	0.88±1.4 (0)	2.3±1.8 (2)[d]
Coverage – 10 mi				
Supermarket	1.4±1.1 (1)	1.4±1.2 (1)	1.1±0.97 (1)	1.8±0.91 (2)
Traditional food stores[g]	2.1±1.2 (2)	2.0±1.4 (2)	1.9±1.1 (2)	2.5±0.89 (3)
Convenience stores	13.8±9.8 (10)	15.4±11.2 (10.5)	11.9±8.5 (9)	15.5±10.2 (14)
Nearest non-traditional food store[f]	2.2±1.7 (2)	2.5±1.9 (2.5)	1.8±1.5 (2)	2.6±1.6 (2)

[a] Proximity determined by the network distance from each CBG population-weighted centroid to the nearest food store; coverage is determined by the number of food stores within a specific network-based distance. Distance (proximity), numbers (coverage), and percentages (socioeconomic characteristics are shown as mean ± standard deviation overall and by category of deprivation; median in parenthesis.

Level of statistical significance for test for trend across ordered groups of socioeconomic deprivation: [b]p <0.05 [c]p<0.01 [d]p<0.001

[e] Components of the neighborhood socioeconomic deprivation index

[f] Non-traditional food stores include all dollar stores, mass merchandisers, and pharmacies that sell food items

[g] Traditional food stores include all supercenters, supermarkets, and grocery stores

Table 2. Availability of fresh and processed fruit and vegetables by type of food stores

		Supercenter (*n*=1) %	Supermarket (*n*=11) %	Grocery (*n*=12) %	Convenience (*n*=140) %	Dollar Store (*n*=16) %	Mass[a] (*n*=4) %	Pharmacy (*n*=1) %
Fruit								
	Fresh	100	100	100	15	0	0	0
Processed	Can (juice)	100	100	100	36.4	75	100	100
Processed	Can (light syrup)	100	100	100	34.3	93.7	50	100
Processed	Frozen	100	90.9	83.3	4.3	0	0	0
Processed	Juice (100%)	100	100	100	95.7	100	100	100
Vegetables								
	Fresh	100	100	100	14.3	0	0	0
Processed	Can	100	100	100	75	100	100	100
Processed	Frozen	100	100	100	10	68.7	25	0
Processed	Juice (100%)	100	100	100	75.7	56.2	100	0

[a] Mass Merchandiser

Table 3. Scores for individual measures of availability and variety of fresh and processed fruit and vegetables by food store type

	Supercenter (*n*=1) %	Supermarket (*n*=11) %	Grocery (*n*=12) %	Convenience (*n*=140) %	Dollar Store (*n*=16) %	Mass (*n*=4) %	Pharmacy (*n*=1) %
Fruit							
Fresh							
0 = none	0	0	0	85	100	100	100
1 = 1-3	0	0	25.0	14.3	0	0	0
2 = ≥4	100	100	75.0	0.7	0	0	0
Can (juice)							
0 = none	0	0	0	63.6	25	0	0
1 = 1-4	0	0	33.3	33.6	75	100	100
2 = ≥5	100	100	66.7	2.9	0	0	0
Can (light syrup)							
0 = none	0	0	0	65.7	6.3	50	0
1 = 1-4	0	0	41.7	32.1	25	50	100
2 = ≥5	100	100	58.3	2.1	68.7	0	0
Frozen							
0 = none	0	9.1	16.7	95.7	100	100	100
1 = 1-4	100	72.7	58.3	4.3	0	0	0
2 = ≥5	0	18.2	25	0	0	0	0

100% Fruit Juice							
0 = none	0	0	0	4.3	0	0	0
1 = ≥1	100	100	100	95.7	100	100	100
Vegetables							
Fresh[a]							
0	0	0	0	86.4	100	100	100
1	0	0	41.7	12.1	0	0	0
2	0	0	25	1.4	0	0	0
3	100	100	33.3	0	0	0	0
Can[a]							
0	0	0	0	25.7	0	0	0
1	0	0	0	29.3	6.2	50	100
2	0	0	0	19.3	25	25	0
3	100	100	100	25.7	68.7	25	0
Frozen							
0 = none	0	0	0	92.1	100	100	75
1 = 1-4	0	0	16.7	7.1	0	0	25
2 = ≥5	100	100	83.3	0.7	0	0	0
100% Vegetable Juice							
0 = none	0	0	0	24.3	43.7	0	100

1 = ≥1	100	100	100	75.7	56.2	100	0

[a] 0 = none; 1= 1-4 vegetables (none are dark green vegetables); 2 = 1-4 vegetables (one dark green) or 5-9 vegetables (none are dark green); 3 = ≥5 vegetables (one dark green).

Table 4. Summary scores for availability and variety of fresh and processed fruit and vegetables by food store type

	Supercenter (*n*=1) %	Supermarket (*n*=11) %	Grocery (*n*=12) %	Convenience (*n*=140) %	Dollar Store (*n*=16) %	Mass (*n*=4) %	Pharmacy (*n*=1) %
Fruit availability							
Mean ± SD	8	8.1 ± 0.54	7.1 ± 1.73	1.9 ± 1.14	3.4 ± 0.62[bc]	2.5 ± 0.58	3
Median	8	8	7.5	1	3	2.5	3
Minimum, maximum	8	7, 9	4, 9	0, 6	2, 4	2, 3	3
Vegetable availability							
Mean ± SD	9	9 ± 0[a]	7.7 ± 1.05	2.4 ± 1.66	3.2 ± 0.75	3 ± 1.4	1
Median	9	9	7.5	2	3	2.5	1
Minimum, maximum	9	9	6, 9	0, 7	2, 4	2, 5	1

Summary scores were created separately for fruit and vegetables by summing category scores for fresh and processed fruit or vegetables.

[a] Statistically significant from grocery stores ($p < 0.001$)

[b] Statistically significant from convenience stores ($p < 0.001$)

[c] Statistically significant from mass merchandisers ($p < 0.05$)

Table 5. Level of availability and variety of fresh and processed fruit and vegetables by food store type

	Supercenter (*n*=1) %	Supermarket (*n*=11) %	Grocery (*n*=12) %	Convenience (*n*=140) %	Dollar Store (*n*=16) %	Mass (*n*=4) %	Pharmacy (*n*=1) %
Fruit availability[a]							
Poor	0	0	0	51.4	0	0	0
Medium	0	0	0	38.6	56.2	100	100
Good	100	100	100	10	43.7	0	0
Vegetable availability[b]							
No	0	0	0	10	0	0	0
Poor	0	0	0	47.9	18.7	50	100
Medium	0	0	0	30	81.2	25	0
Good	100	100	100	12.1	0	25	0

[a] Fruit availability: Poor = summary score 0-1; medium = summary score 2-3; good = summary score 4-9

[b] Vegetable availability: No = summary score 0; poor = summary score 1-2; medium = summary score 3-4; good = summary score 5-9.

Table 6. Access to good availability of fresh and overall (fresh and processed) fruit and vegetables by neighborhood socioeconomic deprivation, using measures of proximity and coverage[a]

	All Deprivation (*n* = 101)	Low Deprivation (*n* = 26)	Medium Deprivation (*n* = 48)	High Deprivation (*n* = 27)
Proximity (in miles)				
Fruit				
Fresh fruit (good)	6.7±5.7 (5.4)	8.1 ± 5.2 (8.2)	8.0 ± 5.4 (9.2)	2.9 ± 5.1 (0.88)[c]
Overall fruit (good)	4.7±4.2 (3.8)	5.6 ± 3.8 (5.3)	5.8 ± 4.0 (4.9)	2.0 ± 4.0 (0.87)[c]
Vegetables				
Fresh vegetables (good)	7.4±6.1 (8.3)	8.6 ± 5.6 (9.1)	8.8 ± 5.7 (9.7)	4.0 ± 6.1 (1.0)[c]
Overall vegetables (good)	4.5±4.1 (3.6)	5.4 ± 3.6 (5.7)	5.3 ± 3.9 (4.5)	2.1 ± 4.0 (0.87)[c]
Coverage – 1 mile				
Fruit				
Fresh fruit (good)	0.47±0.82 (0)	0.65 ± 1.16 (0)	0.50 ± 0.99 (0)	1.89 ± 1.12 (2)[c]
Overall fruit (good)	0.77±1.3 (0)	0.96 ± 1.51 (0)	0.79 ± 1.29 (0)	2.81 ± 1.73 (3)[c]
Vegetables				
Fresh vegetables (good)	0.37±0.64 (0)	0.61 ± 1.1 (0)	0.35 ± 0.76 (0)	1.59 ± 1.08 (2)[c]

Overall vegetables (good)	0.59±0.98 (0)	0.85 ± 1.22 (0)	0.69 ± 1.07 (0)	2.30 ± 1.23 (3)[c]
Coverage – 3 miles				
Fruit				
Fresh fruit (good)	0.91±1.2 (0)	0.65 ± 1.16 (0)	0.50 ± 0.99 (0)	1.89 ± 1.12 (2) [c]
Overall fruit (good)	1.4±1.7 (1)	0.96 ± 1.51 (0)	0.79 ± 1.29 (0)	2.81 ± 1.73 (3) [c]
Vegetables				
Fresh vegetables (good)	0.91±1.2 (0)	0.61 ± 1.1 (0)	0.35 ± 0.76 (0)	1.59 ± 1.08 (2) [c]
Overall vegetables (good)	1.2±1.3 (1)	0.85 ± 1.22 (0)	0.69 ± 1.07 (0)	2.30 ± 1.23 (3)[c]
Coverage – 5 miles				
Fruit				
Fresh fruit (good)	1.2±1.3 (1)	1.0 ± 1.36 (0)	0.87 ± 1.18 (0)	1.89 ± 1.12 (2) [b]
Overall fruit (good)	1.9±1.8 (1)	1.5 ± 1.82 (1)	1.52 ± 1.61 (1)	2.85 ± 1.72 (3) [b]
Vegetables				
Fresh vegetables (good)	0.93±1.1 (0)	0.88 ± 1.27 (0)	0.58 ± 0.92 (0)	1.59 ± 1.08 (2)[b]
Overall vegetables (good)	1.6±1.4 (1)	1.30 ± 1.40 (1)	1.39 ± 1.35 (1)	2.37 ± 1.24 (3)[b]

Coverage – 10 miles

Fruit				
Fresh fruit (good)	2.1±1.2 (2)	2.08 ± 1.29 (2)	1.90 ± 1.22 (2)	2.52 ± 1.19 (3)
Overall fruit (good)	3.4±1.8 (3)	3.58 ± 1.63 (3)	3.14 ± 1.80 (3)	3.70 ± 1.75 (3)
Vegetables				
Fresh vegetables (good)	1.5±1.0 (2)	1.65 ± 1.16 (2)	1.31 ± 0.93 (1)	1.81 ± 0.96 (2)
Overall vegetables (good)	3.3±1.5 (3)	3.35 ± 1.41 (3.5)	3.04 ± 1.58 (3)	3.59 ± 1.52 (4)

[a] Network distance shown as mean ± standard deviation; median in parenthesis

Level of statistical significance for test for trend across ordered groups of socioeconomic deprivation: [b]p <0.01 [c]p<0.001

Table 7. Spatial autocorrelation statistics for accessibility measures (proximity and coverage)

	Distance to the nearest (in miles)		Number of stores within 3 network miles		Number of stores within 5 network miles		Number of stores within 10 network miles	
	Moran's I	**Z-score**	**Moran's I**	**Z-score**	**Moran's I**	**Z-score**	**Moran's I**	**Z-score**
Fresh fruits	0.49	7.67	0.68	10.97	0.63	10.93	0.62	10.36
Overall fruits	0.39	6.57	0.61	9.75	0.55	8.17	0.57	9.16
Fresh vegetables	0.57	8.97	0.72	11.01	0.69	10.93	0.65	10.32
Overall vegetables	0.40	6.33	0.63	9.90	0.54	8.17	0.61	9.54

Table 8. Association between proximity to fruit and vegetables and neighborhood deprivation, using multivariate linear regression model

	Access as network distance to the nearest			
	Fresh fruit (good)	Overall fruit (good)	Fresh vegetables (good)	Overall vegetables (good)
Deprivation	b (SE)	b (SE)	b (SE)	b (SE)
High	-4.47 (0.134)[c]	-3.09 (1.02)[b]	-3.82 (1.44)[b]	-2.91 (1.0)[b]
Medium	-0.86 (1.19)	-0.33 (0.91)	-0.75(1.28)	-0.55 (0.89)
R^2	0.303	0.264	0.291	0.243
P	<0.001	<0.001	<0.001	<0.001

NOTE: In this model, the five equations were simultaneously estimated, controlling for population density. Deprivation entered as categorical variable; low deprivation is referent group. Population density entered as continuous. Results are reported as multivariate-adjusted b (SE). Statistically significant variables are indicated as: [a]<0.05 [b]<0.01 [c]<0.001

Table 9. Association between 3-mile coverage of fruit and vegetables and neighborhood deprivation, using multivariate linear regression model

	Access as number of shopping opportunities within 3 network miles			
	Fresh fruit (best)	Overall fruit (best)	Fresh vegetables (best)	Overall vegetables (best)
Deprivation	b (SE)	b (SE)	b (SE)	b (SE)
High	0.98 (0.21)[c]	1.58 (0.34)[c]	0.75 (0.18)[c]	1.21 (0.25)[c]
Medium	0.11 (0.18)	0.12 (0.30)	-0.02(0.16)	0.10 (0.22)
R^2	0.633	0.497	0.660	0.562
P	<0.001	<0.001	<0.001	<0.001

NOTE: In this model, the five equations were simultaneously estimated, controlling for population density.

Deprivation entered as categorical variable; low deprivation is referent group. Population density entered as continuous.

Results are reported as multivariate-adjusted b (SE). Statistically significant variables are indicated as: [a]<0.05 [b]<0.01 [c]<0.001

Table 10. Association between 5-mile coverage of fruit and vegetables and neighborhood deprivation, using multivariate linear regression model

	Access as number of shopping opportunities within 5 network miles			
	Fresh fruit (best)	Overall fruit (best)	Fresh vegetables (best)	Overall vegetables (best)
Deprivation	b (SE)	b (SE)	b (SE)	b (SE)
High	0.66 (0.27)[a]	1.12 (0.43)[b]	0.49 (0.23)[a]	0.89 (0.33)[b]
Medium	0.12 (0.24)	0.26 (0.38)	-0.07(0.21)	0.35 (0.29)
R^2	0.413	0.265	0.466	0.313
P	<0.001	<0.001	<0.001	<0.001

NOTE: In this model, the five equations were simultaneously estimated, controlling for population density.

Deprivation entered as categorical variable; low deprivation is referent group. Population density entered as continuous.

Results are reported as multivariate-adjusted b (SE). Statistically significant variables are indicated as: [a]<0.05 [b]<0.01 [c]<0.001

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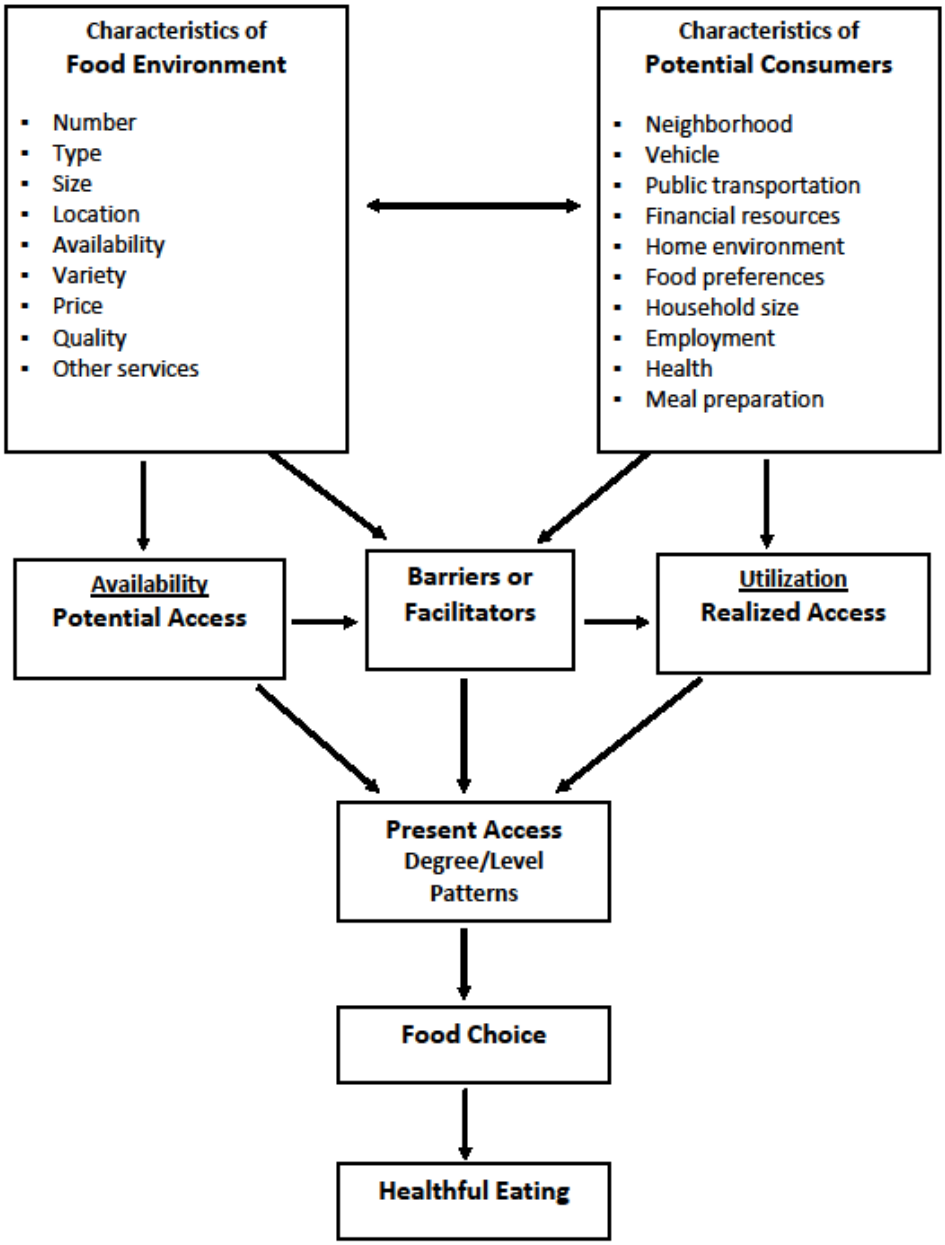

Figure 1. Conceptual Model for Access to Food Environment

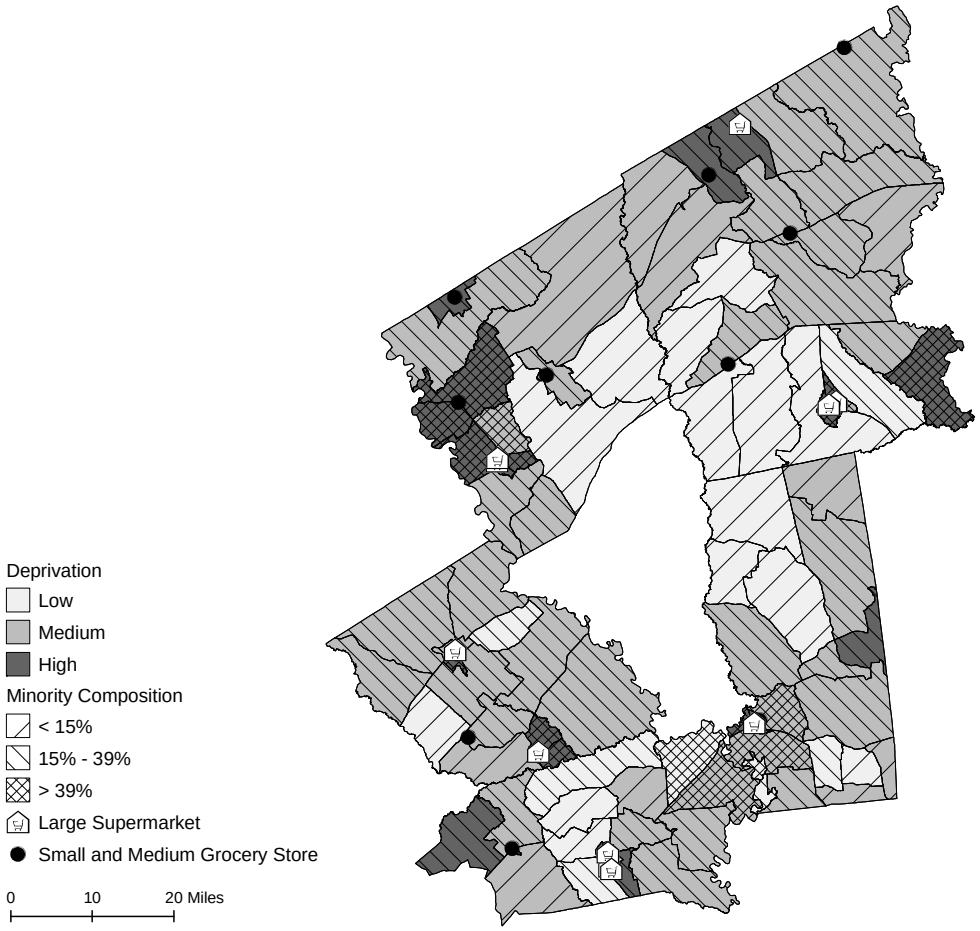

Figure 2. Map of distribution of neighborhood deprivation, minority composition, and supermarkets and grocery stores in the study area.

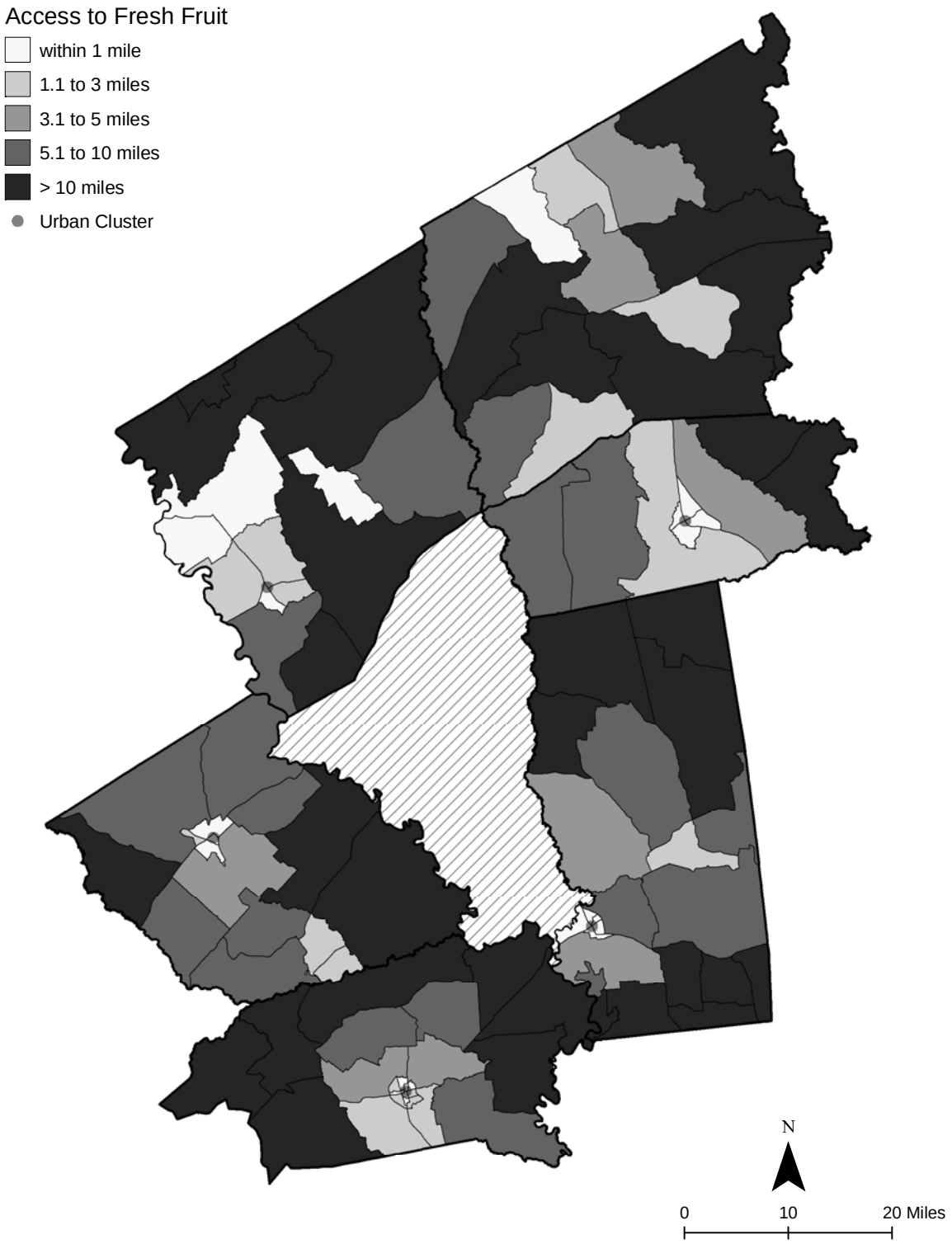

Figure 3. Neighborhood Access to Fresh Fruit

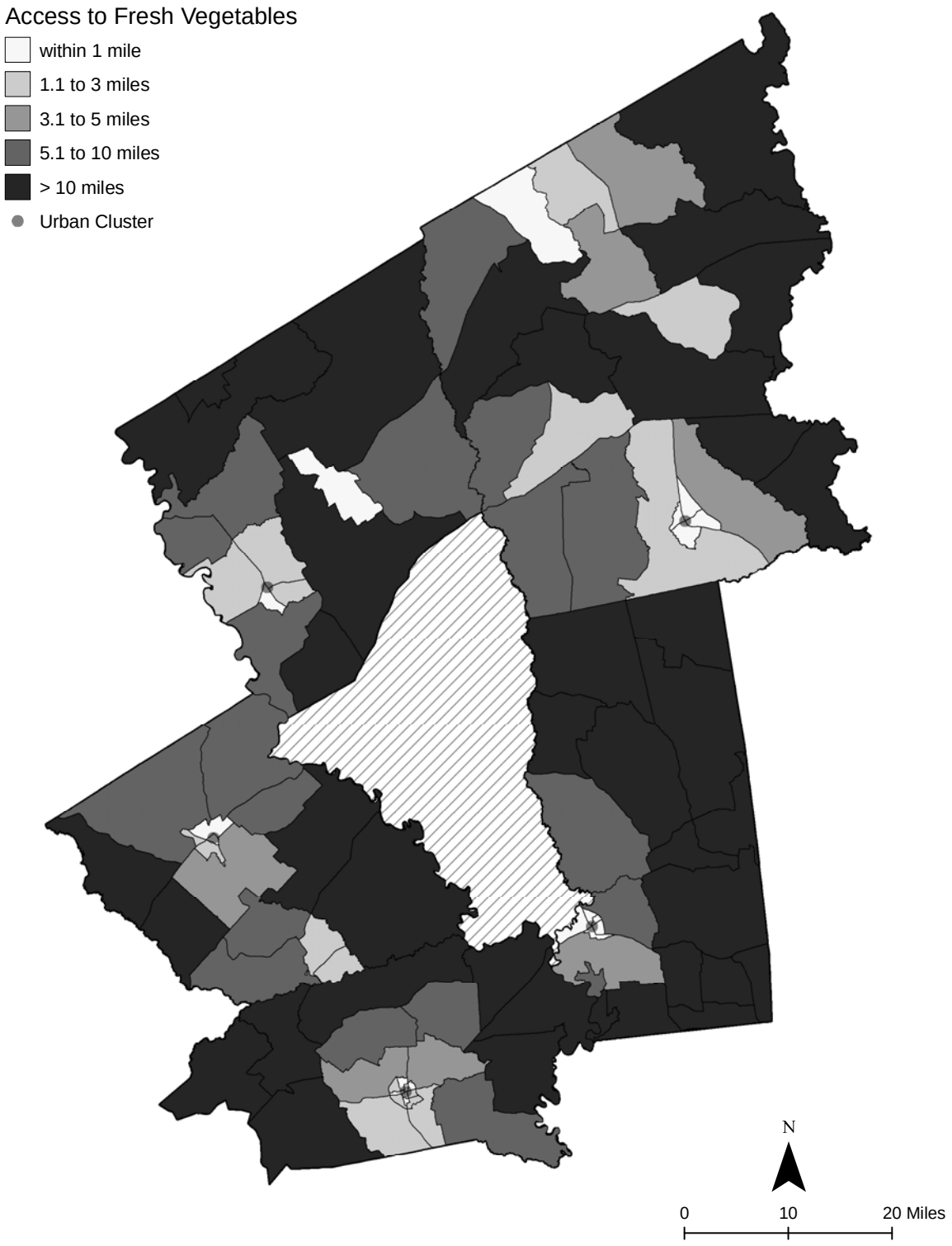

Figure 4. Neighborhood Access to Fresh Vegetables

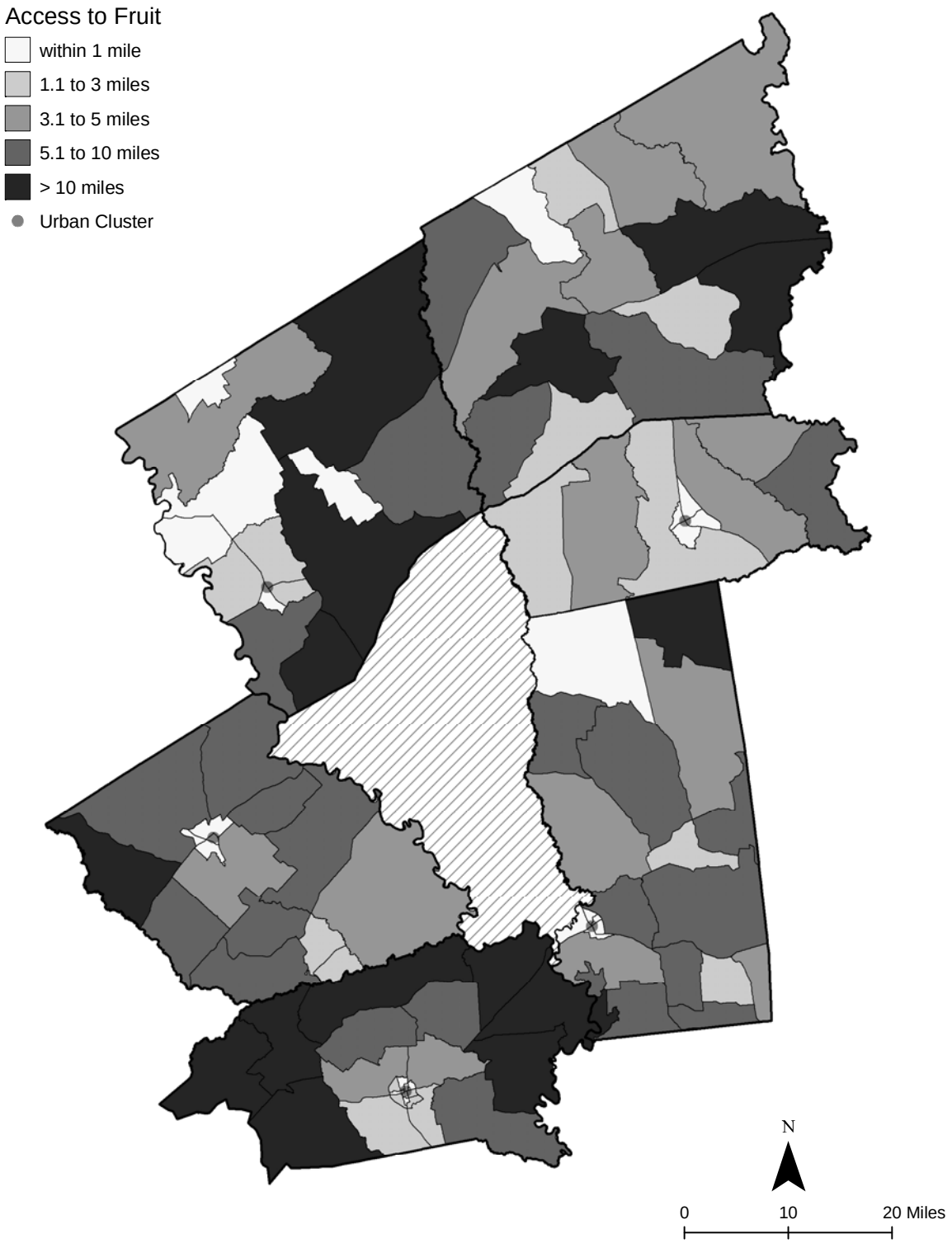

Figure 5. Neighborhood Access to Fresh and Processed Fruit

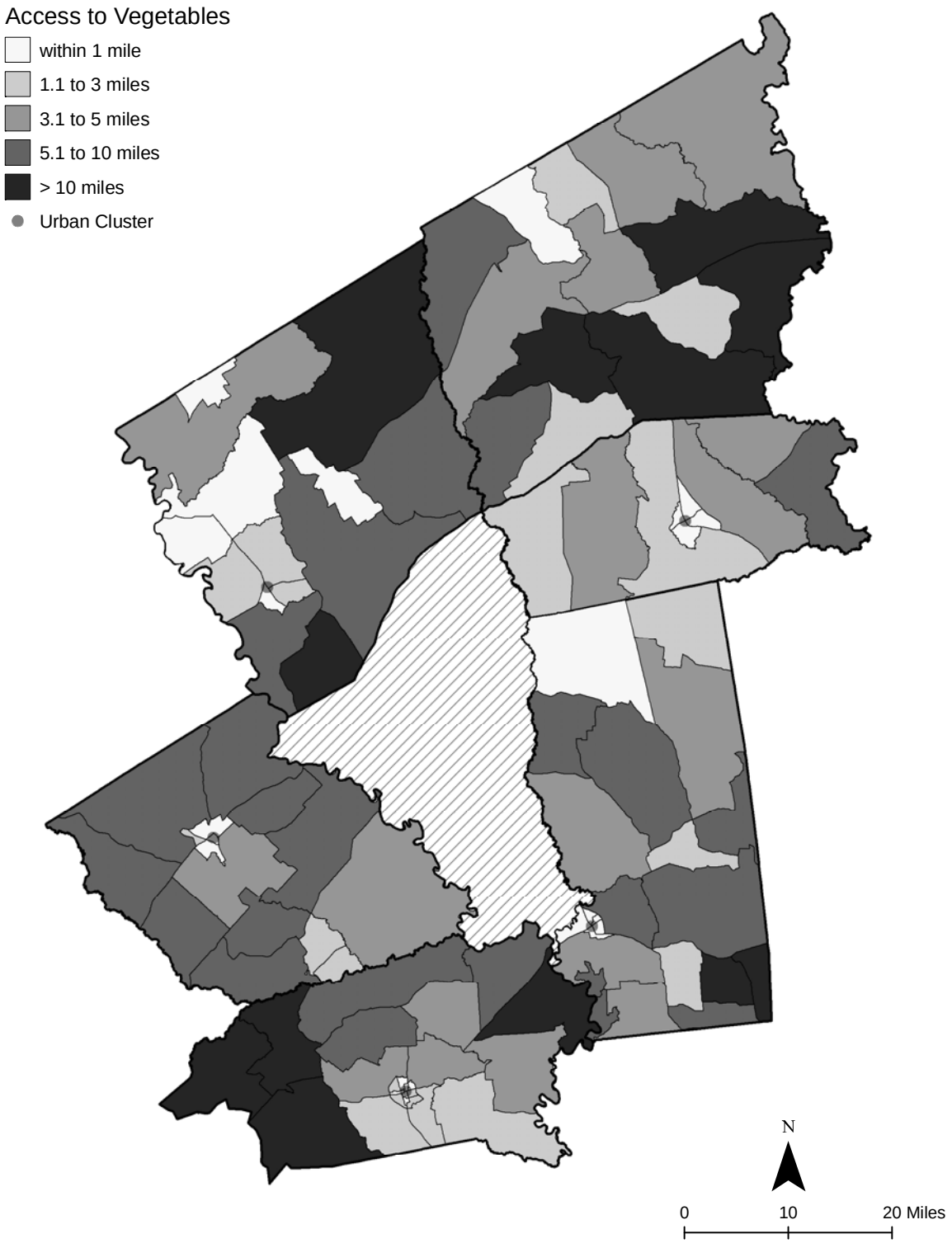

Figure 6. Neighborhood Access to Fresh and Processed Vegetables