

Towards the development of a GIS method for identifying rural food deserts: Geographic access in Vermont, USA

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A B S T R A C T

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The food desert metaphor has been widely used by academics and politicians alike. While there is general agreement on what a food desert is in a relatively vague sense, strategies to identify food deserts, especially in a rural setting, using a systematic method remain undefined. The purpose of this paper is to contribute towards the development of a method for rural food desert identification strategies using the location of food retailers and residential units. We apply a methodologically innovative GIS approach to the primarily rural state of Vermont, USA. Areas of inadequate geographic food access are identified and some are found to overlap with high poverty locations. Aims for future work are identified including fieldwork to validate these findings.

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Introduction

The first application of the phrase ‘food desert’ was claimed to be by a resident of public housing who used it to “capture the experience of what it was like to live in a deprived neighborhood where food was expensive and relatively unavailable” (Cummins & Macintyre 2002: 2115). Since then, its common usage has continued to be primarily qualitative. It has been widely employed by politicians to highlight poverty, social exclusion, and areas with non-existent and/or poor food retail provision (e.g. Acheson, 1998; Hughes, 2000; Social Exclusion Unit, 1998). Most recently, there has been some effort to quantify the concept utilizing a number of discipline-specific approaches (e.g. Apparicio, Cloutier, & Shearmur, 2007; Cummins & Macintyre, 1999; Donkin, Dowler, Stevenson, & Turner, 2000; Guy, Clarke, & Eyre, 2004; Larsen & Gilliland, 2008; Smith, Butterfass, & Richards, 2009; Smoyer-Tomic, Spence, & Amrhein, 2006; Wrigley, Guy, & Lowe, 2002). Through these studies, the literature has come to relative consensus on a general, conceptual, definition of a ‘food desert’ (“areas of relative exclusion where people experience physical and economic barriers to accessing healthy food” [Department of Health, 1996]) without corresponding accord on how to find such areas (other researchers have coined new terms to describe similar situations – for instance, see Wrigley’s (2005) use of ‘unsupportive local food environments’). The spatially unjust nature of food access issues, combined with the increasing availability of GIS data sets, prompted this paper, in which we aim to contribute towards the development of a method for the identification of rural food deserts. Central to this objective is our primary research question: Can we make a meaningful contribution to rural food desert identification strategies using the location of supermarkets and residential units? The innovativeness of this effort is emphasized by the fact that no other rural food desert studies have executed an analysis to investigate geographic access to food with this level of detail. Most previous studies that have measured food deserts quantitatively have been carried out in the United Kingdom and/or in urban areas

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(e.g. Bodor, Rose, Farley, Swalm, & Scott, 2007; Clarke, Eyre, & Guy, 2002; Donkin, Dowler, Stevenson, & Turner, 1999; Donkin et al., 2000; Guy & David, 2004; Pearce, Witten, & Bartie, 2006; Pearce, Witten, Hiscock, & Blakely, 2007; Shaw, 2006; Smoyer-Tomic et al., 2006; Wrigley, Warm, & Margetts, 2003; Zenk et al., 2005).

It is well-established that environmental influences can play a role in food selection and diet. In their call for advanced collaborative efforts between government, corporate, community, and non-profit entities to address the nation's obesity epidemic, French, Story, and Jeffery (2001) cite how the current built environment promotes unhealthy food intake and inactivity. Papas et al. (2007) stressed a similar concern and articulated the need for additional research examining the impact of the built environment and obesity. Food access studies have produced some research that sheds light on the linkages between environment and health. For example, Morland, Diez Roux, and Wing (2006) verified that the local food environment can dictate susceptibility to obesity while the same team of researchers found it was also linked to dietary intake (Morland, Wing, & Diez Roux, 2002). Food retail development, as a component of the built environment, has also been shown to influence diet (Cummins, Findlay, Petticrew, & Sparks, 2005; Wrigley, Warm, Margetts, & Lowe, 2004).

GIS and health

There is a need for a straightforward, easily applicable method for the identification of food deserts. GIS is increasingly being used to bridge public health research with neighborhood-level information in multiple disciplines. For example, Pearce et al. (2006) used GIS to measure the distance from every meshblock (smallest dissemination unit used in New Zealand) to 16 specific community resources over a road network. Topically different, but also utilizing GIS, Rodgers, Bergmann, Salak, Lackland, and Hinson (2007) epidemiological application of GIS examined the geographic distribution of Parkinson's disease and stroke, while McEntee and Ogneva-Himmelberger (2008) used GIS to explore spatial patterns of diesel particulate matter in environmental justice neighborhoods of Boston, MA. When framed as a public health issue (e.g. Lobstein, 1999; Morland et al., 2006), the ability to measure food access reliably becomes increasingly important in resource management for planning intervention strategies.

Qualitative measurements

Previous food desert studies utilized difficult to obtain data, often involving lengthy interviews and/or food index surveys that require significant time and resources, which make their approaches challenging to recreate. Lang and Caraher (1998) discussed food deserts in the context of access to healthy foods and corresponding public health education policies and six years later, Guy and David (2004) solidified the application by identifying potential urban food deserts in Cardiff, providing general food desert criteria that emphasized physical and economic disadvantage and poor nutrition. Shaw (2006) continued the broadly applied, yet quantitatively unrefined, nature of the term, alluding to the fact that food deserts remain undefined and applied a unique food desert classification scheme involving 234 semi-structured interviews that inquired into the obstacles faced by individuals in accessing grocery stores. Hendrickson, Smith, and Eikenberry (2006) identified food deserts in urban areas as those communities "with ten or fewer stores and no stores with more than 20 employees" (no parallel criteria provided for rural settings) and carried out focus group discussions, administered consumer surveys, and performed an inventory of food stuffs (Hendrickson et al., 2006: 372). Each of these studies describes food deserts as areas of general inadequacy in retail provision.

Qualitative food desert identification efforts typically employ a case study approach, which can be both time consuming and difficult to measure against other research. This lack of comparability between studies in addition to the methodological constraints of a case study method was a stimulus for the techniques employed in this paper.

A GIS based approach

GIS in early studies about food deserts and access tended not to utilize GIS technologies for analysis purposes; instead, maps presented rudimentary information such as study area (Wrigley et al., 2002), number of shops per geographic unit (Cummins & Macintyre 1999), and percentage change in socioeconomic variables per geographic unit (Guy et al., 2004). However, Donkin et al. (1999) were the first to use GIS analysis techniques to create maps of distance to outlets selling food over a road network, incorporating availability of individual food items and population density. These authors plotted the results of a food price index on a map to show areas of relative expensiveness. Recent efforts to use GIS to identify food deserts continue to vary in their technique and focus.

Geographic information systems (GIS) have taken on a substantial role in most current accessibility studies. GIS is utilized not only to show graphical information, but often it precedes statistical analysis. For instance, Pearce et al. (2006) used GIS to measure the distance from every meshblock (an indicator of relative distance traveled) to 16 specific community resources over a road network. Subsequently, indices of community resource accessibility were built for the entire country of New Zealand; this consisted of a quintile assignment for each meshblock. Pearce et al.'s (2006) study serves as a perfect example of how GIS has made possible analyses that two decades ago would have been impossible simply because they would have required prohibitive amounts of time. Measuring distance over a road network with accuracy by hand with a ruler and paper map for 38,350 census meshblocks would be a substantial time commitment. Building from their previous study, Pearce et al.'s (2007) research goes beyond a presentation of relative geographic

distance and performs a non-parametric Spearman's rank correlation analysis between access quintiles and deprivation quintiles to show that access to community resources was actually better in deprived areas. Statistical analysis is not always used in GIS applications that assess geographic access, however. Morton and Blanchard (2007) used GIS software to create centroids and measure distance to certain retailers. Lovett, Haynes, Sunnenberg, and Gale (2002) utilized the graphical benefits of a GIS to illustrate travel times and public transport routes to surgeries in East Anglia, UK. They did not perform any complex analysis, but presented a series of maps that show their data elements in a clear and precise manner so as to allow the reader to observe spatial overlaps in these data sets. If this data was presented in tabular format, the length of time to interpret it would be daunting. From these examples, we can conclude that GIS is not only useful for analysis, but also for presentation of information that contains trends that may otherwise go unnoticed if examined in a different layout, such as a table.

GIS has been used in a number of studies examining food access. Studies that examine community resources often include food retailers. However, there are a number of authors that have explicitly mapped and/or used GIS to map and/or measure food access. We can speak generally about two GIS centric approaches. In the first, the authors create original data (possibly using GIS) and map it for presentation. An example of this would be Guy and David's (2004) buffer application around food retailers. A more sophisticated example of this is Donkin et al.'s (2000) creation of price and availability indices. This type of analysis involves taking existing data and mapping it to identify trends and overlaps with other data elements (some of which may be original to the study at hand). The second approach is when statistical analysis is used to correlate one variable, such as physical distance, to another, such as socioeconomic status. Another example would be Larsen and Gilliland's (2008) analysis of walking and public transit access to supermarkets in London, Ontario. Most studies that entail the creation of original data focus on physical and/or economic access.

Three types of access

Food security is the phrase most commonly associated with hunger and food access issues. Maxwell (1996) has discussed the evolution of this term's usage at great length from one of a global/developing world context centered on supply to one of access focused on the individual household level (Maxwell & Smith, 1992). For our study, we are concerned with *food access*, which has become a central tenet of contemporary food security definitions. Take for instance Maxwell and Smith's (1992) summation of existent food security definitions: "secure access at all times to sufficient food" (p. 8) or the most commonly cited definition of food security, "Access by all people at all times to enough food for an active and healthy life" (World Bank, 1986: v). While it has been established that there are three main types of barriers that affect accessibility to food (geographic, economic, and informational), our primary focus is on geographic access, although it is worth briefly describing the informational and economic elements.

Informational access

Informational access can encompass a wide range of factors that relate to the educational, cultural, and social constraints that influence how and why people choose to eat certain foods. Wrigley et al. (2002) developed binary logistic/logit regression models showing that low fruit and vegetable consumption amongst study respondents was strongly associated with low educational attainment. Perhaps the most supportive evidence for this association is Rose's (1999) finding that food security is associated with households whose head has completed high school and Morton and Blanchard's (2007) finding that food desert counties typically have a larger proportion of individuals without a high school diploma. Nord and Andrews (2002) determined that reductions in hunger and food insecurity would require economic growth strategies aimed at households with "less skilled or less educated workers" (Nord & Andrews, 2002: 6). The linkages between item selection and nutritional knowledge are evident, but it is the compounding effect of other subjective elements that make associations so difficult to draw. Do people with sufficient nutritional knowledge without geographic or economic constraints buy healthy food? This type of question is most often investigated qualitatively through participant interviews and surveys with local residents (e.g. Coveney & O'Dwyer, 2008; Whelan, Wrigley, Warm, & Cannings, 2002; Wrigley et al., 2002; Wrigley et al., 2004). The answer to questions like this, however, will not be straightforward. Some people would change their purchasing habits if they were not economically or geographically constrained, but some would not for a plethora of reasons: lack of cooking skills, nutritional knowledge, time, and taste (Zandstra, de Graaf, & Van Staveren, 2001). However illogical it may seem, the reality is that there will always be those who choose to eat unhealthfully (from a nutritional perspective) despite unlimited resources.

Conversely, there are also those who would change the way they eat if given the opportunity. Educational attainment might be an indicator of healthy eating. Lack of cooking skills has also been cited as being linked to socioeconomic status and health (Furey, Strugnell, & McIlveen, 2001; Lang & Caraher, 1998; Shaw, 2006; Stead et al., 2004). Cultural constraints are equally important. The notion that food is part of popular culture (Piachaud & Webb, 1996) has generally been accepted while concurrently being influenced by anthropologically-determined cultural influences and gender roles (Douglas, 1972). Social influences play a critical role in food consumption (Glanz et al., 1993). In their study of social influences, Brug, Lechner, and de Vries (1995) determined that fruit and vegetable consumption was lower amongst those individuals with lower self-efficacy expectations and less positive attitudes.

Economic access

In general, poverty studies indicate that food security is linked to poverty level (Baker, Schootman, Barnidge, & Kelly, 2006; Nord, Jemison, & Bickel, 1999). Economic access, however, involves the examination of not only poverty, but other financial elements that impact one's ability to acquire food, such as food prices and transportation costs. Economic access has been discussed by researchers as being an important factor in identifying inadequate food access. A price index was created by Donkin et al. (1999) to compare prices of food in a cluster of shops; z-scores were assigned to every item and store to highlight relatively expensive items and store locations. The mean prices of food were compared with the income level of the local population to determine how it related to the average cost of a standard weekly shopping list of items. Donkin et al. (1999) found that physical access was not as severe a problem as economic access; a healthy diet for a young man on income support would cost over 5 percent of his weekly income. A similar type of study was carried out in the US by Hendrickson et al. (2006) in which researchers discovered that in areas with the highest poverty, food costs were typically higher and the quality of food was inferior. Eikenberry and Smith (2005) identified study locations based on percent of population living at or below the poverty line and Morton, Bitto, Oakland, and Sand (2005) reported that "[r]ural areas with high levels of poverty and limited or no food sources place burdens of food availability, access, and quality on low-income populations" (p. 93). Poverty is repeatedly used in the literature and cited as being an important criterion in gauging food access and security (Apparicio et al., 2007; Baker et al., 2006; Bodor et al., 2007; Hendrickson et al., 2006; Morton & Blanchard, 2007; Olson, Rauschenbach, Frongillo, & Kendall, 1996; Short, Guthman, & Raskin, 2007). Poverty's focal role in measuring nutrition is not new, as pointed out by Rose and Richards (2004), "[E]arly studies showed that individuals from households in poverty were more likely to exhibit nutritional deficiencies or have diets low in various nutrients" (p. 1081) (US Department of Health, Education, and Welfare 1971, US Department of Health, Education, and Welfare 1974).

Identifying food deserts: calculating geographic access

Geographic and economic access have been measured in an array of previous studies (e.g. Ball, Timperio, & Crawford, 2009; Donkin et al., 1999; Donkin et al., 2000; Dubowitz et al., 2007; Guy & David, 2004; Shaw, 2006; Smith et al., 2009; Whelan et al., 2002; Wrigley et al., 2002; Wrigley, 2002). Most research has assessed geographic access through attributes of locations or individuals, what Kwan, Murray, O'Kelly, and Tiefelsdorf (2003) has termed *place* and *personal* accessibility. From a mapping perspective, personal accessibility would be using point data that contains individual attribute information, such as daily consumption of fruits and vegetables while place accessibility would be placing a 500 meter buffer around a food retailer to determine its service area – a "zone-based aggregate spatial framework" (Kwan et al., 2003). Essential to this discussion (though not explored in this paper) is how geographers can take a geographically focused and designed set of tools, such as a GIS, and employ it to incorporate traditionally non-geographical data, such as opinion or choice. Place and individual accessibility are not static, but are temporally dynamic. In regards to individual accessibility, this fact may be even more so due to increases in informational accessibility (e.g. increase in internet usage rates).

Five-hundred meters is commonly cited as an acceptable distance that urban residents can live from a food retailer before experiencing inadequate food access (Clarke et al., 2002; Guy & David, 2004; Whelan et al., 2002; Wrigley et al., 2002). This distance was first cited by a Government Minister (Hughes, 2000) and was estimated to represent a five to seven minute walking travel time (Donkin et al., 1999); beyond which an individual was determined to be living in a food desert.

We have identified a methodological gap in the literature regarding food desert identification strategies. Rurally focused food access measurements cannot use the urban distance limit of 500 meters since most people live further than 500 meters from a food retailer and rely on an automobile and not on walking. Although the frequency of rural food access studies is increasing (e.g. Burns & Inglis, 2007; Furey et al., 2001; Liese, Weis, Pluto, Smith, & Lawson, 2007; Morton & Blanchard, 2007; Olson et al., 1996; Skerratt, 1999), efforts to measure geographic access in this context have largely been ignored, with the exception of three studies. Kaufman (1999) identified rural food deserts through a "net accessibility ratio" (a ratio of store sales to potential food spending), concluding that over 70 percent of the low-income population of the Lower Mississippi Delta had inadequate food access. The drawback of this study was that it relied on confidential data. Morton and Blanchard (2007) defined rural food deserts using GIS software as counties in which all residents live more than 10 miles to the nearest supermarket chain or supercenter (measured as Euclidean distance). Using a Euclidean distance, however, is limiting in that distance is measured not over the road networks people travel, but "as the crow flies"; the resulting ramification being travel distances will seem much shorter than the reality. Sharkey and Horel (2008) present the most detailed analysis of a geographic access study. The authors calculated the distance between a population-weighted centroid of a census block group to food retailers in Texas. While this analysis provides additional detail above and beyond the studies of Morton and Blanchard (2007) and Kaufman (1999), the limitation we highlight is the fact that their method of using a population-weighted centroid to food stores lacks the detailed measurement we employ (as described below). For instance, the use of a population-weighted centroid can potentially skew distances traveled by rural inhabitants since in rural areas even a census block group can be a very large area.

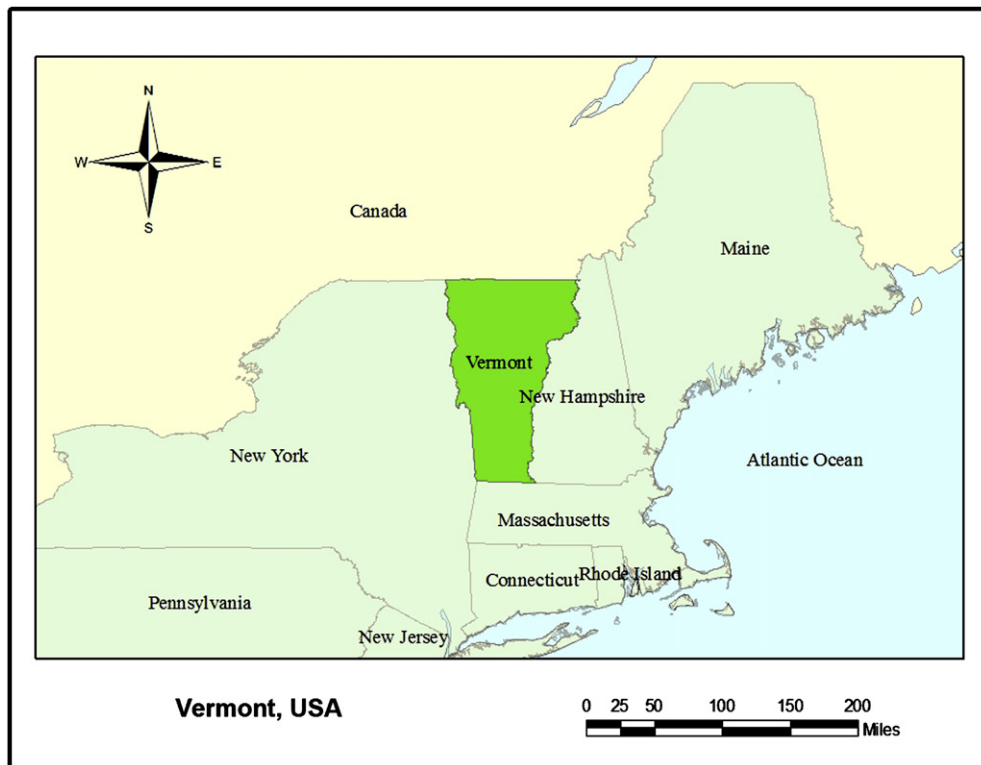


Fig. 1. Vermont, USA.

Methods and procedures

Situated in northern New England, Vermont (see Fig. 1) is a primarily rural state with 608,827 people located throughout its 9515 square miles of land (U.S. Census Bureau, 2005; Vermont Center for Geographic Information, 2007).² Twenty-one percent of the state's land is dedicated to farms, while 15.5 percent of the population is employed in farm and farm-related jobs (US Department of Agriculture, 2006; US Department of Agriculture, 2008). The mean per capita income is \$20,625 and 96.9 percent of the population identifies their race as white (U.S. Census Bureau, 2007). A sizeable portion of Vermont's land and economy is dedicated to agriculture and most of this (70.5% of 2006 total farm receipts) is dedicated to the dairy industry (US Department of Agriculture, 2008), indicating that for most people, the agriculture they are exposed to on a regular basis is not one in which they could obtain edible products. The average percentage of food insecure households between 2003 and 2005 was 9.5 percent (Food Research and Action Center, 2007).

As previously mentioned, we categorize the three types of access reviewed in existent literature as *geographical*, *economic*, and *informational* access. In our effort to contribute towards the development of a method to identify rural food deserts, we focus on geographic access. To accomplish this, we used supermarket and residential locations in conjunction with a Geographic Information System (GIS). Distance between supermarkets and residential units were used as a proxy for geographic access to food.

We plotted the location of food retailers ("food retailers" referring to the North American Industry Classification System number 44511 – Supermarket and Other Grocery [except Convenience] Stores larger than 2500 square feet) ($n = 142$) (ReferenceUSA, 2007), residential units ($n = 231,894$) (Vermont Center for Geographic Information), and roads using ArcGIS software (ESRI, 2005); a snapshot of these plotted data elements is provided in Fig. 2.³ The red line indicates the shortest route to the food retailer from a residential unit (circled). (For interpretation of the references to colour in this sentence, the reader is referred to the web version of this article.)

² In this paper we adhere to the United States Census Bureau's definition of rural. The US Census Bureau defines rural areas as all territory, population, and housing units within an Urban Area or Urban Cluster which are defined as core census block groups or blocks that have a population density of at least 500 people per square mile (US Census Bureau, 2003).

³ ReferenceUSA is an online reference service which contains information on US businesses. The data obtained from ReferenceUSA used in this analysis consisted of the latitude and longitude of every store larger than 2,500 square feet.

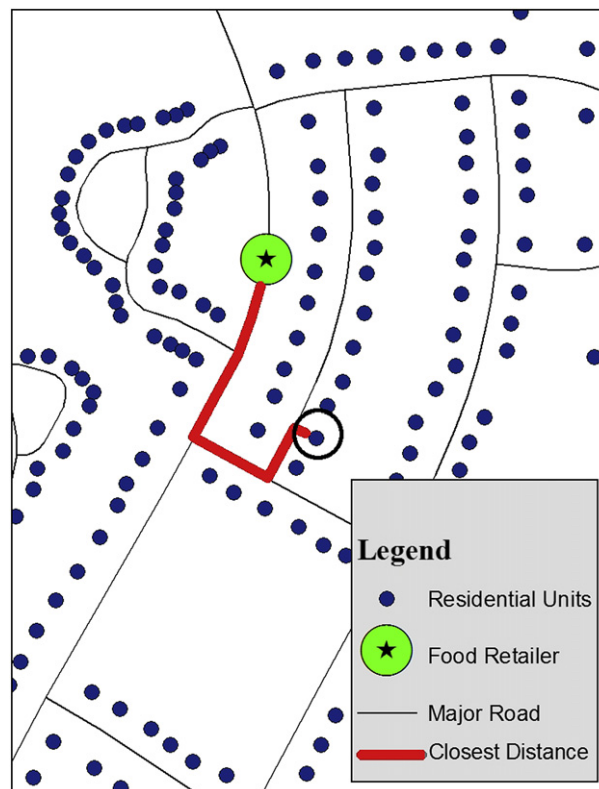


Fig. 2. Snapshot of plotted data elements.

Our justification for only including food retailers 2500 square feet or larger in size was to filter out small convenience stores and gas stations, which typically sell low nutritional value food items at higher prices and non-consumables (Donkin et al., 2000; Morton & Blanchard 2007; Pothukuchi, 2005). Furthermore, our current qualitative field research being conducted in a separate project in a neighboring New Hampshire county has indicated most residents in this northern New England region rely primarily on medium to large food retailers as their home food sources (McEntee 2009).

To calculate these distances we used a network measurement tool (specifically, *Network Analyst Extension Closest Facility* feature of ArcMap 9.1), to measure the distance between every residence and the closest food retailer. Resultantly, each residence had a corresponding *closest distance* data value, which indicated the distance to the closest retailer. These data were aggregated by census tract and divided by the number of residential units to produce the mean travel distance by census tract:

$$\frac{\text{Sum of distances between residential units and retailers}}{\text{\# of residential units}} = \text{Mean distance to food retailers within census tract}$$

This data is displayed in a choropleth map of census tracts, illustrating mean distance values (Fig. 3). Other distance calculation approaches were considered, such as the use of population-weighted centroids and interpolated distance values. These other methods, though not tremendously complex, begin to broaden the analytical distance between data and results – something we aimed not to do in order to maintain a relative ease of reproducibility.

After reviewing previous attempts to identify food deserts using geography in both urban and rural settings, we applied a ten mile threshold to represent geographical access; that is, any census tract which had a greater than 10 mile mean distance value between food retailers and residential units was considered a food desert (see Fig. 4 in *Results* section). We adopted this distance from Morton and Blanchard (2007) who adhered to a ten mile threshold to represent food deserts. Their basis for using this distance was that the average US resident travels approximately 8 miles to obtain groceries according to the National Transportation Survey (MSU 2003) so ten miles would therefore be two miles above average.

Results

Based on our geographic food desert criteria twelve census tracts (equivalent to 4.5 percent of the state's population) are considered food deserts due to the fact that, within these tracts, the mean distance between residential units and food retailers is 10 miles or greater (see Fig. 4). The mean distance to food retailers within food desert tracts was 13.15 miles compared to 4.14 miles at the statewide level.

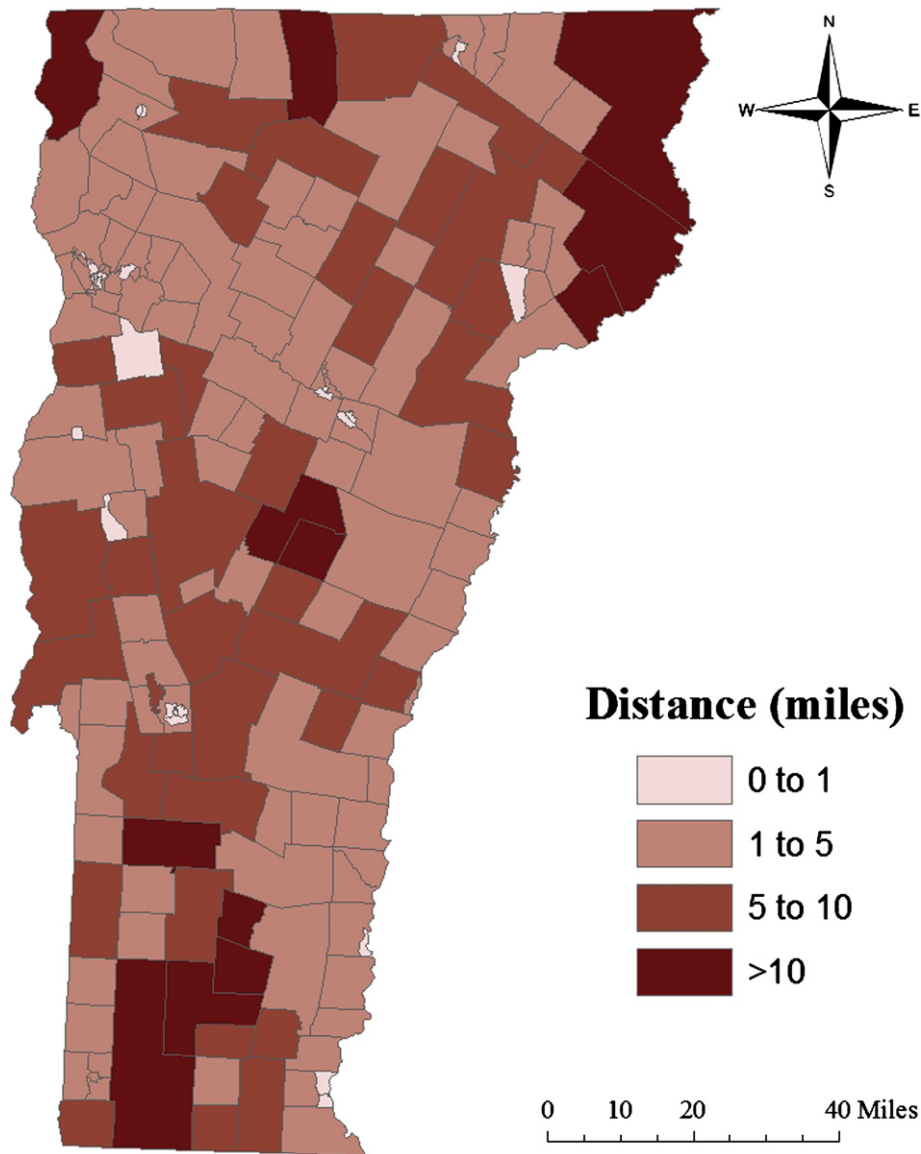


Fig. 3. Mean distance by census tract.

In food desert tracts 81 percent of residents have a high school diploma or greater, while statewide this rate increases to 86 percent. A discrepancy in poverty rates existed, but only by just over 1 percent (food desert census tracts residents experience 10.2 percent poverty while the statewide average is 9.8 percent). Of the fifteen poorest census tracts (defined as percent of individuals below poverty level), we have identified one-third as food deserts. Census tract 9501 (see Fig. 4), not only had the greatest distance value (24.45 miles), but also the lowest educational achievement (defined as percent of individual with a high school diploma or higher) in the state (70.9 percent). Census tract 103 (see Fig. 4), which ranked seventh for distance (11.55 miles), had the fifth lowest educational achievement as well as the eleventh highest poverty level (19 percent).

It should be mentioned that areas with some of the highest poverty rates and lowest educational achievement were located in urban areas of the state. We do not assert food deserts do not exist in these regions (simply because the distance values of less than 10 miles). However, because our study was focused on rural areas, we did not accommodate for specific urban-based access circumstances (e.g. walking is a more likely means of transportation for urban centers).

Discussion

Our results suggest certain areas of the state are at a higher risk of inadequate food access than others. The food desert identification method presented here informs ongoing uncertainty about how geographic access can be measured. Morton

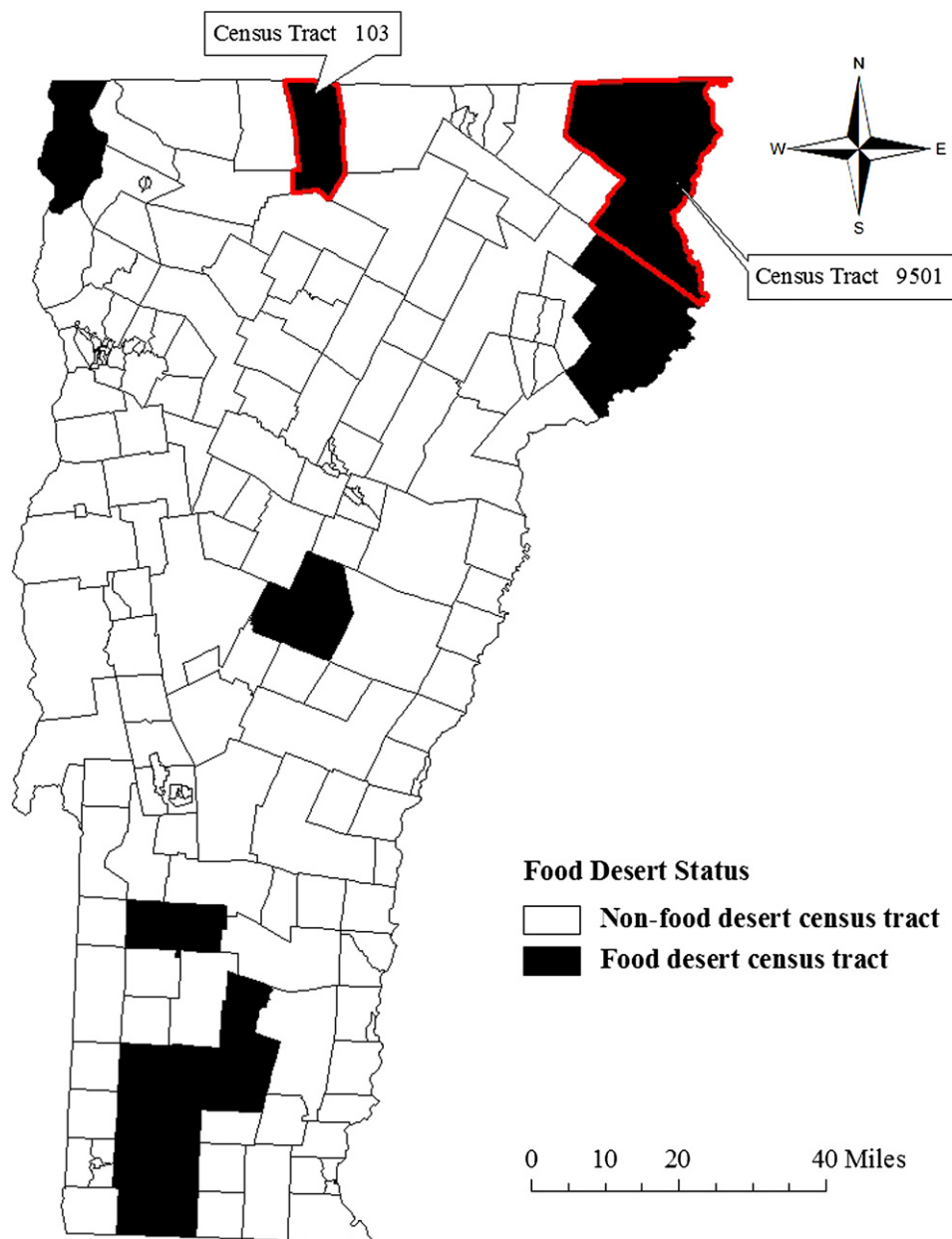


Fig. 4. Food Deserts: Greater than 10 mile mean distance between food retailers and residential units by census tract.

and Blanchard (2007) did not identify any region of VT as a food desert because, according to their study, there are no areas where greater than 50 percent of a county's population is further than 10 miles to a supermarket, supercenter, or wholesale club. The primary problem with their food desert definition is that it assumes an adequate food source can only be found in those three types of relatively large stores. In a place like rural Vermont where "big box" stores such as Walmart, Target, and Sam's Club have faced considerable grassroots opposition from the public in addition to the relatively small population base of the state, Morton and Blanchard's (2007) approach lacks robustness. We have included smaller general stores and independently-owned food retailers in addition to these larger options.

Our method for identifying food deserts contributes towards the development of a method for the identification of food deserts in three ways:

- 1) Detailed data: Our method measures the exact distance between every residential unit and food retailer. We did not rely on the creation of population-weighted centroids (e.g. Sharkey and Horel 2008) and we measured distance

over the road network; roads are the primary mechanism for which the majority of people in rural areas use to travel.

- 2) Time-sensitive: Our primary goal was to contribute towards the development of a food desert identification strategy that was relatively easy to employ and did not require collection of primary data, which usually entails extensive time and resources. After examining the locations of census tracts that travel the furthest in conjunction with poverty and educational attainment, our approach has highlighted areas of the state that are more likely to experience the symptoms of inadequate food access, such as food insecurity and hunger. Total analysis time was approximately twenty hours (not including analysis design and review of results). The task of measuring residence to retailer by hand, without the utilization of GIS, would have been prohibitively burdensome.
- 3) Applicability: Our method is applicable to other rural locations. All states have publicly available GIS data that details road networks. Geo-coded store locations are a proprietary item that can be purchased or accessed through a local college's or university's library. The e911 database provided by the Vermont Center for Geographic Information is unique in that it held statewide data already compiled into GIS-ready format. While few other states have a product that is centrally managed and as complete, other states often have sub-sectional data available and are moving towards statewide coverage and availability. Therefore, the analysis provided here establishes a groundwork for similar applications in other rural areas of the United States as the data becomes available enabling a uniform approach across the country.

Despite these attributes, our methods have two shortcomings. The first is that we assume most people living in Vermont obtained food only from food retailers (justification for including only food retailers larger than 2,500 square feet provided in the Methods and Procedures section). This leaves personal and community gardens and livestock rearing, community supported agriculture, and farmers markets out of the analysis; all could play an increasingly important role in how people access food.^{4,5} The second limitation of this study is that we restricted the analysis to the political boundaries of the state of Vermont, namely the inclusion of only retailers located in Vermont. Residents of food deserts are not restricted by these boundaries and may choose to shop across state or national lines, especially if they work in or commute through other areas. While this may especially affect the food desert status of border census tracts, interior food desert tracts still exist (see Fig. 4). In a similar vein, we also assumed that people select the closest food retailer; in reality myriad of factors impact why a person shops at a particular store, such as hours of operation and availability of certain foods.

The methods designed and employed in this paper present a way to identify food deserts across a range of places. Potential for comparability is one of this methods greatest strength, yet this advantage has come at the cost of sacrificing measures of economic and informational access. Fundamentally, this highlights a *breadth* versus *depth*, *systematic* versus *case study* trade-off which can partially account for the possibility of why food deserts could, in rare instances, be identified in areas where there are none, or vice versa.

Conclusion & next steps

Morton et al. (2005) called for refinement and testing of the food desert concept and we have contributed to this effort by creating and implementing a method that can be applied in rural areas of the country. The food desert concept is under continual refinement and receiving amplified attention after inclusion of a "Study and Report on Food Deserts" in the 2008 Farm Bill (US Congress, 2008). We support the notion that food deserts are comprised of areas where people experience one or all of the three types of inadequate access. The interplays between geographic, economic, and informational access dictate how people access food and provide a framework for research.

Our analysis contributes towards the measurement of geographic access, consequently helping us understand what the key barriers are in obtaining food. The work presented here is meant to move the food desert discussion and development of methods forward in order to assist not only academics, but practitioners who need a relatively straightforward and cost-effective technique to identify potential geographic food deserts without the time and resource requirements of case studies and interviews. More work is needed, however. Refinement of our method requires triangulation. Fieldwork needs to be conducted to compare people's experiences with our findings. This could take the form of a price survey, interviews, and/or surveys that explore consumer satisfaction with their food choices. For instance, our analysis does not identify a residential unit that houses someone who is poor, lacks cooking skills, and is within ten miles of a food retailer as part of a food desert, while classifying residential units that house people who are wealthy and have cooking skills who live greater than ten miles as living in a food desert. Results from additional research would help strengthen (and validate) central elements of our

⁴ We have also assumed that most people will travel by car or other private automobile to food retailers. Vehicle ownership data is unavailable, but according to the 2000 census, 87 percent of workers over the age of 16 used a car, truck, or van to get to work, while 5.5 percent walked, and .7 percent took public transportation. Disability status is also an important consideration when measuring geographic access, but data is unavailable for most of the state. We do know however that 16.7 percent of the state population has a disability compared to the national average of 15.1 percent (Brault, 2008).

⁵ Some recent evidence has emerged indicating that substantive contributions to nutritional well-being can be made by smaller-scale food sources similar in size to convenience stores (Short et al., 2007). However, we chose not to include these smaller size stores due to overwhelming evidence illustrating just the opposite (Horowitz, Colson, Hebert, & Lancaster, 2004; Morland et al., 2006; Powell, Slater, Mirtcheva, Bao, & Chaloupka, 2007).

analysis. In addition to qualitative assessments, we are currently undertaking an assessment of food retail density analyses which attempts to relate food retail density, population density, and food access in a rural context (a similar type of endeavor has recently been conducted by Seliske, Pickett, Boyce, & Janssen, 2009). Empirically demonstrating the utility of the analysis presented in this paper compared to other similar studies is made difficult by the fact that there are not many alternatives to compare to. The majority of other food desert or food access studies have either been located in an urban setting or qualitative investigations. Rural quantitatively focused geographic food access analyses are virtually non-existent with the exception of Morton and Blanchard (2007), which we have considered here.

Our goal in this study was to make a meaningful contribution to rural food desert identification strategies and therefore contribute towards the development of a method for the classification of food deserts in rural areas that could be applied across rural areas of the United States. Utilizing the distance between food retailers and residential units as an indicator of inadequate geographic access we successfully accomplished this objective and provided a detailed measurement of rural geographic access to food. Though some limitations exist as discussed in the previous section, it has also been our intention to push the relatively nascent area of rural geographic food access strategies forward by providing a new set of ideas, tools, and methods. We hope that this study can inform and be used in collaboration with other food desert studies which examine economic and informational access, such as analyses conducted by Donkin et al. (2000), Shaw (2006), and Hendrickson et al. (2006). We anticipate that food deserts will continue to be discussed and scrutinized, both theoretically and practically. However, we are optimistic that our study, specifically our methods, will contribute to efforts to hone this discussion and prevent the perpetual discussion of food deserts that is conceptually generalizable, yet practically disparate.

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References

- Acheson, D. (1998). Independent inquiry into inequalities in health report. Available from: <http://www.archive.official-documents.co.uk/document/doh/ih/part2d.htm#6>. Accessed 02.01.08.
- Apparicio, P., Cloutier, M., & Shearmur, R. (2007). The case of Montreal's missing food deserts: evaluation of accessibility to food supermarkets. *International Journal of Health Geographics*, 6(1), 4.
- Baker, E. A., Schootman, M., Barnidge, E., & Kelly, C. (2006). The role of race and poverty in access to foods that enable individuals to adhere to dietary guidelines. *Preventing Chronic Disease*, 3(3), A76.
- Ball, K., Timperio, A., & Crawford, D. (2009). Neighborhood socioeconomic inequalities in food access and affordability. *Health & Place*, 15, 578–585.
- Bodor, J. N., Rose, D., Farley, T. A., Swalm, C., & Scott, S. K. (2007). Neighbourhood fruit and vegetable availability and consumption: the role of small food stores in an urban environment. *Public Health Nutrition* 1–8.
- Brault, M. (2008). Disability status and the characteristics of people in group quarters: a brief analysis of disability prevalence among the civilian noninstitutionalized and total populations in the American community survey, the United States census bureau report. Available from: <http://www.census.gov/hhes/www/disability/GQdisability.pdf>. Accessed 10.17.08.
- Brug, J., Lechner, L., & de Vries, H. (1995). Psychosocial determinants of fruit and vegetable consumption. *Appetite*, 25, 285–296.
- Burns, C. M., & Inglis, A. D. (2007). Measuring food access in Melbourne: access to healthy and fast foods by car, bus and foot in an urban municipality in Melbourne. *Health & place*, 13(4), 877–885.
- Clarke, G., Eyre, H., & Guy, C. (2002). Deriving indicators of access to food retail provision in British cities: studies of Cardiff, Leeds and Bradford. *Urban Studies*, 39(11), 2041–2060.
- Coveney, J., & O'Dwyer, L. (2008). Effects of mobility and location on food access. *Health & Place*. Author's Accepted Manuscript.
- Cummins, S., Findlay, A., Petticrew, M., & Sparks, L. (2005). Healthy cities: the impact of food retail-led regeneration on food access, choice and retail structure. *Built Environment*, 31(4), 288–301.
- Cummins, S., & Macintyre, S. (1999). The location of food stores in urban areas: a case study in Glasgow. *British Food Journal*, 101, 54–55, 2.
- Cummins, S., & Macintyre, S. (2002). A systematic study of an urban foodscape: the price and availability of food in greater Glasgow. *Urban Studies*, 39, 2115–2130, 16.
- Department of Health. (1996). *Low income, food, nutrition and health: Strategies for improvement*. A Report from the Low Income Project Team to the Nutrition Task Force. London: Department of Health.
- Donkin, A. J., Dowler, E. A., Stevenson, S. J., & Turner, S. A. (1999). Mapping access to food at a local level. *British Food Journal*, 101(7), 554.
- Donkin, A. J., Dowler, E. A., Stevenson, S. J., & Turner, S. A. (2000). Mapping access to food in a deprived area: the development of price and availability indices. *Public Health Nutrition*, 3(1), 31–38.
- Douglas, M. (1972). Deciphering a meal. *Daedalus*, 101, 61–82.
- Dubowitz, T., Acevedo-Garcia, D., Salkeld, J., Lindsay, A. C., Subramanian, S. V., & Peterson, K. E. (2007). Lifecourse, immigrant status and acculturation in food purchasing and preparation among low-income mothers. *Public Health Nutrition*, 10(4), 396–404.
- Eikenberry, N., & Smith, C. (2005). Attitudes, beliefs, and prevalence of dumpster diving as a means to obtain food by Midwestern, low-income, urban dwellers. *Agriculture and Human Values*, 22(2), 187–202.
- ESRI. (2005). *ArcMap version 9.1: Environment systems*. Research Institute Inc.
- Food Research and Action Center. (2007). *State of the states: 2007*. Washington, DC.
- French, S. A., Story, M., & Jeffery, R. W. (2001). Environmental influences on eating and physical activity. *Annual Review of Public Health*, 22, 309–335.
- Furey, S., Strugnell, C., & McIlveen, H. (2001). An investigation of the potential existence of "food deserts" in rural and urban areas of Northern Ireland. *Agriculture and Human Values*, 18(4), 447–457.
- Glanz, K., Kristal, A. R., Sorensen, G., Palombo, R., Heimendinger, J., & Probart, C. (1993). Development and validation of measures of psychosocial factors influencing fat- and fiber-related dietary behavior. *Preventative Medicine*, 22, 373–387.
- Guy, C. M., Clarke, G., & Eyre, H. (2004). Food retail change and the growth of food deserts: a case study of Cardiff. *International Journal of Retail & Distribution Management*, 32, 72–88, 17.

- Guy, C. M., & David, G. (2004). Measuring physical access to 'healthy foods' in areas of social deprivation: a case study in Cardiff. *International Journal of Consumer Studies*, 28(3), 222–224.
- Hendrickson, D., Smith, C., & Eikenberry, N. (2006). Fruit and vegetable access in four low-income food deserts communities in Minnesota. *Agriculture and Human Values*, 23(3), 371–383.
- Horowitz, C., Colson, K., Hebert, P., & Lancaster, K. (2004). Barriers to buying healthy foods for people with diabetes: evidence of environmental disparities. *American Journal of Public Health*, 94, 1549–1554.
- Hughes B. (2000). Speech to third annual local food retailing conference, July, 2000.
- Kaufman, P. R. (1999). Rural poor have less access to supermarkets, large grocery stores. *Rural Development Perspectives*, 13(3).
- Kwan, M. P., Murray, A. T., O'Kelly, M. E., & Tiefelsdorf, M. (2003). Recent advances in accessibility research: representation, methodology and applications. *Journal of Geographical Systems*, 5(1), 129–138.
- Lang, T., & Caraher, M. (1998). Access to healthy foods: part II. Food poverty and shopping deserts: what are the implications for health promotion policy and practice? *Health Education Journal*, 57, 202–211.
- Larsen, K., & Gilliland, J. (2008). Mapping the evolution of 'food deserts' in a Canadian city: supermarket accessibility in London, Ontario, 1961–2005. *International Journal of Health Geographics*, 7, 16.
- Liese, A. D., Weis, K. E., Pluto, D., Smith, E., & Lawson, A. (2007). Food store types, availability, and cost of foods in a rural environment. *Journal of the American Dietetic Association*, 107(11), 1916–1923.
- Lobstein, T. (1999). *Health, income and diet, tackling inequalities in health and diet related disease*. London: Sustain Publication. KKS Printing.
- Lovett, A., Haynes, R., Sunnenberg, G., & Gale, S. (2002). Car travel time and accessibility by bus to general practitioner services: a study using patient registers and GIS. *Social Science & Medicine* (1982), 55(1), 97–111.
- Maxwell, S., & Smith, M. (1992). Household food security: a conceptual review. In S. Maxwell, & T. Frankenberger (Eds.), *Household food security: concepts, indicators, measurements: A technical review, monograph*. UNICEF and IFAD, New York and Rome.
- Maxwell, S. (1996). Food security: a post-modern perspective. *Food Policy*, 21(3), 155–170.
- McEntee, J. C., & Ogneva-Himmelberger, Y. (2008). Diesel particulate matter, lung cancer, and asthma incidences along major traffic corridors in MA, USA: a GIS analysis. *Health & Place*, 14(4), 817–828.
- McEntee, J.C. (2009). Re-localization of rural food systems: A key ingredient in the creation of sustainable communities?. Presented at the 2009 Association of American Geographers Annual Meeting. Las Vegas, NV. 22–27 March 2009.
- Morland, K., Diez Roux, A. V., & Wing, S. (2006). Supermarkets, other food stores, and obesity: the atherosclerosis risk in communities study. *American Journal of Preventive Medicine*, 30(4), 333–339.
- Morland, K., Wing, S., & Diez Roux, A. (2002). The contextual effect of the local food environment on residents' diets: the atherosclerosis risk in communities study. *American Journal of Public Health*, 92, 1761–1767.
- Morton, L., Bitto, E., Oakland, M., & Sand, M. (2005). Solving the problems of Iowa food deserts: food insecurity and civic structure. *Rural Sociology*, 70(1), 94–112.
- Morton, L. W., & Blanchard, T. C. (2007). Starved for access: life in rural America's food deserts. *Rural Realities*, 1(4), 1–10.
- Nord, M., & Andrews, M. (2002). Reducing food insecurity in the United States: assessing progress toward a national objective. Food Assistance and Nutrition Research Report, No. 26–2.
- Nord, M., Jemison, K., & Bickel, G. (1999). *Measuring food security in the United States: Prevalence of food insecurity and hunger, by State, 1996–1998*. Food Assistance and Nutrition Research Report. Food and Rural Economics Division, Economic Research Service, U.S. Department of Agriculture. Report No. 2.
- Olson, C., Rauschenbach, B., Frongillo, E., Jr., & Kendall, A. (1996). *Factors contributing to household food insecurity in a rural upstate New York county*. Institute for Research on Poverty Discussion Paper, no. 1107–96. Division of Nutritional Sciences Cornell University.
- Papas, M. A., Alber, A. J., Ewing, R., Heizisouer, K. J., Gary, T. L., & Klassen, A. C. (2007). The built environment and obesity. *Epidemiologic Reviews*, 29, 129–143.
- Pearce, J., Witten, K., & Bartie, P. (2006). Neighbourhoods and health: a GIS approach to measuring community resource accessibility. *Journal of Epidemiology and Community Health*, 60(5), 389–395.
- Pearce, J., Witten, K., Hiscock, R., & Blakely, T. (2007). Are socially disadvantaged neighbourhoods deprived of health-related community resources? *International Journal of Epidemiology*, 36(2), 348–355.
- Piachaud, D., & Webb, J. (1996). *The price of food: Missing out on mass consumption*. London: STICERD London School of Economics.
- Pothukuchi, K. (2005). Attracting supermarkets to inner-city neighborhoods: economic development outside the box. *Economic Development Quarterly*, 19(3), 232–244.
- Powell, L., Slater, S., Mirtcheva, D., Bao, Y., & Chaloupka, F. (2007). Food store availability and neighborhood characteristics in the United States. *Preventative Medicine*, 94, 189–195.
- ReferenceUSA, Inc. 2007. Omaha, NE.
- Rodgers, J., Bergmann, K., Salak, V., Lackland, D., & Hinson, V. (2007). Geographic distribution of Parkinson's disease and stroke in South Carolina. *Annals of Epidemiology*, 9(9), 723.
- Rose, D. (1999). Economic determinants and dietary consequences of food insecurity in the United States. *Journal of Nutrition*, 129, 517S–520S.
- Rose, D., & Richards, R. (2004). Food store access and household fruit and vegetable use among participants in the US Food Stamp Program. *Public Health Nutrition*, 7(8), 1081–1088.
- Seliske, L. M., Pickett, W., Boyce, W. F., & Janssen, I. (2009). Density and type of food retailers surrounding Canadian schools: variations across socioeconomic status. *Health & Place*, 15(3), 903–907.
- Sharkey, J. R., & Horel, S. (2008). Neighborhood socioeconomic deprivation and minority composition are associated with better potential spatial access to the ground-truthed food environment in a large rural area. *The Journal of Nutrition*, 138, 620–627.
- Shaw, H. J. (2006). Food deserts: towards the development of a classification. *Geografiska Annaler, Series B: Human Geography*, 88(2), 231–247.
- Short, A., Guthman, J., & Raskin, S. (2007). Food deserts, oases, or mirages? Small markets and community food security in the San Francisco Bay Area. *Journal of Planning Education And Research*, 26(3), 352–364.
- Skerratt, S. (1999). Food availability and choice in rural Scotland: the impact of "place". *British Food Journal*, 101(7), 537–544.
- Smith, C., Butterfass, J., & Richards, R. (2009). Environment influences food access and resulting shopping and dietary behaviors among homeless Minnesotans living in food deserts. Online publication: Feb, 2009. *Agriculture & Human Values*. 10.1007/s10460-009-9191-z.
- Smoyer-Tomic, K. E., Spence, J. C., & Amrhein, C. (2006). Food deserts in the Prairies? Supermarket accessibility and neighborhood need in Edmonton, Canada. *The Professional Geographer*, 58, 307.
- Social Exclusion Unit. (1998). *Bringing Britain together: A national strategy for neighbourhood renewal*. London: The Stationery Office.
- Stead, M., Caraher, M., Wrieden, W., Longbottom, P., Valentine, K., & Anderson, A. (2004). Confident, fearful and hopeless cooks: findings from the development of a food-skills initiative. *British Food Journal*, 106(4), 274–287.
- US Census Bureau. (2003). Census 2000 basics. Available from: <http://www.census.gov/mso/www/c2000basics/chapter4.htm>. Accessed 05.18.09.
- US Census Bureau. (2005). Information & research services, population division 2005, census 2000 gateway. Available from: <http://www.census.gov/main/www/cen2000.html>. Accessed 20.11.05.
- US Census Bureau. (2007). U.S. census bureau: state and county quickfacts. [Homepage of U.S. Census Bureau]. [Online]. Available from: <http://quickfacts.census.gov/qfd/states/50000.html>. Accessed 28.02.07.
- US Department of Agriculture. (2006). National agricultural statistics service, NASS – 2002 census of agriculture. Available from: http://www.nass.usda.gov/Census_of_Agriculture/index.asp. Accessed 01.16.07.
- US Department of Agriculture. (2008). Economic research service, Vermont fact sheet. Available from: <http://www.ers.usda.gov/StateFacts/VT.htm>. Accessed 03.12.08.

- US Department of Health, Education, and welfare. (1971). *Centers for disease control. Ten-state nutrition survey in the United States, 1968–1970. Preliminary report to congress*. Atlanta, GA: DHEW.
- US Department of Health, Education, and Welfare. (1974). *National Center for Health Statistics. Preliminary Findings of the First Health and Nutrition Examination Survey, United States, 1971–72*. DHEW Publication No. (HRA) 74-1219-1. Rockville, MD: DHEW.
- US Congress. (2008). *Food, conservation, and energy act of 2008, 110th congress*. US Government Printing Office.
- Vermont Center for Geographic Information. (2007). Vermont Center for Geographic Information Website. Available from. <http://www.vcgi.org>.
- Whelan, A., Wrigley, N., Warm, D., & Cannings, E. (2002). Life in a 'Food Desert'. *Urban Studies*, 39(11, 18), 2083–2100.
- World Bank. (1986). *Poverty and hunger: Issues and options for food security in developing countries*. Washington, DC: World Bank Policy Study.
- Wrigley, N. (2002). 'Food Deserts' in British cities: policy context and research priorities. *Urban Studies*, 39(11), 2029–2040.
- Wrigley, N. (2005). *Food poverty and retail access what recent UK-US research reveals*. Cambridge – MIT Institute Workshop.
- Wrigley, N., Guy, C., & Lowe, M. (2002). Urban regeneration, social inclusion and large store development: the seacroft development in context. *Urban Studies*, 39, 2101–2114, 14.
- Wrigley, N., Warm, D., & Margetts, B. (2003). Deprivation, diet, and food-retail access: findings from the leeds 'food deserts' study. *Environment and Planning A*, 35(1), 151–188.
- Wrigley, N., Warm, D., Margetts, B., & Lowe, M. (2004). The leeds 'food desert' intervention study: what the focus groups reveal. *International Journal of Retail Distribution & Management*, 32(2), 123–136.
- Zandstra, E. H., de Graaf, C., & Van Staveren, W. A. (2001). Influence of health and taste attitudes on consumption of low- and high-fat foods. *Food Quality and Preference*, 12, 75–82.
- Zenk, S. N., Schulz, A. J., Hollis-Neely, T., Campbell, R. T., Holmes, N., Watkins, G., et al. (2005). Fruit and vegetable intake in African Americans income and store characteristics. *American Journal of Preventive Medicine*, 29(1), 1–9.