ACCESS TO FOOD IN COLUMBIA, MISSOURI

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ABSTRACT

Access to basic food resources is an issue of global significance. This is especially true in urban environments where dependence on stores for food is high. Given this, do inequities in access to basic food resources exist in urban environments? If so, what populations lack adequate access or are most vulnerable to fluctuations in food availability? In this thesis, approaches for measuring access to urban food are examined and a modeling methodology for assessing the sensitivity of populations to changes in food availability is proposed. The developed approach is applied to a Midwestern community for which findings and implications for access to food are discussed.

CHAPTER 1: INTRODUCTION

1.1 The Relationship Between Diet and Health

The Centers for Disease Control reports that over 78 million adults and approximately 12.5 million children and adolescents in the United States (U.S.) are obese (Ogden et al. 2012). Recent studies have provided evidence that adult obesity has increased from 13 percent of the U.S. population in the 1960's to 32% in 2004 (Wang and Beydoun 2007). It is predicted that by the year 2015 75 percent of adults will be overweight or obese (with 41 percent of adults being obese) and 24 percent of children and adolescents will be either overweight or obese in the U.S.(Wang and Beydoun 2007). The dangers of obesity include an increased risk of diabetes, heart disease, cancer, and stroke, among others (CDC 2011). From a public health perspective, ameliorating the causes of obesity would have significant positive impacts on a community's well-being.

Many factors influence the obesity rate. These include culture, changes in technology, international trade, and changes in occupational demands (Wang and Beydoun 2007). Medically, obesity is caused by an imbalance between caloric gain and energy expenditure. Increasingly, research is suggesting that features in the built environment may somehow influence an individual's exercise and dietary habits. For instance, geographic inequities in distribution of opportunities for physical activity may be one environmental factor influencing caloric intake and exercise (Wang and Beydoun 2007).

1.2 Access to Food in Urban Environments

The United States Department of Agriculture (USDA 2009) defines a healthy diet as one that includes the recommended servings of fresh fruits and vegetables and is low in fats and oils (USDA 2011 a). However, many obstacles to a healthy diet can exist. An individual's access to sources of food is often identified as a major factor impacting the dietary opportunities available. For example, the cost (i.e. time/distance/effort) required to access resources can represent a barrier to many individuals. If an individual perceives the cost of accessing a particular resource as too high, then the set of alternatives available to them becomes more restricted (Story et al. 2008). Distance is often considered to be a good approximation of the cost an individual incurs in traveling between two locations. If the cost of travel to one location is higher than the cost of travel to other alternatives, then the location's attractiveness will decrease as will the probability of it being visited (Church and Murray 2009). An example of such decision-making behavior with respect to food may be a consumer choosing frozen dinners from a convenience store rather than traveling to a more distant supermarket that has a wider (and cheaper) selection of healthier alternatives. The idea that there is a distance or range beyond which an individual is unlikely to have access to a resource is fundamental to the study of food systems, as well as location science in general (USDA 2009, Church and Murray 2009, McEntee and Agyeman 2010).

1.3 Food Deserts

The term 'food desert' is increasingly used to describe areas that have poor access or a relative locational disadvantage to healthy foods (Wrigley 2002, USDA 2009,

Healthy Communities 2010). Unlike the related concept of food security, food deserts don't relate to absence of food, but rather an increase in effort required in accessing different alternatives (USDA 2011). Distinguishing between healthy and unhealthy sources of food helps explain what is sometimes referred to as the food access paradox (Christian 2010). The food access paradox is that individuals with low access to food may actually be at a higher risk for obesity than those with high access due to the substitution of less nutritious, calorie dense foods for fresh produce (ibid.). Individuals living in food deserts don't experience low access to food in an absolute sense but rather experience lower levels of access relative to other locations in the community. Although proximate alternative sources for food may indeed exist in a food desert, those sources may not offer the range of foods needed to sustain a healthy diet. For example, in the context of fresh produce, smaller groceries and convenience stores have been found to be less likely to offer fresh produce and more likely to stock non-perishable items. As a result, access to supermarkets is commonly considered as a proxy for sources of healthy food given they offer a more consistent and diverse supply of fresh foods (Short 2007, Rose et al. 2009, Sharkey & Horel 2009, Bader et al. 2010).

Prompted by the Food Conservation and Energy Act of 2008, the USDA published a nationwide report in 2009 called "Access to Affordable and Nutritious Food: Measuring and Understanding their Consequences" which indicated 23.5 million people in the United States lived in food deserts (USDA 2009). The term "food deserts" has gained further momentum since the beginning of First Lady Michelle Obama's *Let's Move* campaign and the Obama Administration's Healthy Food Financing Initiative (HFFI) (Healthy Communities 2010).

Beginning in 2010, these programs have sought to reduce obesity through the promotion of exercise and healthy eating. The HFFI is based off a state of Pennsylvania program, the Fresh Food Financing Initiative, and has allocated approximately $400 million to improve access to healthy foods through offering financial incentives to retailers selling healthy foods. The *Let's Move* campaign also recognizes farmer's markets as sources of healthy food and promotes their participation in subsidy programs such as the Supplemental Nutrition Assistance Program (SNAP) so that the food they sell is affordable to those with limited incomes (Healthy Communities 2010).

The reason for food desertification of an urban area is often traced back to changes in the ambient retail environment. In many urban areas, inequities in development, expansion, changing demographics and employment opportunities have been seen to affect locational decisions made by grocery stores and supermarkets. The result, in some cases, has been the relocation of stores from the urban core to more peripheral suburban areas having more space, cheaper land, less crime, and better transportation. In other cases, chain supermarkets have out-competed or simply bought out smaller centrally located grocers, subsequently leading to their closure. While beneficial to some populations, these changes in retail location have also left portions of urban areas with decreased access to food. In many instances, these newly created food deserts are also home to individuals with limited means to access the more distant alternatives, thus exacerbating the problem (Wrigley et al. 2002; Hawkes 2008).

1.4 Criticisms of Food Deserts

The usefulness of the food desert concept has been called into question given a variety of methodological and interpretative problems associated with its practical application (Pearson 2005, Short 2007). For instance, the USDA's methodology employs U.S. Census tracts as the areal unit upon which food deserts are defined. However, Census tracts are a fairly coarse representation of space, masking important variations in the socio-economic structure of a region. Further, given that Census tracts are known to vary considerably in size and morphology over a region, they can be problematic from an analytical perspective (USDA 2009). Identification of food deserts at a more disaggregate level, such as U.S. Census block-groups or blocks, would likely provide give a more detailed view of geographic variations in access. Additionally, it is believed that the use of only supermarkets as sources of fresh produce can bias estimates of food availability of food in a community (Short 2007). Therefore public policy makers may find that an approach more tailored to the actual retail environment of a particular urban area is needed to provide a better understanding of access (USDA 2009a).

1.5 Need for Study and Overview

In the state of Missouri, obesity rates are reflective of those observed nationwide. In 1986, Missouri had an obesity rate of less than 10 percent of the population. However, in 2010 it was one of twelve states that had an obesity rate of over 30 percent (CDC 2011). Columbia, Missouri is a medium sized community in Central Missouri with a population of approximately 109,000 people (US Census 2009). While Columbia is currently host to many supermarkets, the USDA food desert report identifies three Census tracts meeting its definition of a food desert (USDA 2011). However, when this

finding was reported in local media, many Columbia citizens commented online that they disagreed with the designation. "Food isn't sold where there are no buyers" said one commenter, referring to the fact that the Census tracts in question corresponded with either the downtown business district or the University of Missouri campus. Another commenter stated "This is just a shady marketing ploy to get us all excited about 3 census tracts in Columbia where, presumably, healthy food is unavailable. Those poor, starving people in the Grasslands...", the Grasslands being a wealthy neighborhood. (Columbia News Tribune 2011). However, others have claimed some areas of Columbia do lack access (Columbia Missourian 2012).

To address these issues this thesis explores the measurement of geographic access to retail food locations in the urban environment. First, this thesis reviews the pertinent literature associated with access to food, including the concept of access, different types of access, the significance of access to food, as well as methodological and practical problems associated in the measurement of access to food. Next, Chapter 3 proposes a methodology for studying access to food that builds on previous research in an attempt to better address some of the shortcomings related to the measurement of access. Chapter 4 details an implementation of this methodology in a case-study of Columbia, Missouri. Chapter 5 presents the results of the study and with further discussion provided in Chapter 6. Finally, conclusions and potential future work on the subject is presented in Chapter 7.

1.6 Study Question

Given the disparity between the national study by the USDA and the opinions of locals it is of value to conduct a local study of Columbia, Missouri in order to gain a greater understanding of local conditions and how sensitive measurements of food access are to a more in depth approach and how it compares to the national study. The results of such a study will provide valuable insight into the confidence one can have of the utility of the national study to truly represent local conditions of food access. The purpose of this thesis is to evaluate the sensitivity of locations to measures of geographic access to retail food. In order to accomplish this, this thesis provides a framework to better account for and evaluate locational inequities in the geographic and economic costs of accessing sources of food. The developed framework incorporates 1) the analysis of many different network distance-based access standards, 2) a measure of the level of opportunity for access at each access standard assessed, and 3) a measure of food prices and availability using a market-basket selection of products. Sensitivity of evaluating access to changes in the geographical representation of demand for food to the modifiable areal unit problem is also investigated.

CHAPTER 2: LITERATURE REVIEW

2.1 Diet and Health

The World Health Organization (WHO) and Food and Agricultural Organization (FAO) reports that available food in developed and developing nations has increased in quantity and diversity over recent decades (WHO/FAO 2002). This increase has also corresponded with an increase in the consumption of energy dense foods high in fats and low in unrefined carbohydrates (ibid.). Additionally, individuals are increasingly tending toward a more sedentary lifestyle with less physical activity than previous generations. This is due in part to widespread changes in the global economy that have decreased the need for manual labor (ibid). The combination of these changes in diet and exercise has contributed to an increase in obesity, diabetes, cardiovascular ailments and other chronic diseases that are often caused in part by lifestyle. Thus, it has been recommended that a diet comprised of a major portion of fruits, vegetables, and whole grains is an essential contribution to maintaining good health. In the past, food policy in many nations has focused mainly on preventing hunger. What is becoming increasingly important is not simply ensuring that people have a secure source of food but also facilitating access to the types of foods that are essential to good nutrition and support good health (WHO/FAO 2002).

2.2 Food Deserts

The idea of nutritious food is important to the concept of food deserts. The term "desert" is somewhat misleading since it implies a complete lack of food. In the context of food systems, it more specifically references a lack of *healthy* foods such as fresh

fruits and vegetables (Wrigley et al. 2002, USDA 2009). Individuals classified as living in food deserts typically don't lack access to food of all types but lack reasonable access to healthy foods. Thus, they are believed to be more likely to substitute less healthy, more widely available alternatives in their diets (USDA 2009).

The use of the term 'food desert' originated from the public policy sector in England during the 1990's (Wrigley 2002). Although the term was new, the topic of inequalities in access to food had been addressed in studies by governmental organizations since the 1960's, and likely before (Wrigley 2002). "Food desert" is a metaphor that is easy to conceptualize in general, but one that has proved difficult to define specifically. Broadly speaking, a food desert is an area which lacks, relative to other parts of a region (generally a city), access to an adequate food supply (Clark et al. 2002). The USDA defines a food desert as an "area in the United States with limited access to affordable and nutritious food, particularly such an area composed of predominantly lower income neighborhoods and communities" (USDA 2009). Furey (2001) defines a food desert as an area "where people do not have easy access to healthy, fresh foods, particularly if they are poor and have limited mobility". While these and other definitions vary, they show that a food desert is usually not simply a place that has low access to food but one which is also impacted by some other measures of deprivation such as low-income and poor accessibility within the transportation system.

The creation of the socio-economic environment food deserts describe is associated with the changing spatial distribution of food retailers which has led to changing levels of access throughout urban regions. Beginning in the 1950's and 1960's, U.S. supermarkets, primarily located in urban centers, began to adjust their retail

locations to ensure their market areas effectively served the changing distribution of consumer demand. At the same time, traditional grocers became faced with strong competition from larger supermarkets, often subsequently resulting in their closure (Hawkes 2008). Thus, many areas once served by food retailers have been experiencing a decrease in access to food. Stores locating in the peripheries of urban areas corresponded to an increased focus by stores on consumers with automobiles rather than those using other forms of transportation (Thomas 2010). The supermarket has subsequently been surpassed by the rise of supercenters that market food and non-food items at a single location (Thomas 2010). This trend reached a peak in the 1980's and 90's with the construction of many large supercenter stores, such as Wal-Mart, whose numbers increased from 68 to 888 between 1994 and 2001 (Hawkes 2008). The geographic footprint of these supercenters almost necessitates their location in the fringes of urban areas given their appetite for space (Thomas 2010). A similar trend has also been observed in Europe and the United Kingdom (UK) where supermarket chain stores have become more prevalent at the expense of the smaller corner store (Furey 2001, Wrigley et al. 2002, Shaw 2006).

Before much in-depth study had occurred, it was assumed that food deserts would be found primarily in low income, minority neighborhoods in the inner-city (Wrigley 2002). The belief was that poor access contributed to poor diets which in turn, contributed to health problems. As more research on access to food in urban environments was conducted, the results began to provide evidence contrary to the original hypotheses, showing that many of the lower income neighborhoods did not lack access to reasonably priced, reasonably stocked food stores (Wrigley 2002). Subsequent

studies have also provided further conflicting evidence. In one case, Apparicio et al. (2007) did not find any firm evidence supporting the existence of food deserts in Canada.

While diet has been shown to influence health, the food desert concept also implies that lower access to healthy foods translates to lower consumption of those foods. However, "it is important to note…that differences in the retail food environment do not always represent disparities" (Ford and Dzewaltowski 2008). Disparities in this case refer to differences significant enough to impact healthy diets (ibid.). A number of studies have examined the connection between health or diet and access to foods. Much of the research done outside of the U.S. has been inconclusive in establishing an association between access to healthy foods and diet or health. A study in the UK looking at the relationship between fruit and vegetable consumption concluded that there was no significant association between price, availability, and low socio-economic status with the quantity of fruits and vegetables the participants in the study reported (Pearson et al. 2005). A study on communities in New Zealand also did not find an association between proximity to fast-food restaurants and obesity; rather that individuals were more likely to be obese the further away they were from fast-food restaurants (Pearce et al. 2008). Further, in a review of the literature on food access White (2006) found that studies in the UK have shown a weak relationship between access to food and consumption of fruits and vegetables.

However, studies on communities in the U.S. have shown a much higher association between health and diet and access to healthy food. In particular, evidence of a positive association between lower access and an increased risk of cardiovascular problems (Diez Roux et al. 2001; Morland et al. 2002), insulin resistance (which can be a

precursor to diabetes 2) (Auchincloss et al. 2008), diet quality of pregnant women (Laraia et al. 2004) and obesity (Morland et al. 2006, Ford and Dzewaltowski 2008) has been reported. However, these associations are not determinative since diet and health are related to a host of other factors including personal eating preferences, culture, income, and dietary knowledge among others (White 2007, USDA 2009).

2.3 Access

Access is a concept central to the definition of food deserts. Many different ways of measuring access exist and differences in measurement can potentially have significant ramifications on the results. Access is generally defined as the opportunity (or cost) associated with gaining entry into a system (Matisziw et al. 2010). With respect to food resources, McEntee and Agyeman (2010) review three ways in which access can be conceptualized: a) geographic b) economic and c) informational. Similarly, other taxonomies for understanding access have been proposed such as a) ability b) assets and c) attitude (Shaw 2006). The USDA (2009) strategy for delineating food deserts incorporates the first two of these types of access in its analysis. Their approach first considers distance from supermarkets (geographic/ability), and then focuses on those distant populations that are categorized as low-income as well. In addition to this, data on the variations in travel time to supermarkets is also presented, which Shaw (2006) considers a form of assets. The USDA (2009) also recognizes that social attitudes can play a role in how individuals perceive access to food and how consumer knowledge can impact the ability to prepare food and eat nutritionally balanced meals even if physical access is high.

Many food studies consider only supermarkets under the assumption that smaller stores lack the selection necessary for a nutritious diet (McEntee et al. 2010). Both Short (2007) and Raja (2008) claim that a network of small stores can act together to provide an adequate availability of necessary items at competitive prices. Short (2007) also claims that the standard market baskets don't take into account the varying diets of various minority groups. Therefore studies may claim inadequate access when a sufficient selection of nutritious food items may indeed exist. Pearson's (2005) study contended that it was attitude rather than access that led to poor diets in his study area. Cummins and Macintyre (2002) stated that many of the studies cited by other studies for support of their arguments are only exploratory or pilot projects and thus are insufficient for drawing conclusions about food access. However, as mentioned previously, there is a growing acknowledgement that food deserts do appear to exist in many urban areas (Apparicio 2007, Beaulac et al. 2009, USDA 2009).

Some researchers posit that it is not low access to healthy foods but rather high access to healthy foods that most significantly influences consumption. This concept is sometimes referred to as "food swamps", which are areas that are saturated with a variety of unhealthy food options such as fast food restaurants, convenience, and liquor stores. These outlets offer many energy dense and processed foods that are considered to be unhealthy. (Rose et al. 2009, USDA 2009).

2.4 Economic Access

Economic access to food refers to the retail cost incurred by the consumer. This cost is a primary consideration for the consumer since the total cost of a purchase must fit

within their budgetary limitations. This aspect of access is especially important since higher prices can influence consumers to select lower priced alternatives. In many cases though, lower priced alternatives include many less nutritious options (USDA 2009). Another strategy for seeking alternatives to higher priced foods is to consider multiple sources for a product and to track pricing and special offers (i.e. coupons) over time. However, such activities can be considered resource intensive, especially for working households (USDA 2009). Yet another strategy is to seek out programs and services designed to facilitate access to healthy foods by subsidizing cost to the consumer, such as the meals-on-wheels, WIC, food stamps, etc.

Studies of economic access are usually done by surveying stores using a market basket approach (Chung and Meyers 1999; Hendrickson et al. 2004; Short 2007; Sharkey and Horel 2009; Rose et al. 2009). A market basket is a selection of food items that are considered basic necessities that are generally available at grocery stores, thus permitting their cost to be compared among a set of stores. Food store assessments using market baskets are usually only feasible in smaller local assessments as they would be very difficult to conduct on a larger scale (i.e. national). However the USDA Thrifty Food Plan (TFP) (USDA 2002) is commonly used for the market basket (Chung and Meyers 1999; Rose et al. 2009). The TFP allows for comparison between different studies and allows the selection of goods to be based on the USDA's (2002) determination of essential goods, rather than the reasoning of the researcher. However, some studies have used different market baskets that they deemed more appropriate given the characteristics of their study area (Short et al. 2007; Raja et al. 2008).

Market basket surveys provide not only an assessment of the availability of food items but the cost of purchasing them. This measure of monetary cost is important to assess how affordable each store is relative to other stores in the area. Such a measure can reveal that an area that apparently has access in terms of geographic distance to a food store may in fact have poor economic access due to the high cost of shopping there. In studies, such as USDA (2009), that consider the socioeconomic status of individuals in addition to physical distance to stores a price assessment is valuable in categorizing the costs faced by consumers at different locations. The USDA's study is national and didn't include market basket assessments because of the large number of stores it mapped. Instead it assessed socioeconomic status based on census information only. In a local study such as is done in this thesis, a price assessment can shed light further light on the economic challenges faced by individuals.

2.5 Informational Access

Informational access entails "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". Also called attitudinal access by Shaw (2006), this type of access is related to characteristics beyond the physical and economic constraints that influence consumer shopping behavior. For example, although an individual might live in close geographical proximity to a food source and have sufficient funds to purchase healthy food, they might lack the knowledge to select foods that provide a balanced diet and/or the individuals simply do not have the skills to prepare food. Another example of how individual behavior can influence diet is if an individual is accustomed to dining at restaurants

instead of preparing meals at home. This group of personal preferences, dietary knowledge, perceptions other factors is not usually addressed directly in food desert studies but is included by some to address the many factors besides physical and economic reasons that affect diet.

2.6 Geographic Access

Geographic access relates to the cost incurred in the journey to obtain food. In this sense, access cost can be viewed as a function of the time, distance, and/or effort incurred in shopping. Thus, cost of access is very much tied to the modal options for transportation available to a consumer, their ability to exploit these options, as well as the supporting transportation infrastructure. For instance, the availability of an automobile and a good road network can effectively extend a consumer's access in terms of more efficient travel and increasing their number of viable alternative stores. Similarly, good access to public transportation can facilitate access to sources of food given cost effective, frequent service is provided to potential stores from the customer's entry point. In some instances though, good access to a transportation system (i.e. proximity to a bus stop) does not imply good access to food as potential sources may involve a considerable cost to reach given poor accessibility of the entry location with respect to the transit network (USDA 2009).

Distance metrics are a common way of approximating the cost of moving between two locations. That is, the cost of moving between two locations is assumed to increase as distance or geographical separation between two locations increases. Different distance metrics are available to suit a range of assumptions on how movement between

locations may be constrained. In the simplest case, Euclidean or straight-line distance between two points can be used to approximate cost of movement. In geographical analysis, Euclidean distance represents a movement that is not constrained by any features in the landscape, including the curvature of the Earth.

While these assumptions are fairly limiting as applied to the movement of people, Euclidean distance is widely applied given it can be readily computed between any pair of coordinates. For example, Wrigley et al. (2002) use Euclidean distance to approximate an area's access to supermarkets. While Euclidean distance is a common proxy for the cost of movement over space, it often underestimates cost in cases where other factors (i.e. infrastructure, terrain, traffic, crime, etc.) influence the cost of movement.

Other distance metrics have been devised to take into account constraints to movement. In cases where the curvature of the Earth is known to affect movement, the Great Circle distance can be used. Also, in instances where movement is known to be constrained to two perpendicular straight line steps, the Manhattan distance can be applied (Church and Murray 2009). If movement is known to be constrained to take place only between contiguous sets of features in the landscape (i.e. infrastructure) network distance can be used. Network distance measures distance along a transportation network, such as roads. For example, in an evaluation of access to commercial passenger air transportation, Matisziw and Grubesic (2010) consider access a function of the cost incurred by an individual in driving from a home location to an airport. Smoyer-Tomic et al. (2006) and Larsen & Gilliland (2008) use network distance to assess access to supermarkets. Network distance also is easily adjusted to reflect other types of costs

encountered along portions of the network, such as speed limits and capacities associated with different road types.

After a geographic access metric and has been selected, many approaches to evaluating access involve setting a distance/cost standard within which access is considered available and beyond which access does not exist. Recent approaches in the food access literature have tended to focus on only one or a few access standards. Often these access standards are based on public policy decisions about at which distance a person has poor access for their mode of travel (e.g. car, by foot etc.). These access standards vary considerably depending on their source. For example, the USDA recommends an access distance standard of 0.5 mile when considering pedestrian travel and 1.0 mile when considering travel by car. Whereas, applications in Canada and the UK commonly advocate a 0.5 kilometer standard for pedestrian travel and 1.0 kilometer for car travel. Table 1 provides a summary of some of the different representations of geographic assess that have been applied in the food desert literature. One potential drawback of assuming an access standard is that the researcher simply assumes a reasonable distance that an individual can travel to reach a store. This is a questionable assumption since it assumes that the ability of individuals to access stores is equal instead of varying for different segments of the population. Applying a single, or a few, standards of access for an entire population is possibly constricting in this regard. It might be more fruitful to avoid making the assumption of the distance at which an individual can access a store.

Study	Setting	Measure of access	Access standard	Spatial unit of analysis
Apparicio et al. (2007)	Urban	closest supermarket; number of supermarkets within 1,000 m; Avg. distance to closest 3 supermarkets	Network	U.S. Census tract
Bader et al. (2010)	Urban	800 meters (~.5 mi)walkable; 1600 meters (~1 mi) drivable	Network	Census tract
Boone-Heinonen et al. (2011)	Urban	1,3,5,8.05 km	Euclidean	survey respondent address
Chung and Myers Jr. (1999)	Urban	Stores within same ZIP code	Containment	ZIP code
Clarke et al. (2002)	Urban	500 meters	Euclidean	Researcher defined neighborhood
Donkin et al. (1999)	Urban	2 km, 500 m	Euclidean	wards, postcode
Eckert and Shetty (2011)	Urban	1 mi, 2 mi	Network	block group
Freedman and Bell (2009)	Urban	1 mi, 2 mi	Euclidean	Researcher defined neighborhood
Hubley (2011)	Rural	10 mi	Euclidean	Census block
Kirkpatrick and Tarasuk (2010)	Urban	1 km, 2 km	Euclidean)	households
Larsen and Gilliland (2008)	Urban	500 meters; 1000 meters	Network	Census tract & blocks for pop
McEntee and Agyeman(2010)	Rural	10 mi rural	Network	residential units aggregated to
Russell and Heidkamp (2011)	Urban	1/4;1/2;1 mile	Network	block group
Schafft et al. (2009)	Rural	10 mi	Network	centroids of ZIP codes aggregated to school districts

Shaw (2006)	Urban/Rural	access if supermarket w/I grid square	N/A	250x250 m grid urban, 500 x 500 m grid rural
Short et al. (2007)	Urban	supermarkets w/i neighborhood	N/A	Neighborhood
Smoyer-Tomic et al. (2006)	Urban	1 km	Network	postal code centroids
Wrigley et al. (2002)	Urban	500 meters	Euclidean	Researcher defined neighborhood

Table 1. Measures of geographic access to food

Just as many different measurement schemes have been considered in the assessment of access to food, many different representations of the demand for food have also been used (Table 1). These representations of demand have ranged from the individual level (i.e. Boone-Heinonen 2011) to highly aggregated forms such as U.S. Census tracts or U.S. ZIP codes (Chung and Myers 1999, Schafft 2009, Bader et al. 2010). They have also ranged from uniform spatial representations (i.e. grid (Shaw 2006, USDA 2009)) to very irregular and inconsistent topologies (i.e. neighborhood (Clarke 2002, Short 2007)).

Census tracts, block-groups, and blocks are the areal units used by the U.S. Census to aggregate individuals. These divisions are frequently used in studies. Tracts are the largest units, with an average size of 4,000 people. Block Groups have between 600 and 3,000 people and Blocks are the smallest areal unit used by the Census Bureau. (U.S. Census Bureau 2011).

While differences in the spatial representation of demand for food are inevitable, it is well-known in the geographical literature that different areal representations can give rise to an analytical bias known as the modifiable areal unit problem (MAUP) or,

alternatively, the ecological fallacy (Openshaw 1984a,b). The modifiable areal unit problem refers to the fact that analysis results can vary depending on the spatial unit (i.e. polygon) used to summarize geographical attributes in a study. In the case of access to food, the decision to use Census tracts, Census blocks, or ZIP codes will influence the geographic relationships between stores and the populations summarized by the areal representations, potentially resulting in conflicting measures of access. This is a result of aggregating complex phenomena such as population into a single areal unit, masking any variations in the underlying spatial distribution of the attributes of the unit. While difficult or impossible to completely eliminate, the effects of the MAUP can somewhat be mitigated through the use of more disaggregate areal units (Church and Murray 2009). To illustrate this, consider the entire population of a large area (Columbia, MO for example) represented in aggregate. Then imagine a study of access based on the distance between that single area (Columbia) and another location (a store, for example) was less than or greater than a given threshold (say, one mile). In this extreme case, the entire population of the study area would either have access or not have access regardless of if certain parts of the area were further away than the given threshold.

Taking things to the other end of the spectrum, if the location of each and every person in the study area was precisely located to the exact point where they lived then a very precise measure of access could be obtained since there would be no aggregation of the population into areal units (or each person could essentially be a single areal unit representing a single person). In reality the areal units most commonly available for analysis lie between these two extremes.

Levels of geographic access can vary significantly throughout a region. Aside from some locations requiring more travel to gain access, locations can vary in the number of alternatives that are available for access. For example, the service areas of facilities such as stores often coincide, providing some areas with access to multiple stores. In analyses that only look at whether a demand location has access in a discrete fashion (either has access or does not) differentials in the extent to which access is available are lost. For example, if an area only has access to one store then it is more vulnerable to the loss of that store or an increase in prices than an area that has effective access to a number of stores. Further, relatively higher densities of a store type could be a signal of the level of competition among that type of store and may signal lower prices. This method of measuring access is used in the health care field and sometimes referred to as a *container* approach (Higgs 2004). It is also commonly applied in food access studies (Apparicio et al. 2007, Larsen and Gilliland 2008).

2.8 The USDA Food Desert Study

The USDA study is important because of its influence on public policy in the United States. There are actually two variations of the USDA's measurement of food deserts. In the initial report, "Access to Affordable and Nutritious Food: Measuring and Understanding Food Deserts and Their Consequences" (2009), the USDA used a 1 kilometer square grid to measure where individuals lived and how far away they were from stores. When the food desert locator map was created in 2011 it aggregated its measure of access at the census tract level because census tracts are more commonly used, can be uniquely identified, and organizations and communities that are likely to apply for HFFI funding are more familiar with them (USDA 2011a). In both cases

Euclidean distance was used to measure distance to a supermarket (USDA 2009, USDA 2011a)

USDA (2009) required food stores to have annual sales of or greater than $2 million to qualify as a source of food in its study. The set of stores considered were obtained from a Nielsen company called Trade Dimensions TDLinx, the USDA's own list of Supplemental Nutrition Assistance Program (SNAP), and some additional sources such as company websites and other online sources for investigation and verification of annual sales and types of food sold (USDA 2009). In total, the USDA list of supermarkets or supercenters with over $2 million in annual sales contained 40,108 stores. The store data from TDLinx and SNAP were both from 2006 (USDA 2009)

Other databases of potential stores exist and have been too been considered. For instance, Kowaleski-Jones et al. (2009) examined store databases from Dun & Bradstreet, InfoUSA, and a Utah State database of stores and found that approximately one third of the stores listed in any database were not found in the others. This raises concerns about the completeness of the USDA (2009) list of stores. The requirement of $2 million in annual sales may also ignore many stores that do sell fresh produce.

2.9 Summary of Methodological Limitations

While the concept of food deserts has been explored in numerous studies, it has drawn criticism in the representations of access upon which the studies are premised (Pearson et al. 2005, USDA 2009, Raja et al. 2009). These criticisms are primarily directed at the manner in which proximity to food is measured, the criteria delineating a 'food desert', as well as the set of goods and services that are 'essential' in promoting

good health (Short 2007). At the core of these debates is the tendency of many approaches to provide a single metric that defines populations or areas that have access to a service. While such approaches may be suitable for providing a basic guideline, the ability of individuals to access food can vary considerably even at very small scales of analysis. Thus, over generalizations of access risk misrepresenting the abilities of individuals. The following section on methodology will attempt to address these drawbacks.

CHAPTER 3: METHODS

Some studies of food access use focus groups and surveys to gain an understanding of consumer behavior (Whelan et al. 2002, Hendrickson et al. 2006, Freedman and Bell 2009). While those behavioral characteristics provide valuable insight on the dietary choices of an individual, the focus of this study is on the geographic and monetary costs facing consumers as they move throughout the built environment. Similar to other studies, this study used a geographic information system (GIS) to build a representational model of the transportation component of access. A GIS facilitates the organization of data into layers that can be geographically juxtaposed and queried with respect to one another. The key components of this analysis framework are a representation of the transportation system assumed to support urban movement, some areal unit of analysis representing the geographic organization of demand (i.e. population or areas) of the region for food, as well as the location of potential sources of retail food (i.e. supermarkets, community gardens, convenience stores etc.).

In an attempt to avoid premising an area's level of access on a particular socio-economic profile of that area, a socio-economic agnostic approach for evaluating locational access is adopted in this paper. That is, access to sources of food is considered for every location within an urban region, irrespective of the characteristics of resident populations. This approach is taken for several reasons. First, premising locational access on a subset or aggregation of a resident population can risk falsely representing the needs of other groups. Second, the distribution and composition of urban populations and their characteristics is always changing. Therefore, it is important to provide a

representation of access that is more robust to these population dynamics. To better account for these issues, the developed methodology characterizes access over a range of distance criteria for each location instead of over a subset of populations for a single distance range. This continuous representation of access facilitates a more complete understanding of what level of access different populations experience.

3.1 Systematic Analysis of Geographic Access

As discussed in Chapter 2, many different distance-based access standards have been proposed and utilized in studies examining access to food. These discrete access thresholds are rather myopic given that they assume access to be available within the set access standard and not available outside that standard. However, such all-or-nothing approaches for determining access ignite much debate as evidenced by the food desert literature. To better address this deficiency and to gain better insight on how variations in urban structure can give rise to variations in access, a systematic approach for evaluating access is proposed.

Given a set of areal units with demand for access to food (indexed $i \in I$), a set of food source (i.e. stores) locations (indexed $j \in J$), the cost of moving between demand area i and store j (c_{ij}), an access standard (S) reflecting the maximum transportation cost that can be incurred while still maintaining effective access, the set of stores providing access to demand area i $N_i = j \mid c_{ij} \leq S$. The presence of access at any location i can be denoted as a binary/integer variable where $X_{ij}^S = \begin{cases} 1 \text{ if } c_{ij} \leq S \\ 0 \text{ otherwise} \end{cases}$. Access at location i to food at a specified standard S $\left(A_i^S\right)$ can then be viewed in a number of ways.

1. As a binary/integer construct (Clarke 2002, Smoyer-Tomic 2006, Apparicio 2007, Larsen and Gilliland 2008, Schaft 2009, Freedman 2009, Bader 2010, Russell 2011, Eckert 2011, Boone-Heinonen 2011):

$$A_i^S = \begin{cases} 1 \text{ if } \sum_{j \in N_i} X_{ij}^S \geq 1 \\ 0 \text{ otherwise} \end{cases} \quad (1)$$

2. As weighted by the number of stores within a stated access standard (Chung and Myers 1999, Shaw 2006, Apparicio 2007, Larsen and Gilliland 2008):

$$A_i^S = \sum_{j \in N_i} X_{ij}^S \quad (2)$$

3. As a weighted combination of number of stores and distance (Apparicio 2007):

$$A_i^S = \sum_{j \in N_i} c_{ij} X_{ij}^S \quad (3)$$

In this thesis, the second approach is selected since it not only provides an assessment of whether or not an area has access, but also provides a measure of the opportunity for access an area has relative to other locations.

Given that there is much debate about what access standard (*S*) is appropriate for a region or population subgroup, a systematic approach where *S* is varied incrementally to better account for the effect of urban structure on level of access. For example, elderly populations may perceive access very differently than a healthy young adult.

3.2. Economic Access

Aside from geographic considerations, economic constraints are also known to be a barrier to access to food. As discussed in Chapter 2, economic access can be analyzed through store surveys using a market basket approach. The USDA Thrifty Food Plan

(2002) is adopted in this thesis to help augment the analysis of geographic access. This approach was chosen because it is a commonly used market basket in other studies and is based on the USDA's recommended diet (USDA TFP 2007). The TFP market basket methodology involves a surveying of each store in which the price, size, brand, and availability of each item on the list is recorded. Therefore, a market basket survey of all supermarkets for an urban area as well a sampling of smaller groceries and convenience stores provides a reasonable depiction of variations in the cost of food at stores in the study area. After the stores have been surveyed, the total price and availability of food at each store can be inferred. Additionally, by dividing the total cost by the number of items the store had in stock an average price per food item at each store can be calculated as another measure of the cost of shopping at any given location.

3.3 GIS Implementation

The measurement of geographic access to food was implemented as a Python script that makes use of the analytical capabilities of ArcGIS, a commercial geographic information system. The necessary input to the GIS is a representation of road structure, store locations, and an areal representation of demand for food (i.e. population, tabulation areas, etc.). In particular, the following procedures are automated for each access standard *S*:

1) Service areas based on network distance are created for each store using Esri's Network Analyst. Figure 1 illustrates network-based service area for a single store.

2) A spatial join is then conducted between the store service areas and the demand areas to determine the extent to which demand areas and population have access at that particular *S*. That is, a general summary of the number of areal units and their population served by stores within a region is provided. Table 2 shows some typical summary info of the information collected for each service standard.
3) The number of stores to which each demand area has access at each distance standard (equation (2) in section 3.1) is also reported in order to provide a more detailed summary of how the level of access is impacted given a change to the standard (*S*). Figure 1 shows a small example of a few services areas around a location.

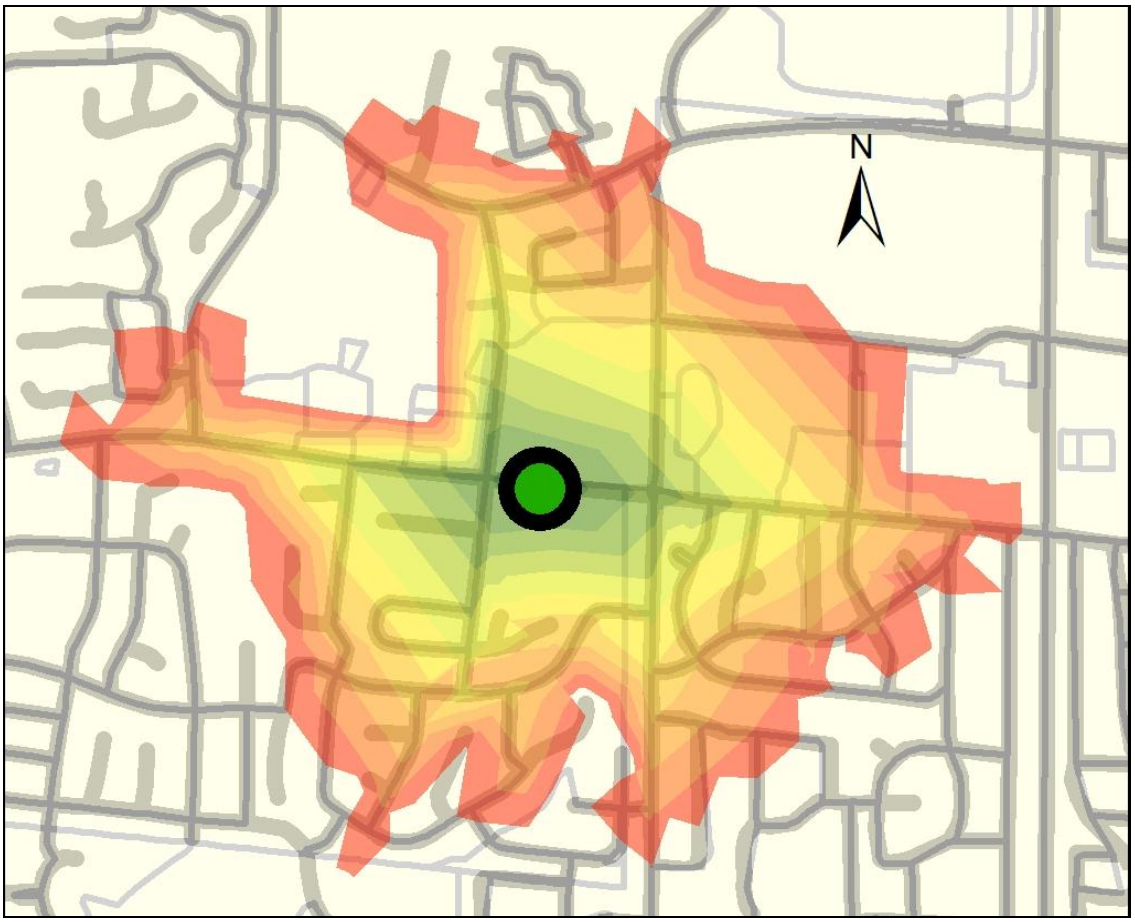

Figure 1. Store location and area served within 100 meters -1,000 meters.

Service standard (meters)	Total population	Total zones(Census blocks)	Population served	Percent of total population served	Number of zones Served	Percent of zones served
100	108,498	2,698	55	0.05%	2	0.07%
200	108,498	2,698	194	0.18%	5	0.19%
300	108,498	2,698	623	0.57%	11	0.41%
400	108,498	2,698	1,095	1.01%	20	0.74%
500	108,498	2,698	1,153	1.06%	25	0.93%
600	108,498	2,698	1,562	1.44%	31	1.15%
700	108,498	2,698	2,471	2.28%	39	1.45%
800	108,498	2,698	3,436	3.17%	43	1.59%
900	108,498	2,698	4,065	3.75%	52	1.93%
1,000	108,498	2,698	4,542	4.19%	65	2.41%

Table 2. Example summary of access for each service standard

The value of this iterative approach is that it allows one to see how access changes throughout a range of service standards instead of a single measure of access. Doing so provides insight into the impact improving transport accessibility would have on areas of the community.

Esri's Network Analyst is used to measure the network distances from each store location (represented as a point), creating a service area polygon representing the areas that could have access to that store for a particular access standard. In this thesis, areas that intersect a service area are considered to have coverage while those areas outside any service area are considered not to have access. Many studies consider a geographical areal unit to have access only a single representative point within that area (usually a centroid) is within the access standard. However, doing so assumes that the point adequately represents the location of population, something that is usually very unrealistic.

By tracking the demand areas and their characteristics (i.e. populations) identified as having access at each access standard evaluated, a more detailed representation of geographical access to retail food for an urban area can be generated. This is opposed to other studies that use only a few access standards at most to measure access (i.e. Table 1). In those studies a distance at which a person has access is not typically varied to account for error/uncertainty in the measurement method or differing characteristics of the urban form that may influence access. This study does not impose a single discrete measure of access but rather returns a more continuous rendering of how it changes in response to different access standards.

CHAPTER 4: ACCESS TO FOOD IN COLUMBIA, MO

4.1 Study Area

The methodology outlined in Chapter 3 is applied to assess geographic access to retail food in the town of Columbia, Missouri. Columbia is a mid-sized college town of approximately 110,000 people (US Census 2010), served by 16 supermarkets as well as a range of convenience and specialty food stores. The USDA Food Desert Locator map (2010) identified three census tracts in Columbia as food deserts according to their criteria of being more than 1 mile away from a supermarket and having 20 percent or greater levels of poverty.

4.2 Data

A 2010 TIGER/Line roads Shapefile is used to represent the transportation infrastructure and possibilities for movement among locations in the city. The location of food retailers in Columbia was obtained from the Center for Applied Research and Environmental Systems (CARES) in 2011. These locations are reported as point features representing different types of retail locations (16 supermarkets, 43 convenience stores, 22 community gardens, 15 liquor stores, 10 food pantries, and 97 fast food restaurants). The Census 2010 data is aggregated at the block level and provides information on the socio-economic composition of each area (i.e. population and ethnicity). Census block groups and tracts are used to compare the effect aggregating data into larger geographical units has on access to supermarkets.

2006-2010 American Community Survey (ACS) data was used to provide further demographic detail for Columbia (U.S. Census Bureau 2011). In particular, the following ACS data are used: percentage of population without vehicles, percentage of

single families, percentage of people in poverty, percentage of people at or below 200 percent poverty, and Percentage of people over 65 years old.

ACS data is reported at the tract level and is estimated at the block level (by the author) by multiplying the percentage of the Census tract population that had that characteristic by the block level populations. For example, if 20% of the population of Tract *A* did not have access to a vehicle this percentage was multiplied by the population of each Census block that fell within that tract. Therefore the ACS data is an estimate and cannot be used with the same level of confidence as the true block level data.

The retail food stores were surveyed by the author in early 2012 between January and March using the market basket approach from the 2002 USDA food assessment toolkit (USDA 2002). In particular, fifteen supermarkets (Sam's Club not included), six smaller groceries, and three convenience stores were surveyed for prices and availability of items on the market basket list. Table 7 depicts the suite of products surveyed and the information collected in the surveys.

4.3. Analysis of Access[1]

Since this study uses network-based measures of access, a network dataset is first created using Esri's Network Analyst in ArcGIS. The network dataset is built from the TIGER roads files. Once built, service areas for each store are approximated using Network Analyst in accordance with a range of access standards. The access standard is varied in 100 meter increments from a minimum of 100 meters to a maximum of 10,000 meters (the point at which all areas in Columbia had access to at least one store). Thus, 100 services areas are generated and evaluated in total.

[1] This process was coded in Python and used in ArcGIS 10

At each access standard, the characteristics of the areal units (i.e. Census blocks) found to have access are tracked (Appendix B shows the output for one file). This summary information includes percentage of population covered, percentage of city area covered, percentage of areal units covered, and a breakdown of the percentage of population and area covered by one store, two stores, up to coverage by ten stores. This latter measure helps give an idea of how many service areas overlap at different service distances.

At each access standard interval, the number of stores to which each areal unit (e.g. Census blocks, block groups, tracts) is tabulated as in equation (2). This basic procedure is conducted to assess the impact of areal representation on measurement of access to better understand the effects of the MAUP. These results are then compared with the food deserts in Columbia as identified by USDA(2011 a). To facilitate comparison with the USDA(2011 a) delineations, all blocks (or tracts) more than 1,600 meters (~1 mile) away from supermarkets having poverty rates of 20% or more are selected. A map is produced showing both the USDA designated food deserts as well as the blocks selected in this thesis using similar criteria as USDA(2009, 2011 a).

CHAPTER 5: RESULTS

Figure 2 shows all of the nested service areas ranged between 100 meters – 10,000 meters for the supermarkets in Columbia, MO. These service areas are shaded from green to red as the access standard increases. Similar service areas are built for all sets of food sources used (i.e. other stores (smaller grocers and secondary stores), community gardens, food pantries, convenience stores, liquor stores, and fast food restaurants). The visualizations of those service areas are not shown, however, the relationship between populations covered and access standards are presented in Figures 3-14 through maps displaying selected service areas (800 m, 1,600 m, 2,000 m, and 4,000 m) in Section 5.2.

Figures 3, 5, 7,9,11, and 13 provide a comparison of the percentage of the population with access to food sources when Census tracts, block groups, and blocks are used as the areal unit of demand. All of the curves converge around access distances between 4,000 and 4,500 meters. At lower access standards, the coarser areal units (i.e. tracks and block groups) indicate a greater level of access than that reported using the more disaggregate Census blocks.

Steeper curves indicate that greater numbers of people are covered with smaller increases in the service standard. Less steep portions indicate that it would take more effort (decrease in cost) to provide assess to these locations.

Figures 4,6,8,10,12 and 14 display the same information as their preceding graphs, respectively, but show the percent of the population gaining access at each access standard interval increase. Accompanying average distances and standard deviations for

the data are shown to gain a measure of the variability of the data. Another measure of sensitivity to increases and decreases in accessibility can be taken by looking at the immediate vicinity of any access standard. In the U.S. 1 mile is the most common access standard used in food desert studies so it is evaluated here by looking at the access intervals 100 meters before and after it (i.e. 1,500 meters and 1,700 meters). A higher percentage of change means that any decrease in access cost (road improvements, for example) would affect a greater percentage of the population. However it also means that any errors in measurement have a larger effect on the miscalculation of individuals with access.

Figure 16 shows the additional access gained by considering the benefit of secondary stores. For example, at the 1,600 meter level there is approximately a 20% increase in the percentage of the population with access. However, many of these stores may be costlier and offer a much smaller market basket, as indicated by store surveys.

Food Source	Percent of population within 100 meters of 1,600 m (~1 mile) access standard
Supermarkets	7.72%
Community Gardens	6.57 %
Food Pantries	4.36%
Convenience Stores	6.22 %
Liquor Stores	4.93%
Fast Food Restaurants	7.99%

Table 3 Percent of population within 100 meters of 1,600 (~1 mile) access standard

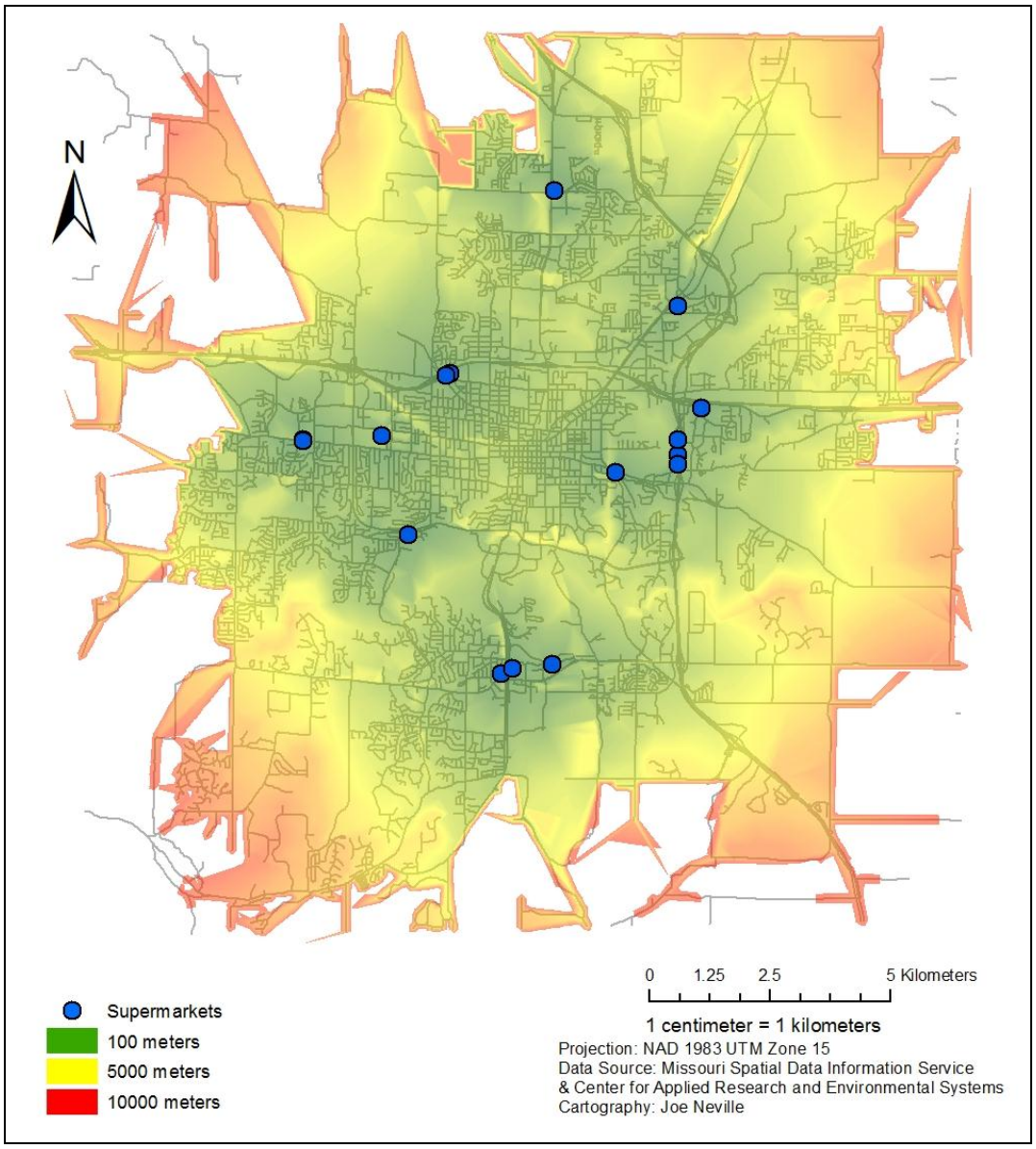

Figure 2. Nested supermarket service areas (100 meters -10,000 meters)

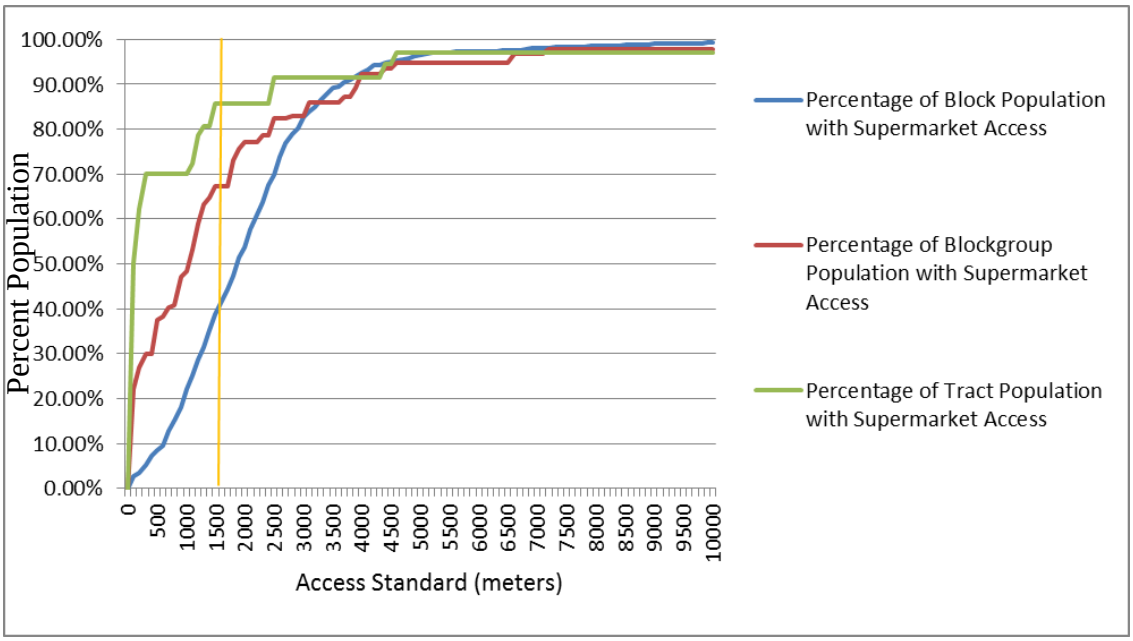

Figure 3. Supermarket access for Census tract, block group, and block-level geographies

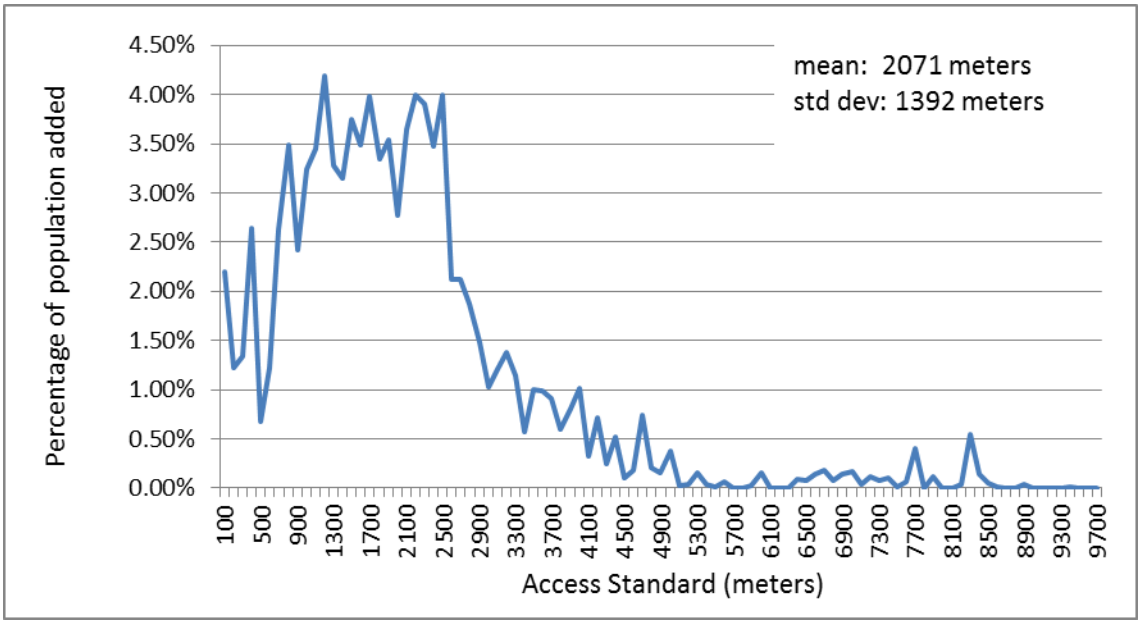

Figure 4. Percentage of Census block population with supermarket access

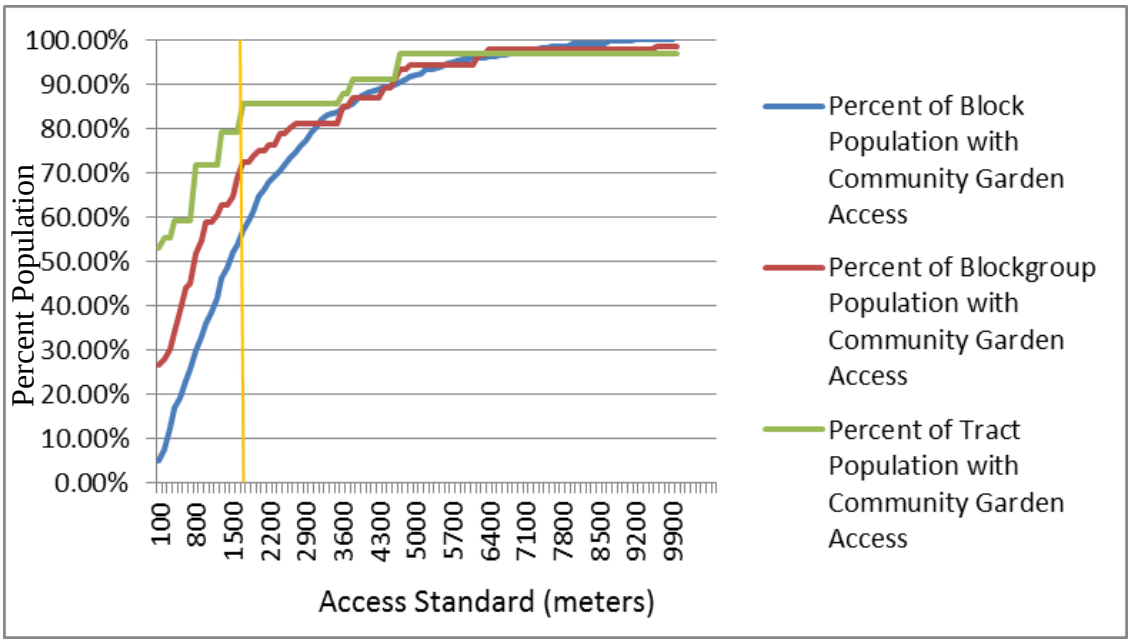

Figure 5. Community garden access for Census tract, block group, and block-level geographies

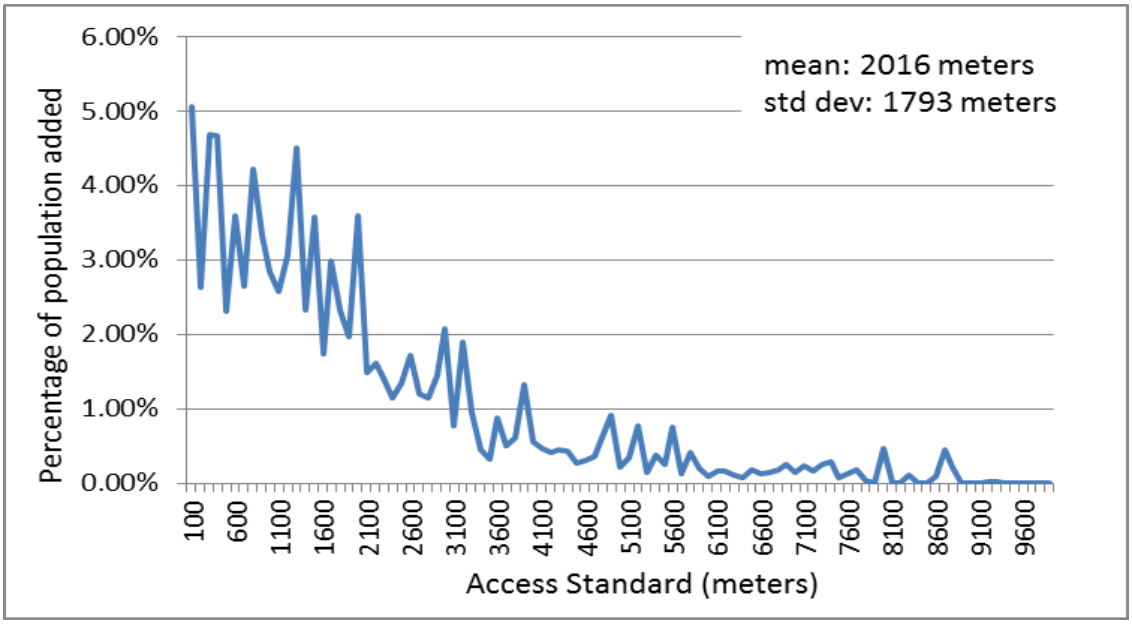

Figure 6. Percentage Census block population community gardens access

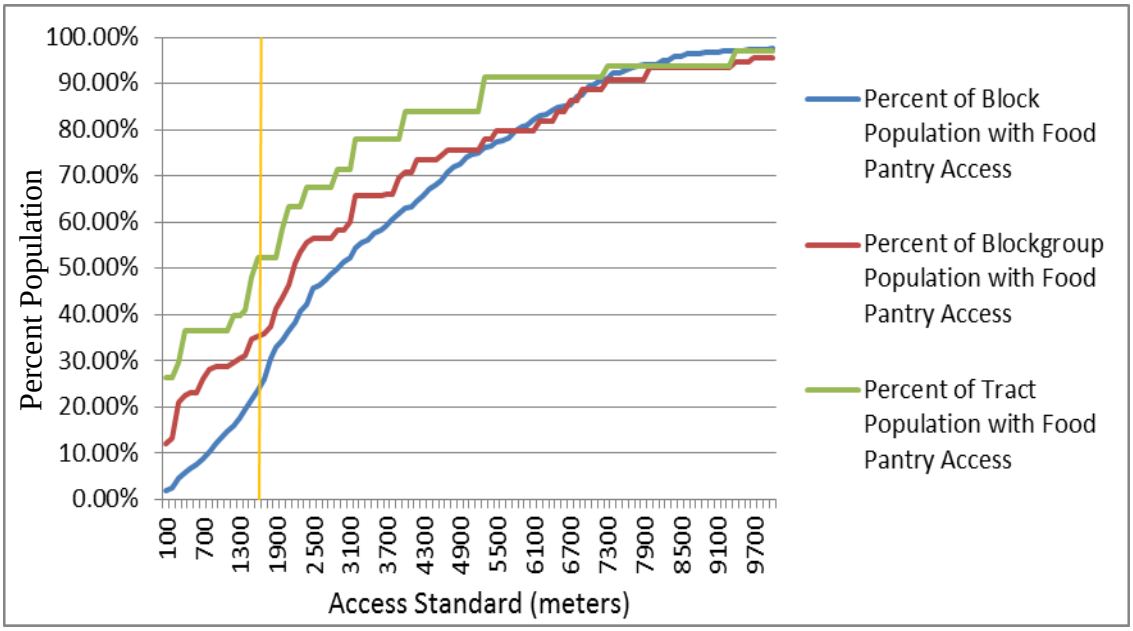

Figure 7. Food pantry access for Census tract, block group, and block-level geographies

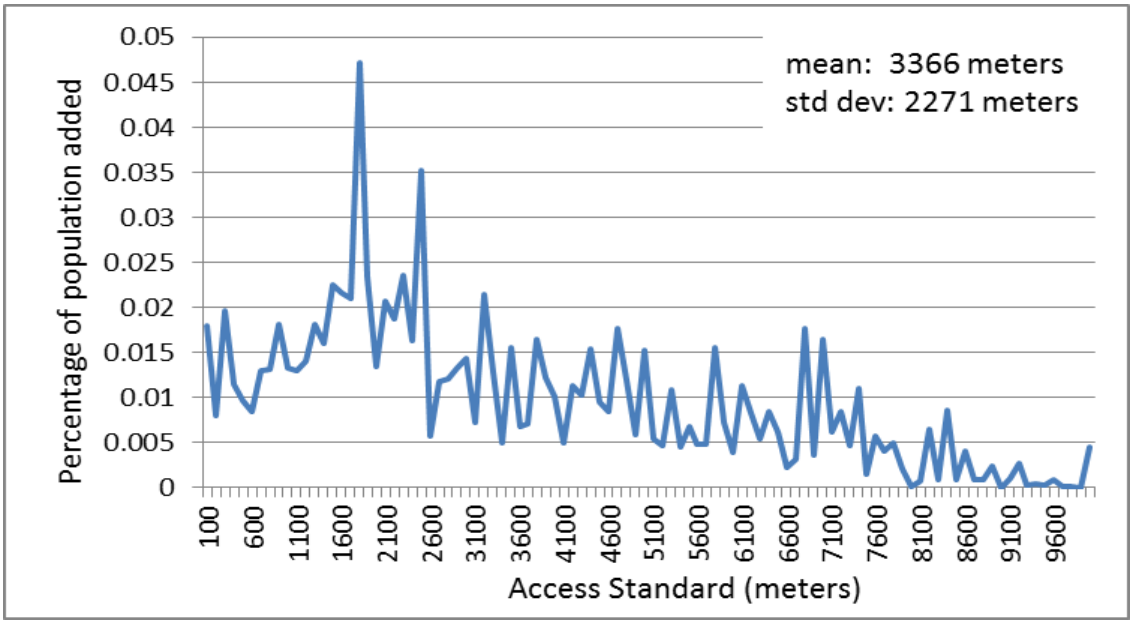

Figure 8. Percentage Census block population food pantry access

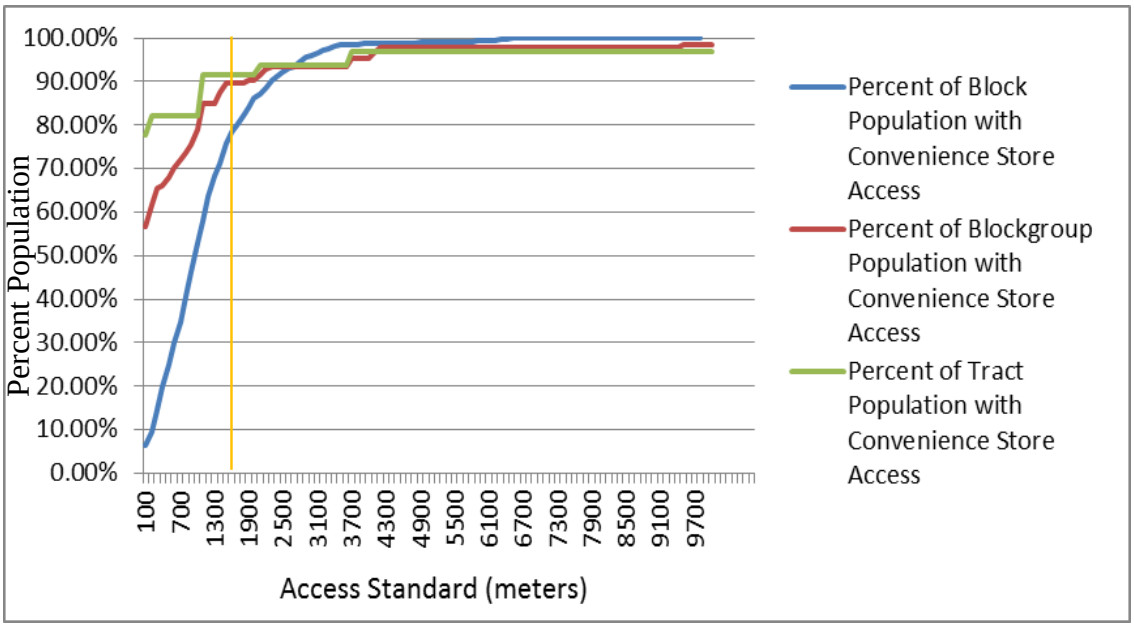

Figure 9. Convenience store access for Census tract, block group, and block-level geographies

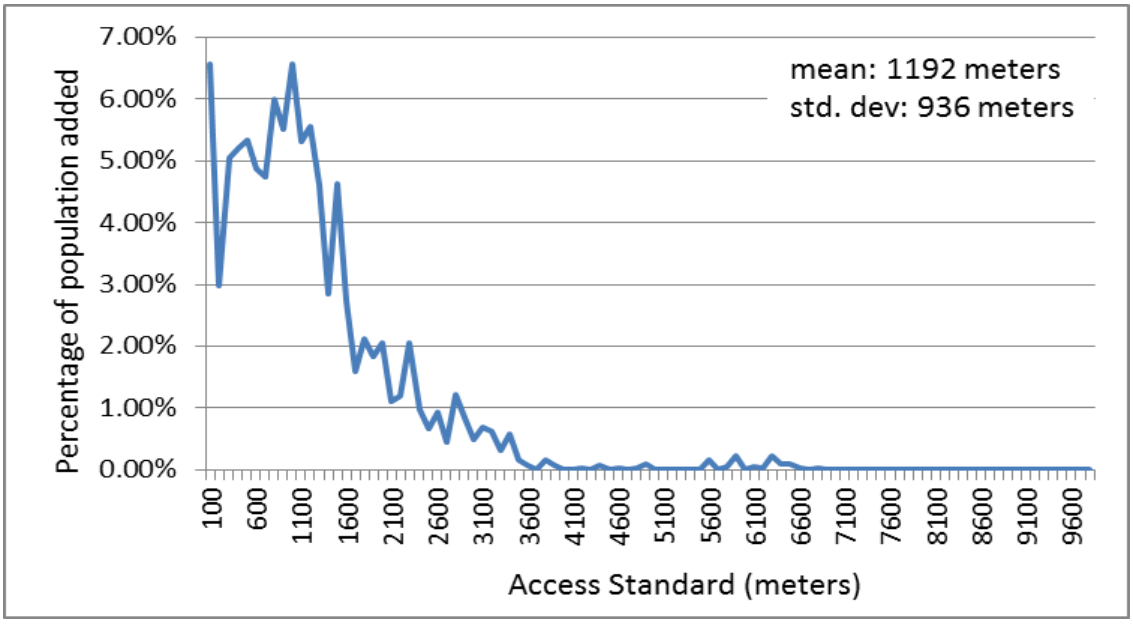

Figure 10. Percentage Census block population convenience store access

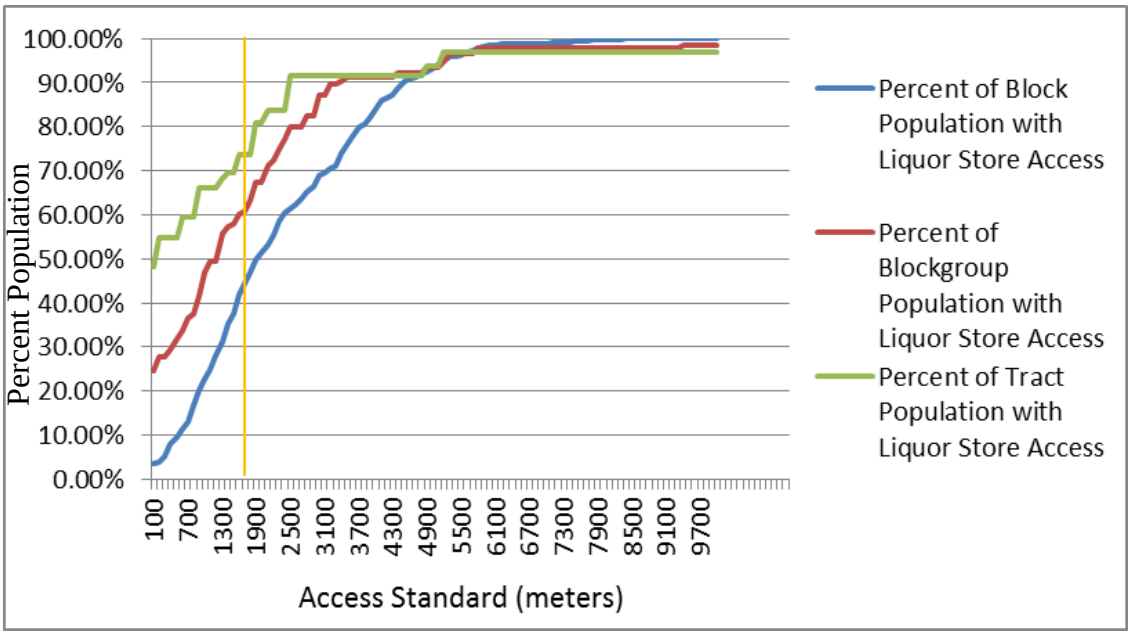

Figure 11. Liquor store access for Census tract, block group, and block-level geographies

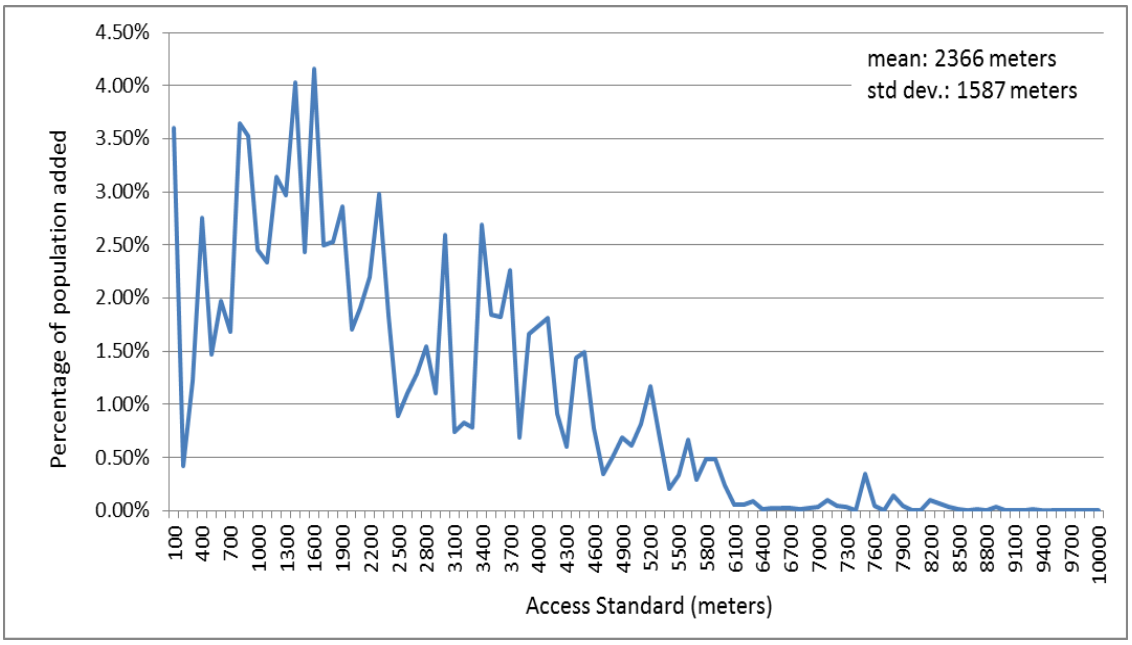

Figure 12. Percentage Census block population liquor access

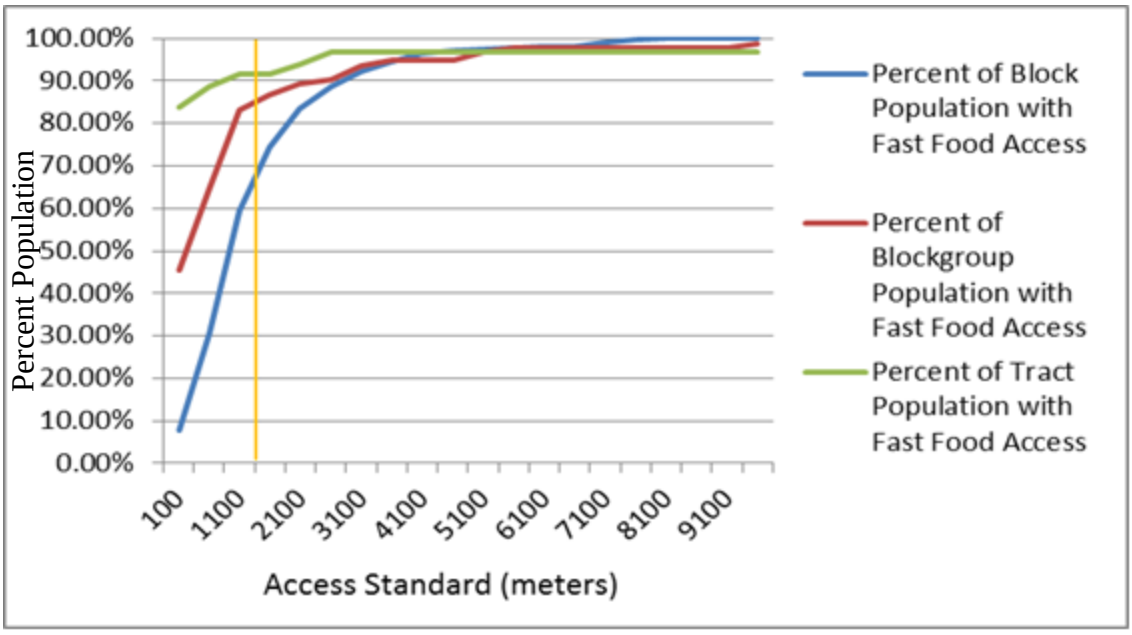

Figure 13. Fast food restaurant access for Census tract, block group, and block-level geographies

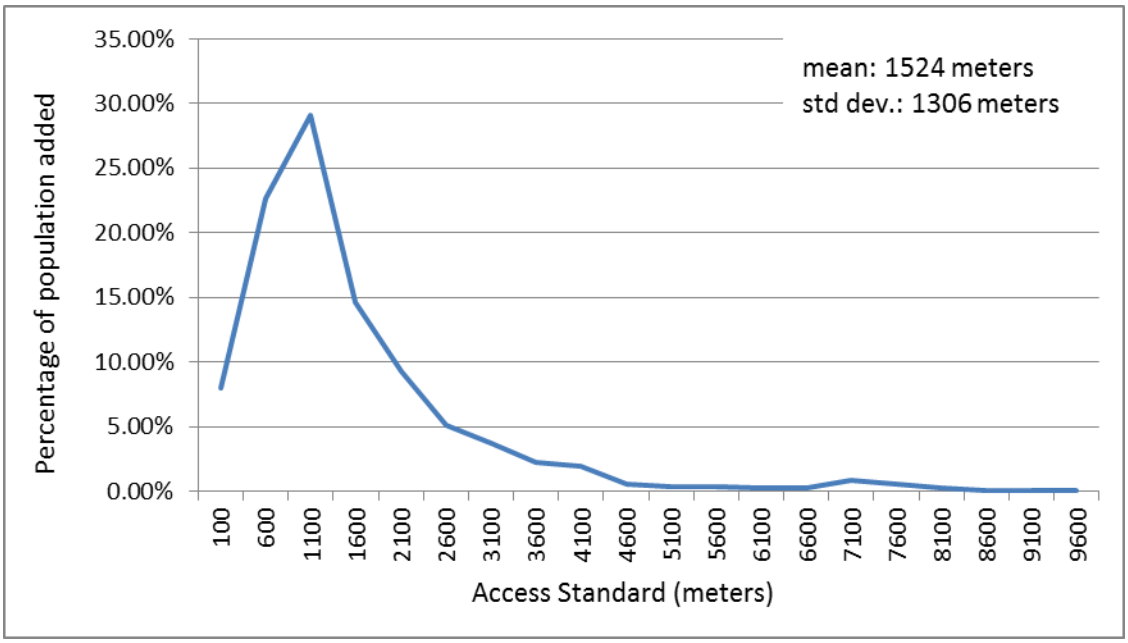

Figure 14. Percentage Census block population fast food restaurant access

		Average Distance to Food Locations (meters)					
	Population Count	**Super markets**	**Food Pantries**	**Community Gardens**	**Convenience Stores**	**Fast food**	**Liquor**
Total Population	108498	2070.86	3319.56	2015.45	1191.38	1524.38	2366.29
Total Pop Std Dev.	-	1391.76	2273.40	1793.37	936.40	1306.33	1586.57
Black	12217	1869.39	2560.15	1864.16	944.80	1305.04	1837.44
White	85740	2105.91	3445.84	2049.32	1238.43	1564.90	2443.88
Asian	5628	2104.98	3454.99	1925.14	1129.30	1514.98	2510.86
Hispanic	3729	1942.67	2865.27	1863.42	1006.52	1311.72	2117.24
200 percent poverty	46342	1949.84	3066.64	1712.00	1037.13	1327.99	2015.86
Poverty	26915	1907.71	3112.78	1576.57	999.13	1260.38	1945.64
Single Parent Families	13394	2087.77	3167.43	2129.01	1159.15	1508.50	2272.48
Senior	8822	1970.19	3455.64	2064.44	1215.04	1536.30	2638.02
No Vehicle	8038	1891.48	2436.19	1483.06	862.58	1135.21	1735.92

Table 4. Summary of average distances to food sources measured at block level

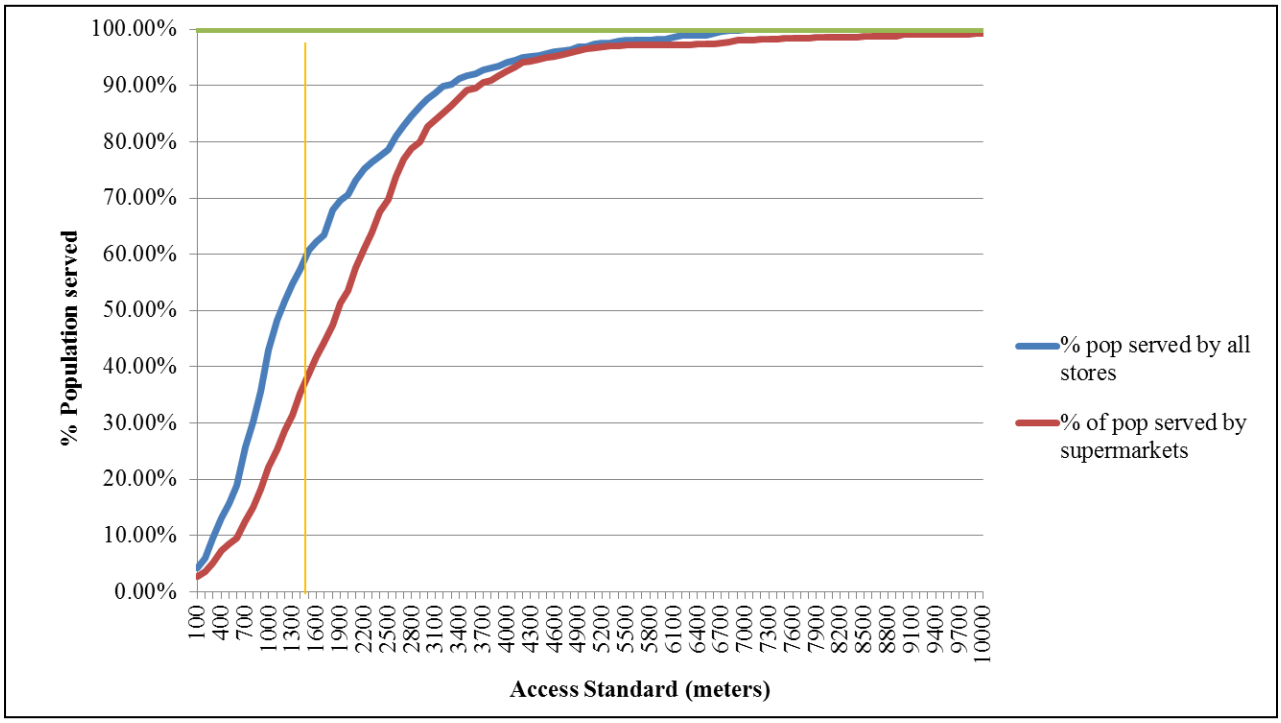

Figure 15. Comparison of added access from other stores

Table 4 shows the summary statistics of the average distance to various food sources for the entire population and for selected sub-populations. The results of the access to different food sources show that the average distance to a supermarket was ~2.07 km (1.29 mi). The only sub populations that exceeded this distance were those who identified as White and Asian whose average distances were both ~2.1 km. Black populations and those without vehicle access (not mutually exclusive populations) were the closest on average to food pantries while White and Asian populations were the furthest away on average. The populations closest to community gardens tended to have less (or no) vehicles (~1.48 km away) be more impoverished (~1.58 km), and be comprised largely of Hispanic and Black populations (~1.86 km). Black populations and those in poverty and those without vehicles tended to be in greater proximity to convenience stores, fast food restaurants and liquor stores. Table 4 also shows the standard deviation from the average distance for the total population. This gives a measure of the variation around the mean distance.

5.1 Store Surveys

The results of the store survey show that the 15 stores classified as supermarkets have the largest selection of foods and the lowest prices in general. Aldi did not have 11 of the items on the market basket list but it did have a full selection of produce which is the main interest of this study. Schnuck's was the most expensive supermarket based on the sum of the prices divided by the number of available items. It was more expensive than some smaller stores such as Walgreen's and Dollar General but those smaller stores

did not carry fresh produce when they were surveyed. Aldi was the cheapest on the basis of average unit cost while World Market was the most expensive. The cheapest store that had a complete market basket was Wal-Mart. The specialty shops and convenience stores tended to have the highest product prices and the lowest selection of goods on the list.

This data is an indicator of the relative costs an individual would have to pay for groceries at stores in Columbia. The same set of goods is more likely to be cheaper at places like Aldi and Wal-Mart than at other stores such as Schnuck's or Clover's. This survey did not assess quality or freshness of items nor did it evaluate the overall shopping experience by rating things such as customer service or cleanliness of store.

Figure 16 relates the average product prices found at each supermarket. The cost of the market basket is normalized by the number of items at each store. On this map, store symbol size is scaled with respect to product cost.

	Availability (87 items total)	Total cost ($)	Total cost ($)/availability
Aldi	76	106.26	1.40
Wal-Mart East	87	154.11	1.77
Wal-Mart South	87	159.00	1.83
Moser's B. Loop	87	159.25	1.83
Gerbes West	87	160.46	1.84
Wal-Mart West	87	163.20	1.88
HyVee East	86	163.19	1.90
HyVee West	87	171.37	1.97
Moser's Rangeline	87	171.96	1.98
HyVee South	87	174.03	2.00
Gerbes South	87	180.83	2.08
Eastgate	82	182.16	2.22
Gerbes North	87	196.83	2.26
Patricia's	84	218.70	2.60
Dollar General B. Loop	47	123.07	2.62
Target	46	123.09	2.68
Walgreen's	40	137.51	3.44
Schnuck's	86	305.81	3.56
Casey's	28	129.94	4.64
Clover's West	70	395.54	5.65
Fastlane/ Phillip's 66	11	71.87	6.53
Petro Mart	9	66.04	7.34
Root Cellar	32	235.76	7.37
World Harvest	32	249.97	7.81

Table 5. Summary of store market basket survey

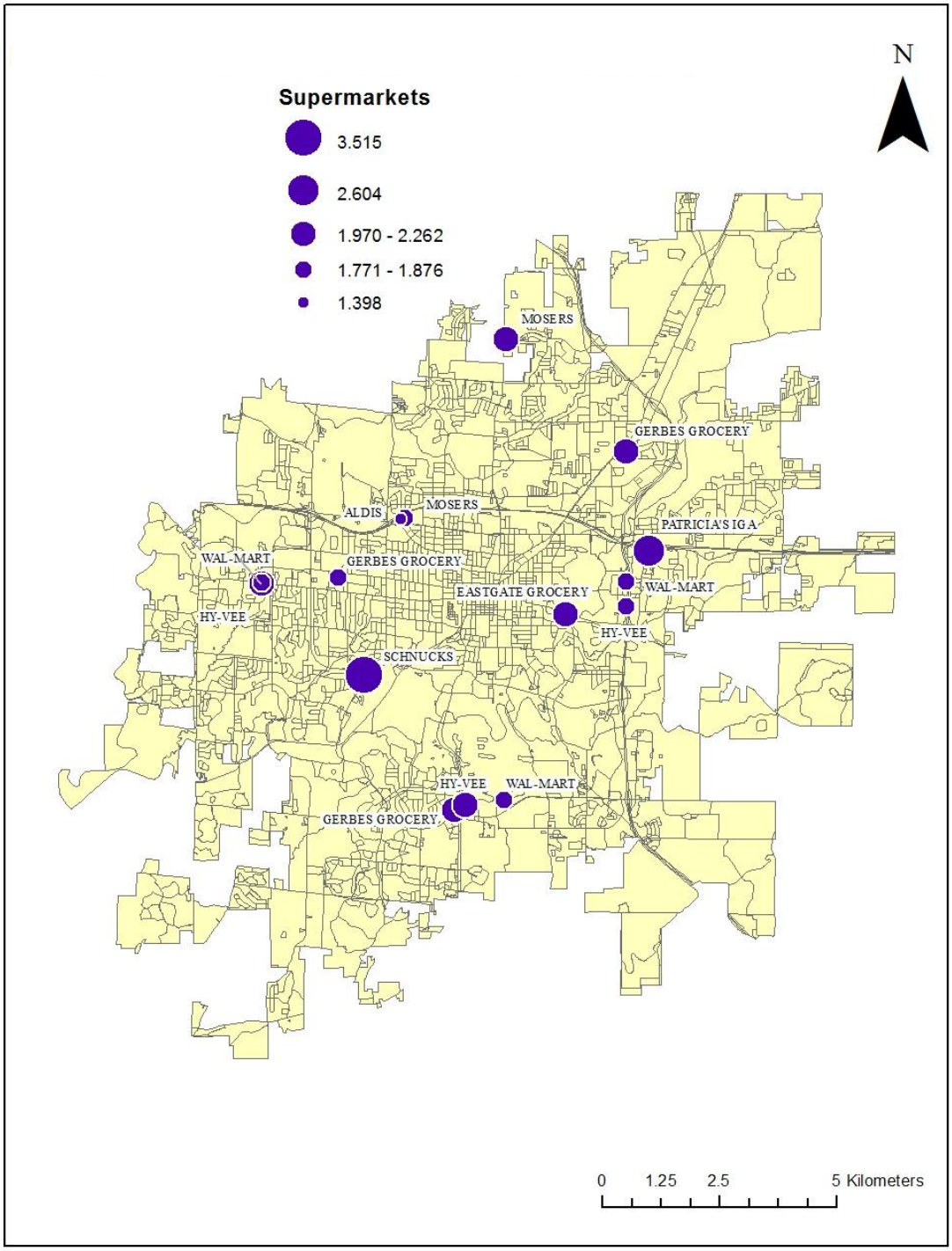

Figure 16. Average product cost ($)

5.2 Multiple Store Access

Figures 17 – 46 show Columbia Census blocks with access to more than one store at access standards of 800 m, 1,600 m, 2,000 m, and 4,000 m. However, Figures 37-40 display access standards of 600 m, 1600 m, 2100 m, and 4100 m. since access to fast food restaurants was instead calculated in 500 meter increments.

The following Sections describe access to supermarkets (5.2.1), community gardens (5.2.2), food pantries (5.2.3), convenience stores (5.2.4 liquor stores (5.2.5), and fast food restaurants (5.2.6).

It can be seen in figure 17 that for supermarkets that the coverage at 1600 meters (~1 mile) leaves the center and many peripheral areas of Columbia without access.

5.2.1 Supermarket access

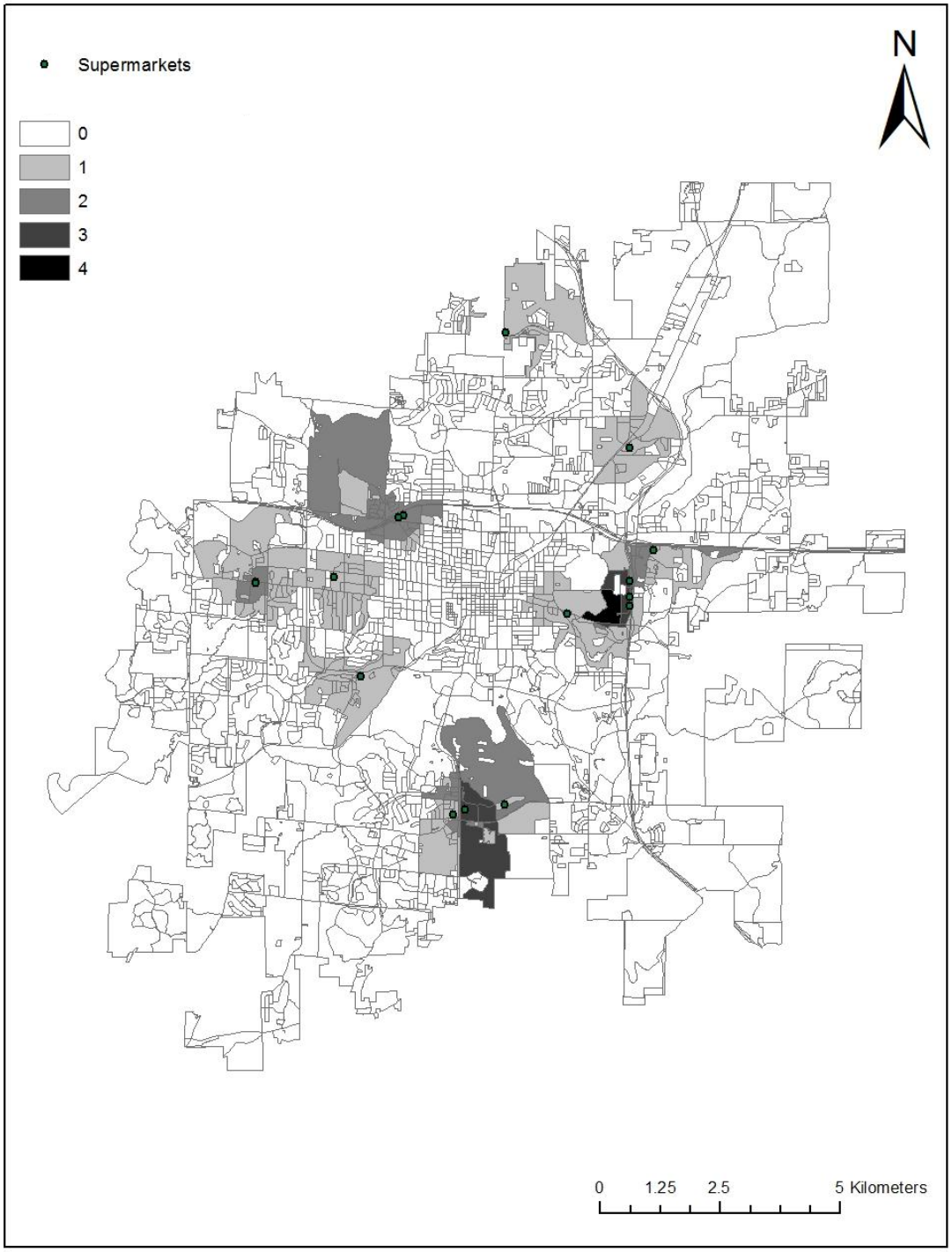

Figure 17. Number of supermarkets within 800m of Census blocks

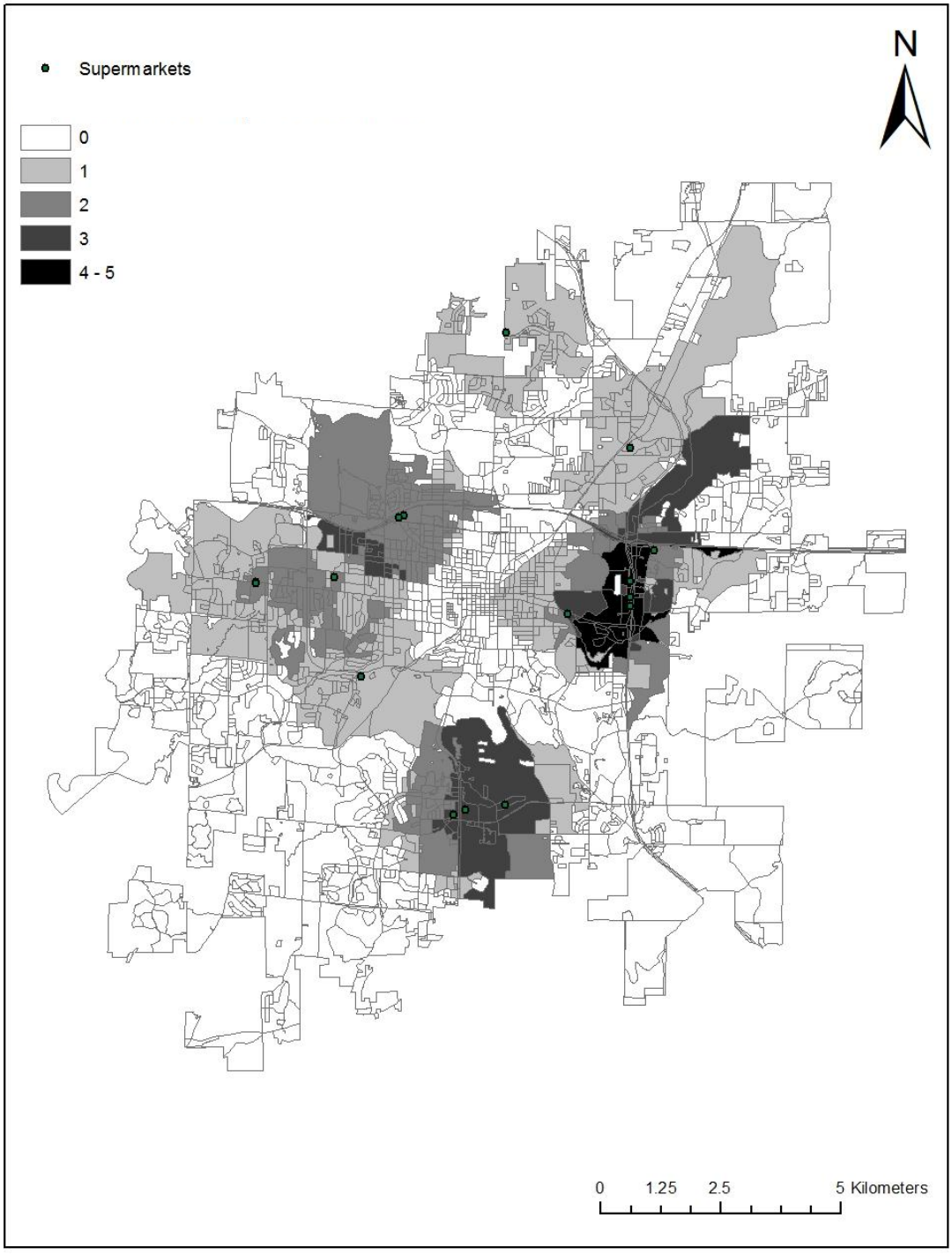

Figure 18. Number of supermarkets within 1600m of Census blocks

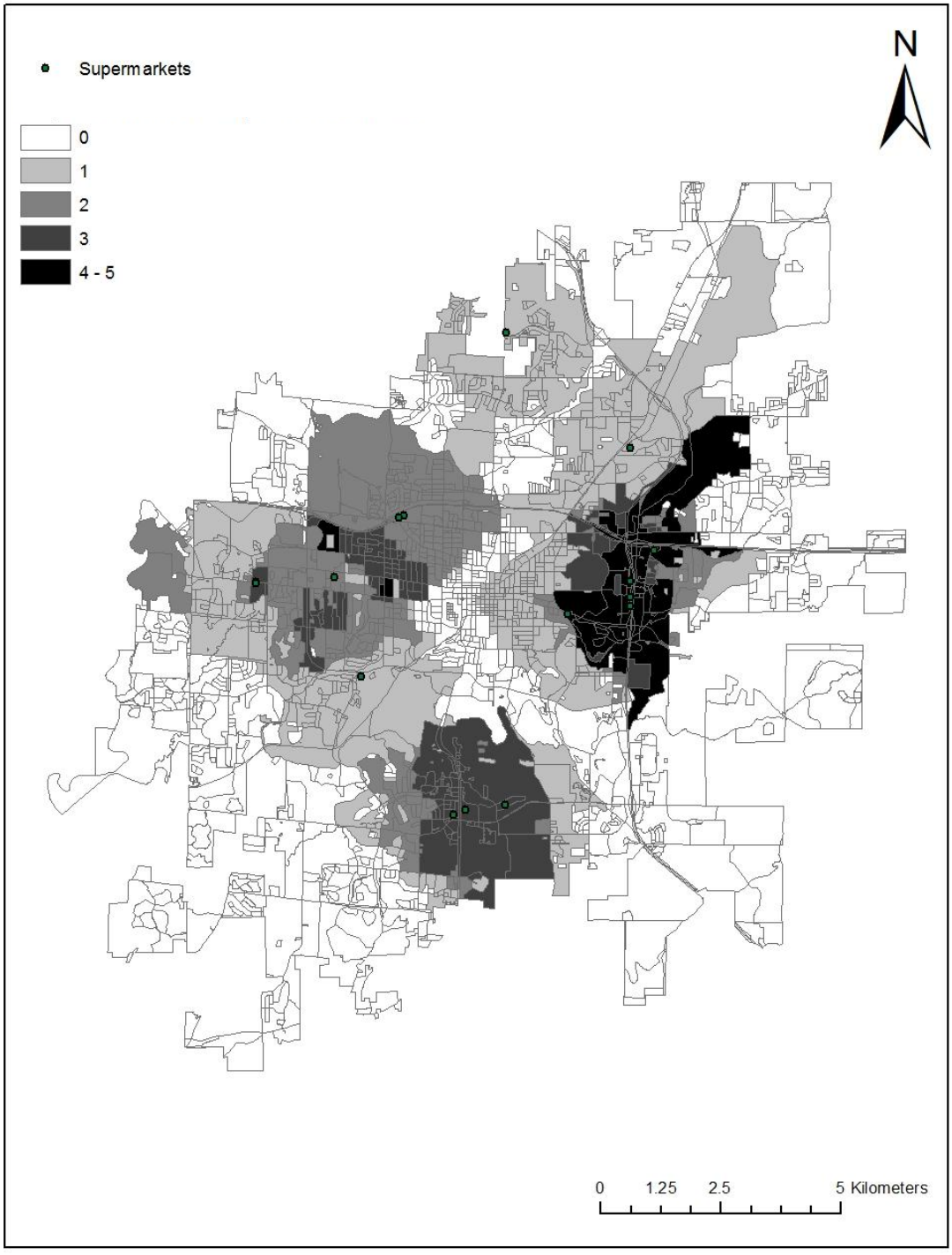

Figure 19. Number of supermarkets within 2000m of Census blocks

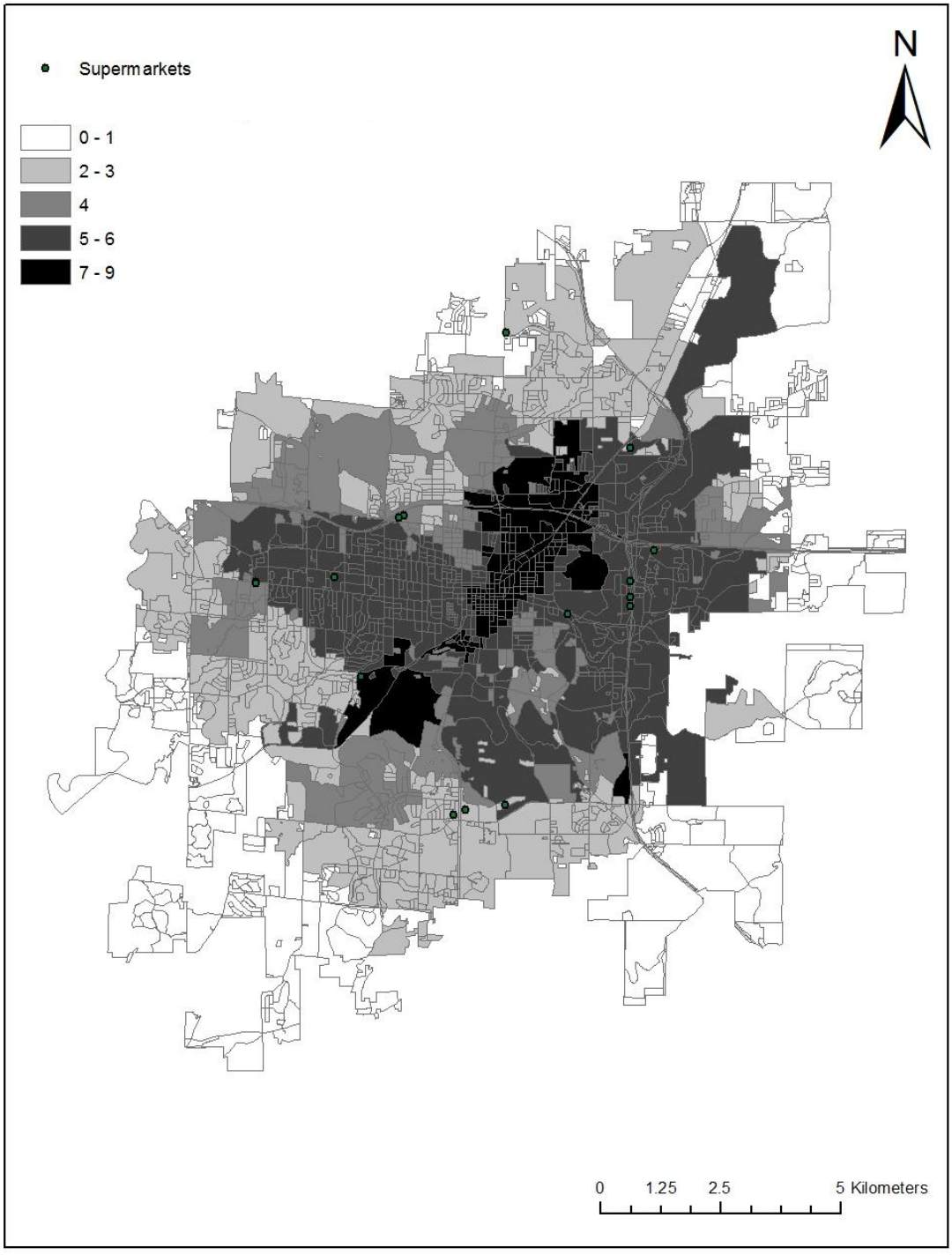

Figure 20. Number of supermarkets within 4000m of Census blocks

5.2.2 Community garden access

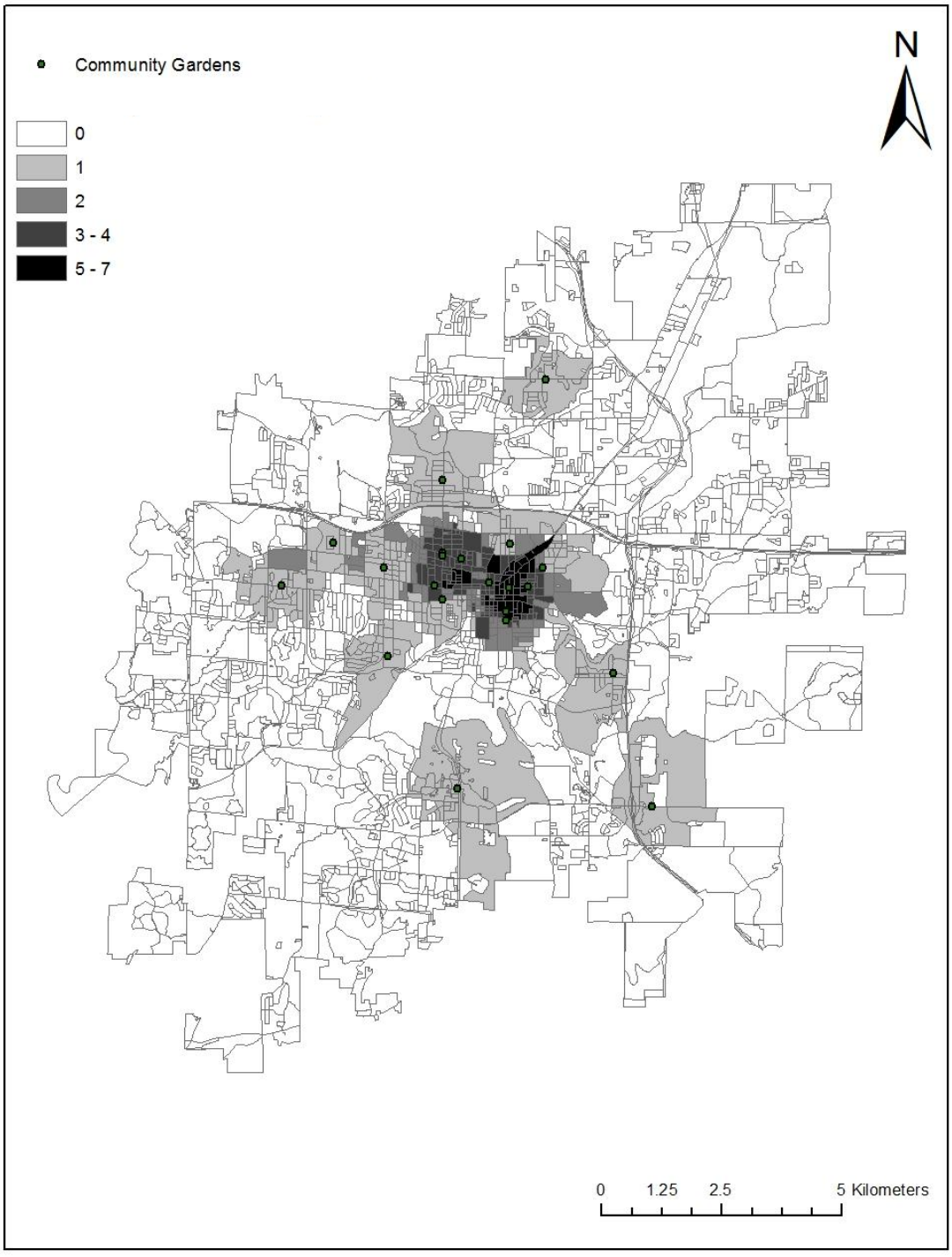

Figure 21. Number of community gardens within 800m of Census blocks

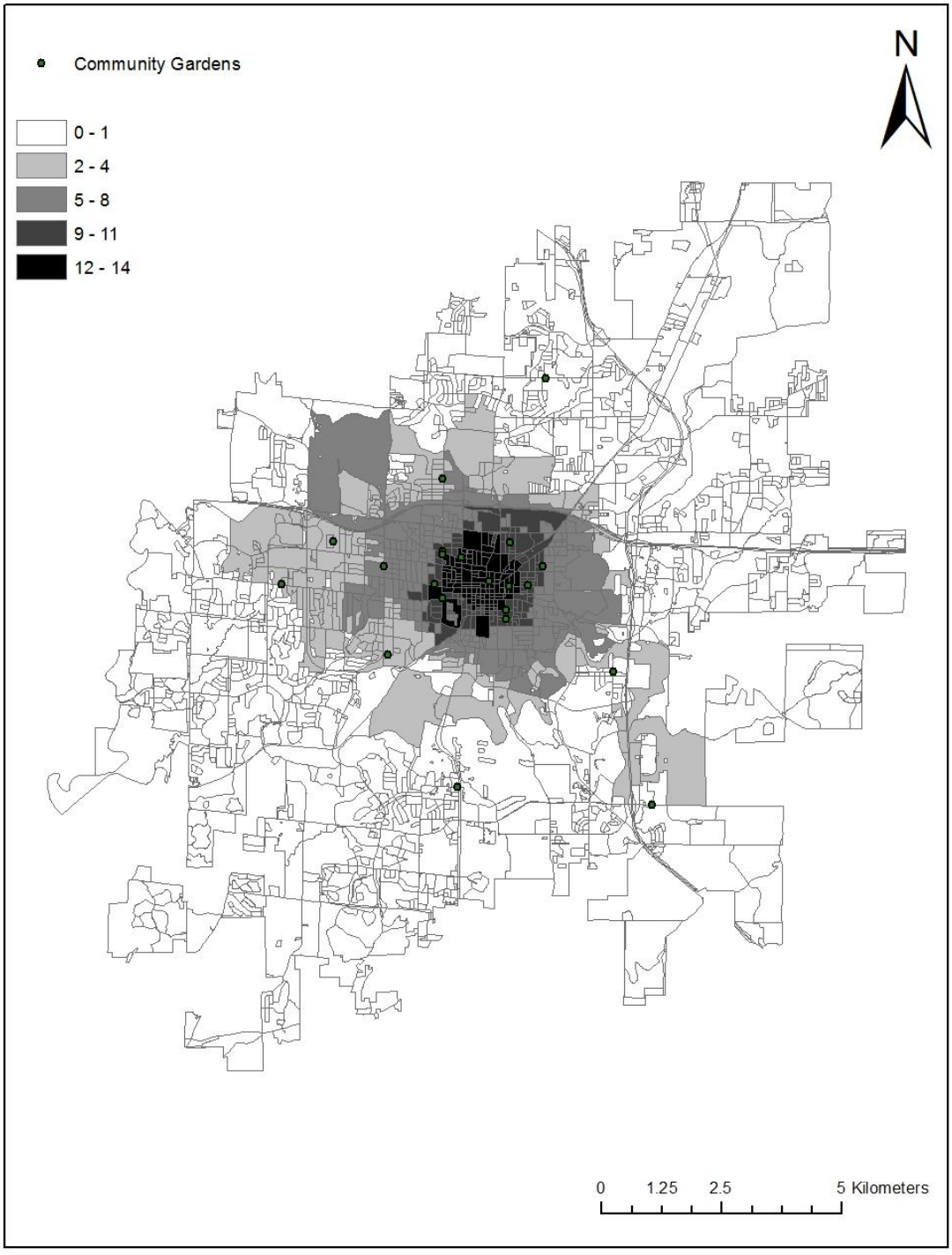

Figure 22. Number of community gardens within 1600m of Census blocks

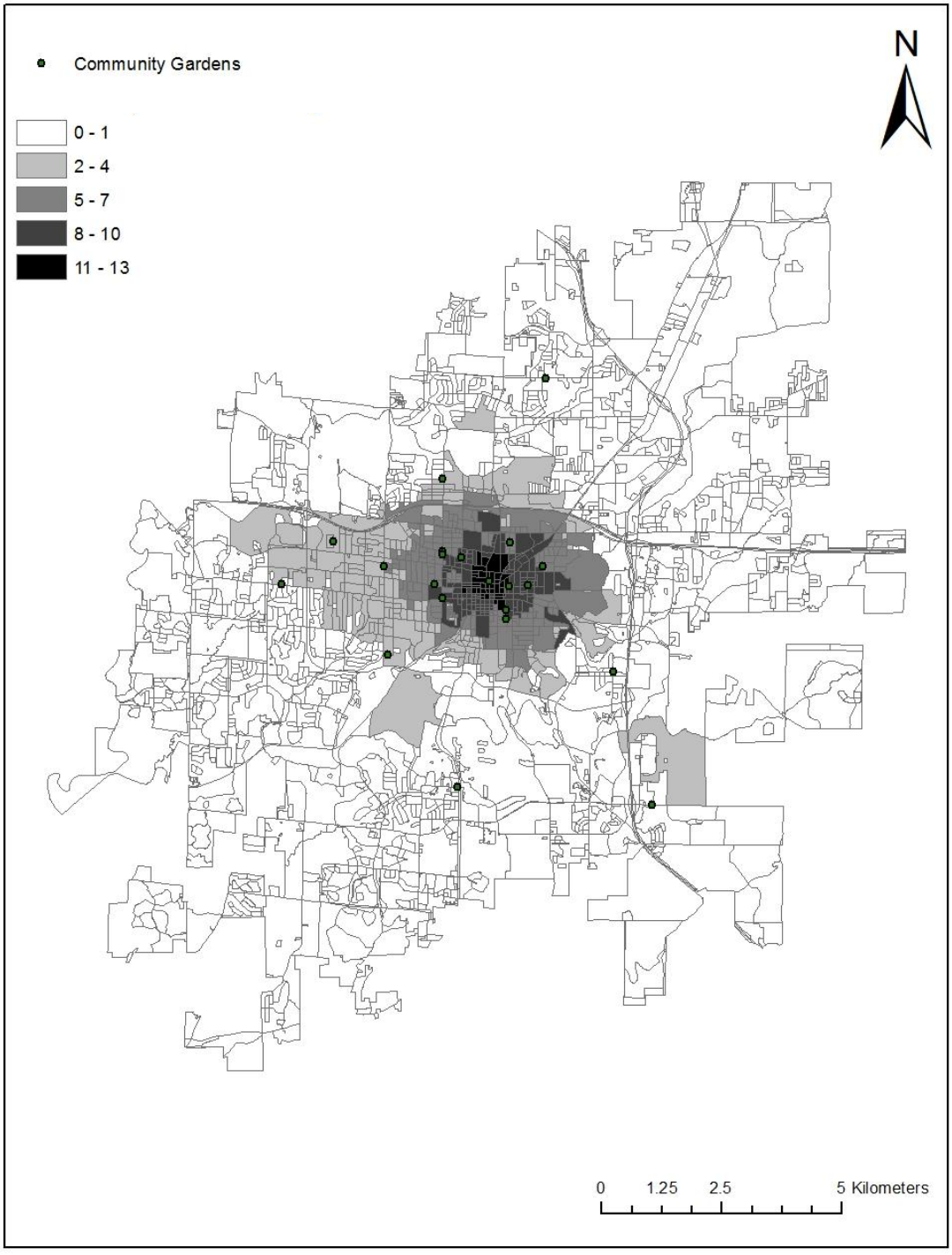

Figure 23. Number of community gardens within 2000m of Census blocks

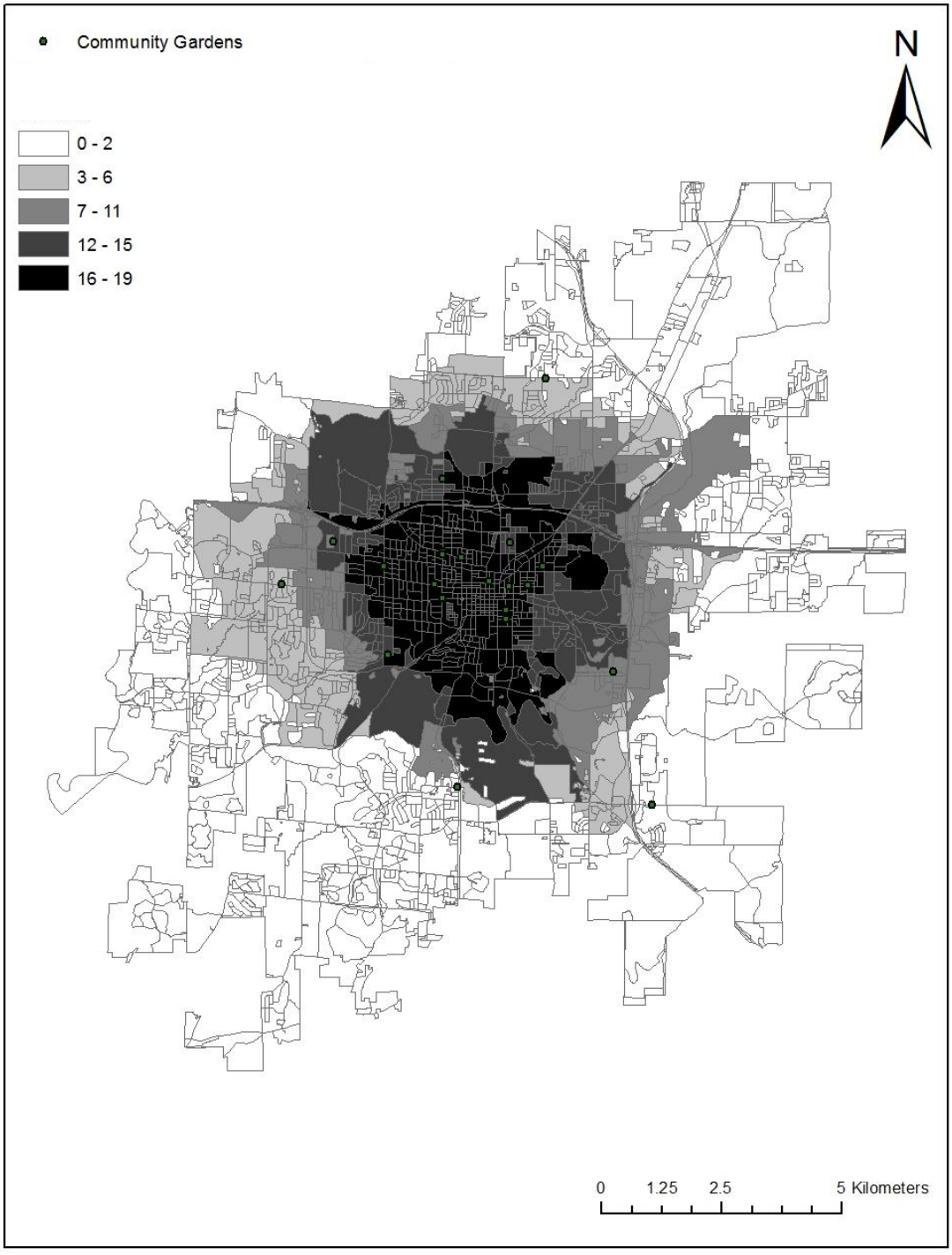

Figure 24. Number of community gardens within 4000m of Census blocks

5.2.3 Food pantry access

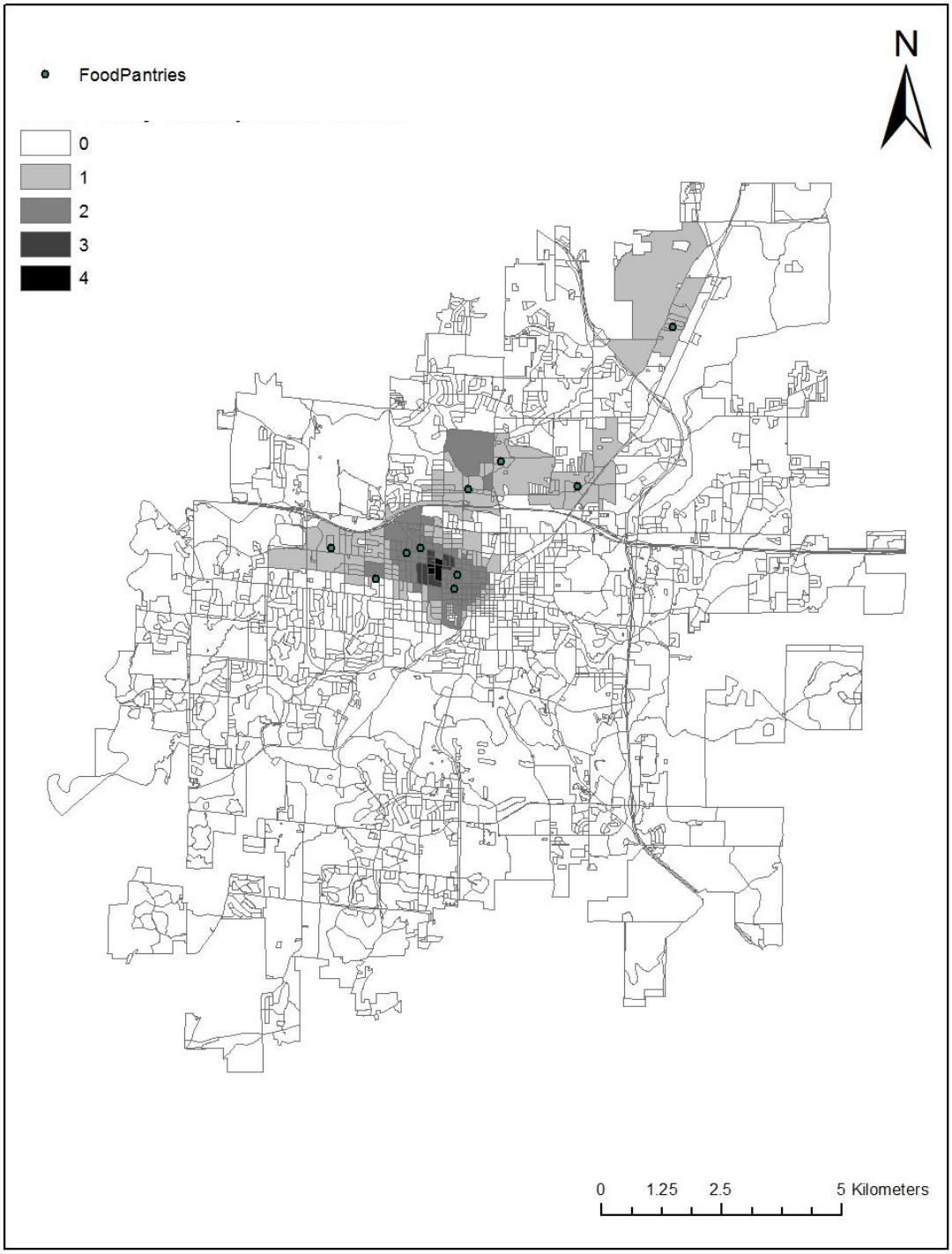

Figure 25. Number of food pantries within 800m of Census blocks

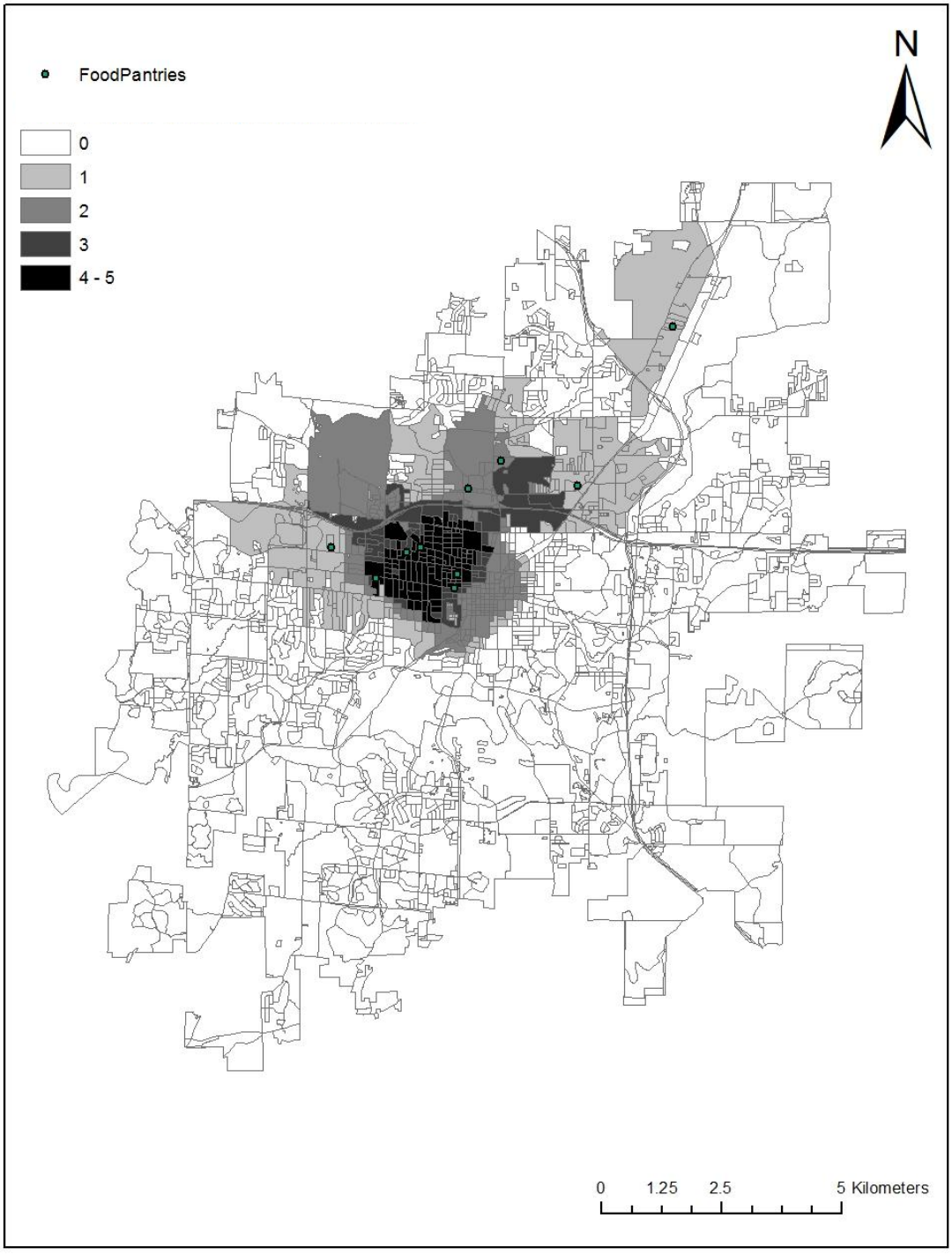

Figure 26. Number of food pantries within 1600m of Census blocks

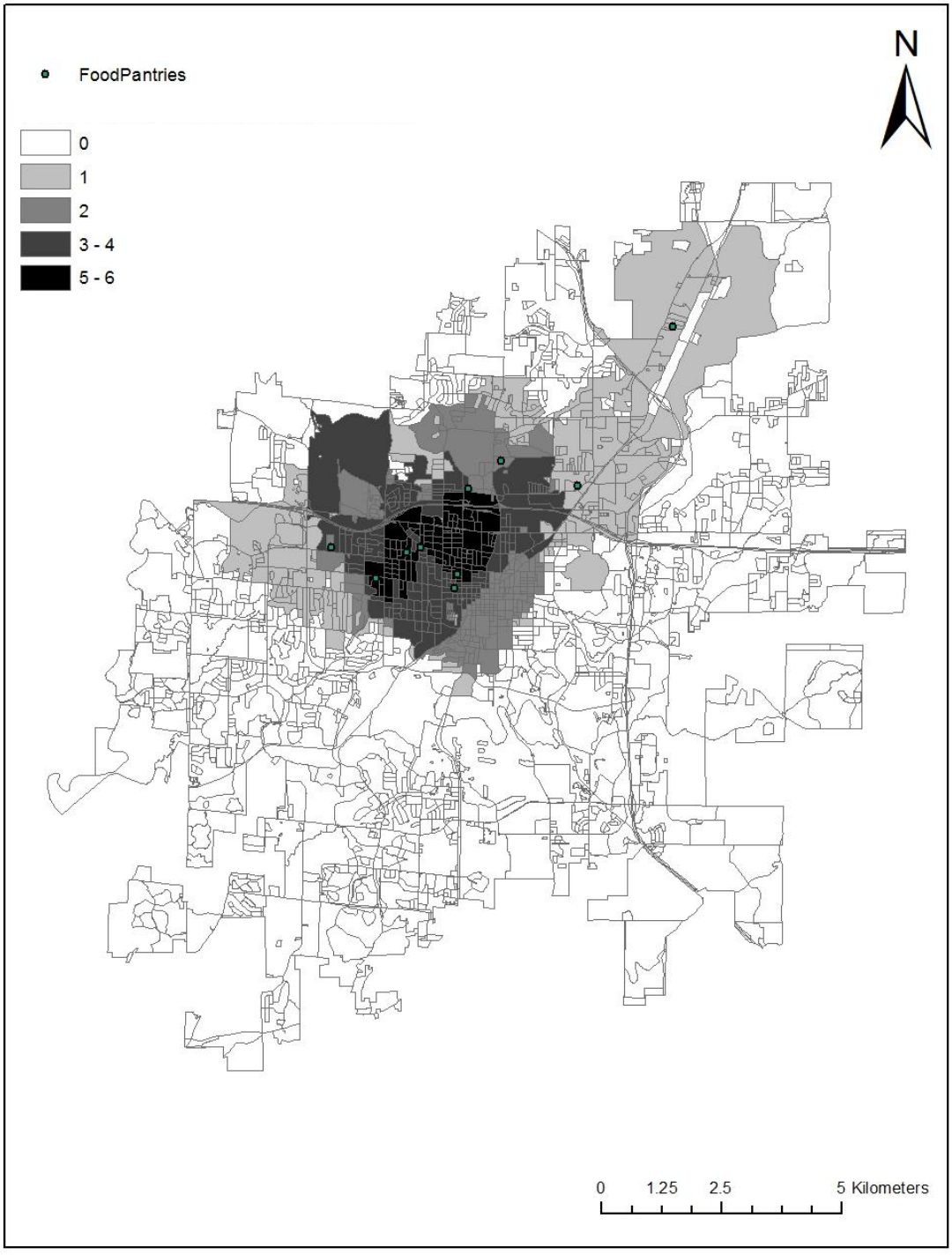

Figure 27. Number of food pantries within 2000m of Census blocks

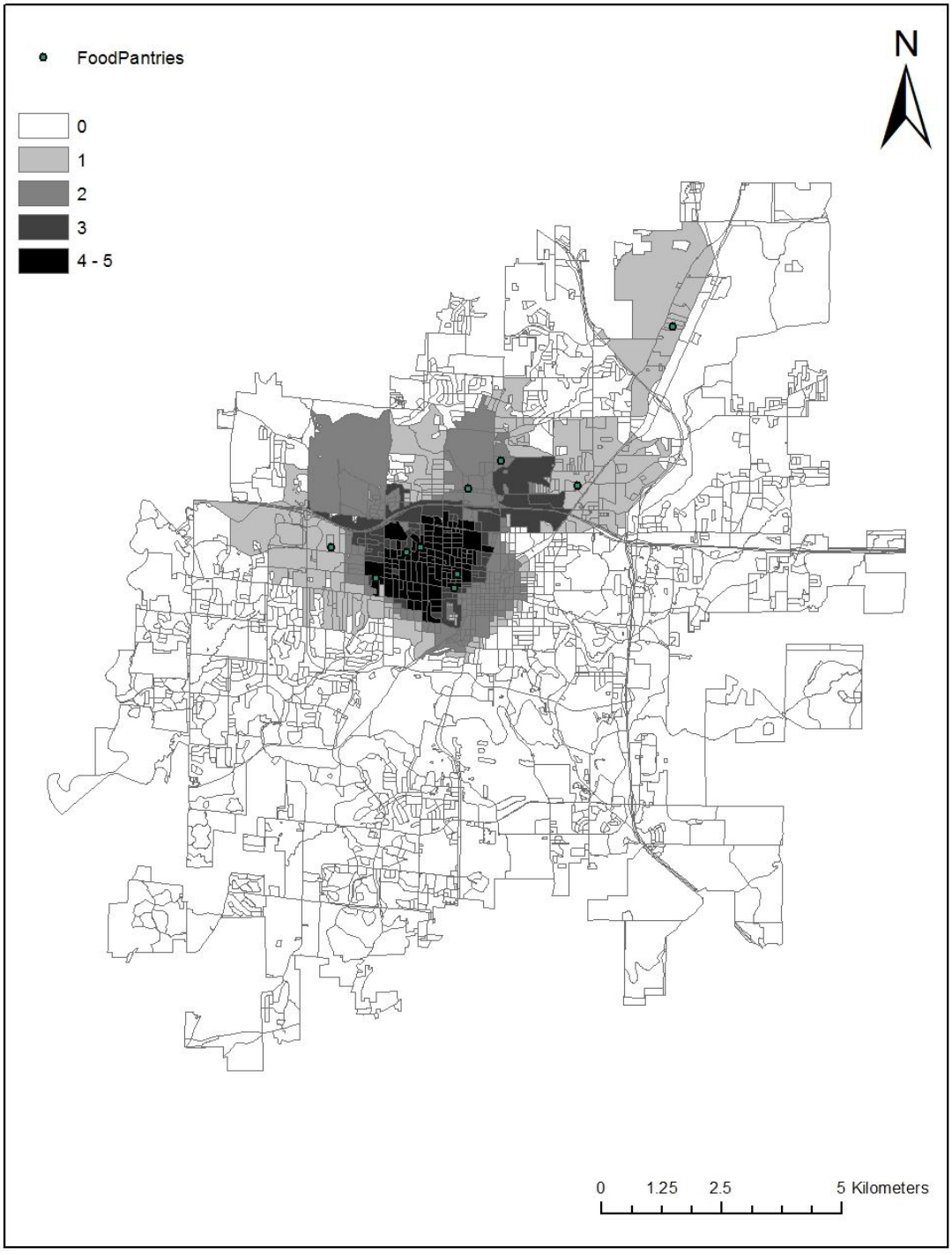

Figure 28. Number of food pantries within 4000m of Census blocks

5.2.4 Convenience store multiple coverage maps

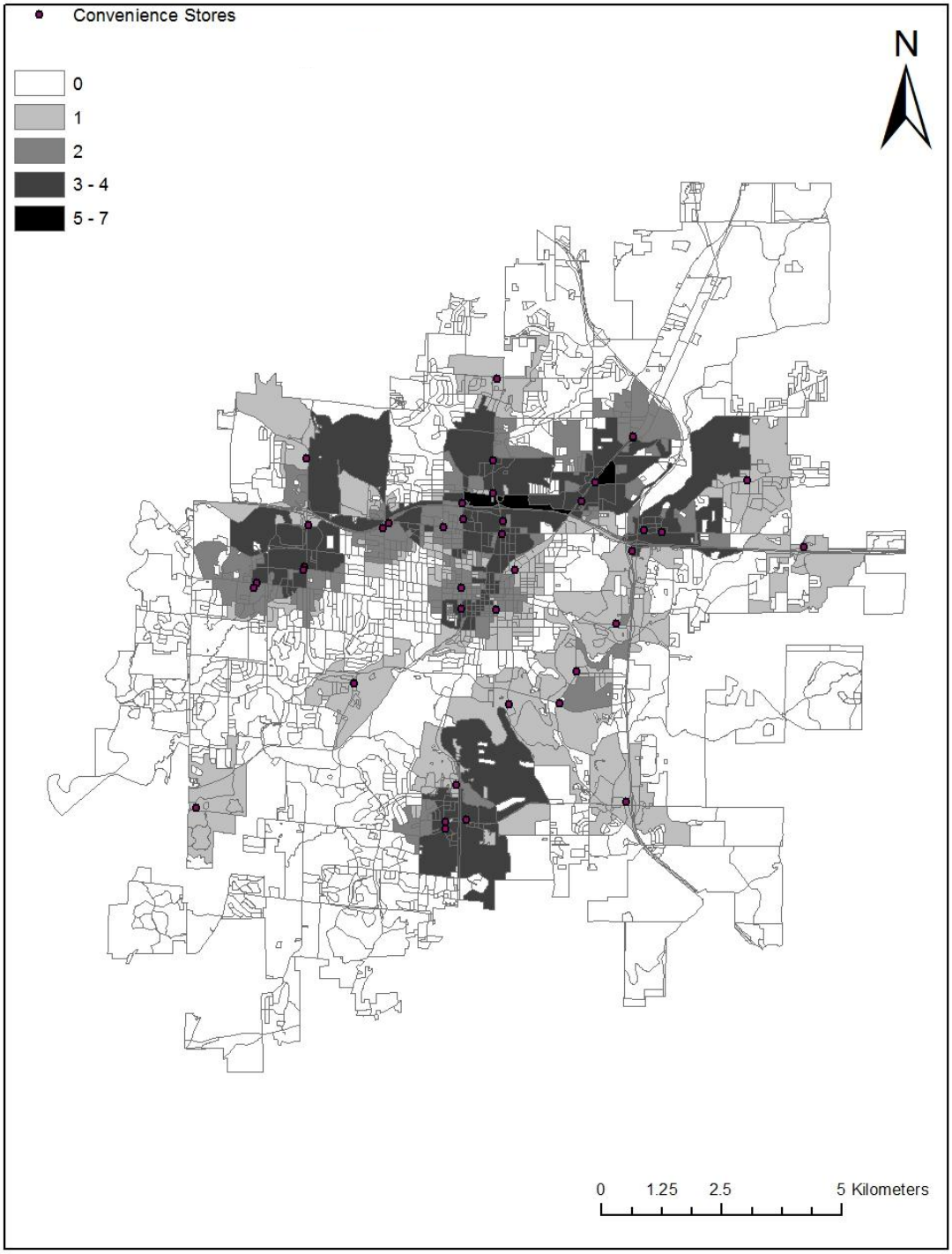

Figure 29. Number of convenience stores within 800m of Census blocks

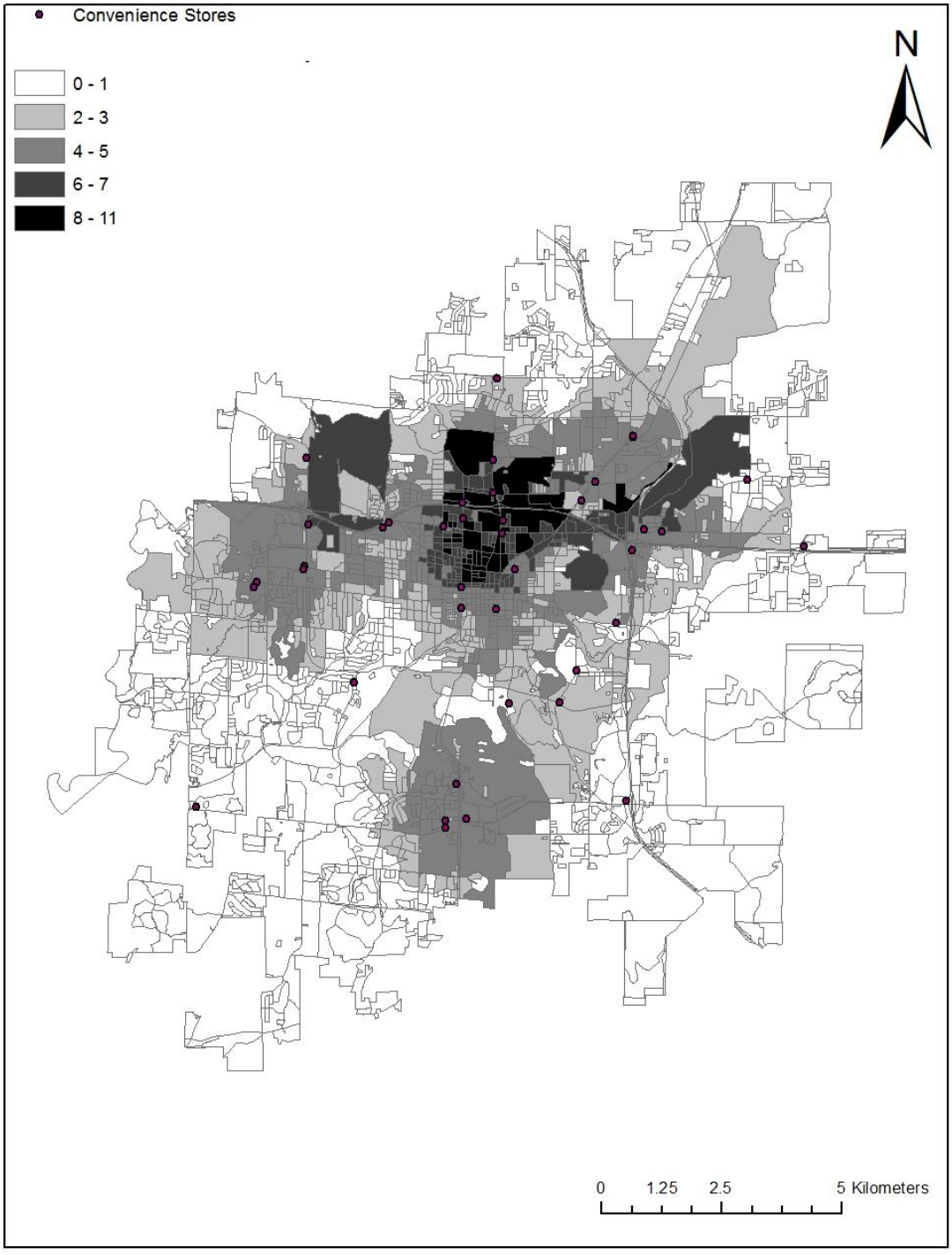

Figure 30. Number of convenience stores within 1600m of Census blocks

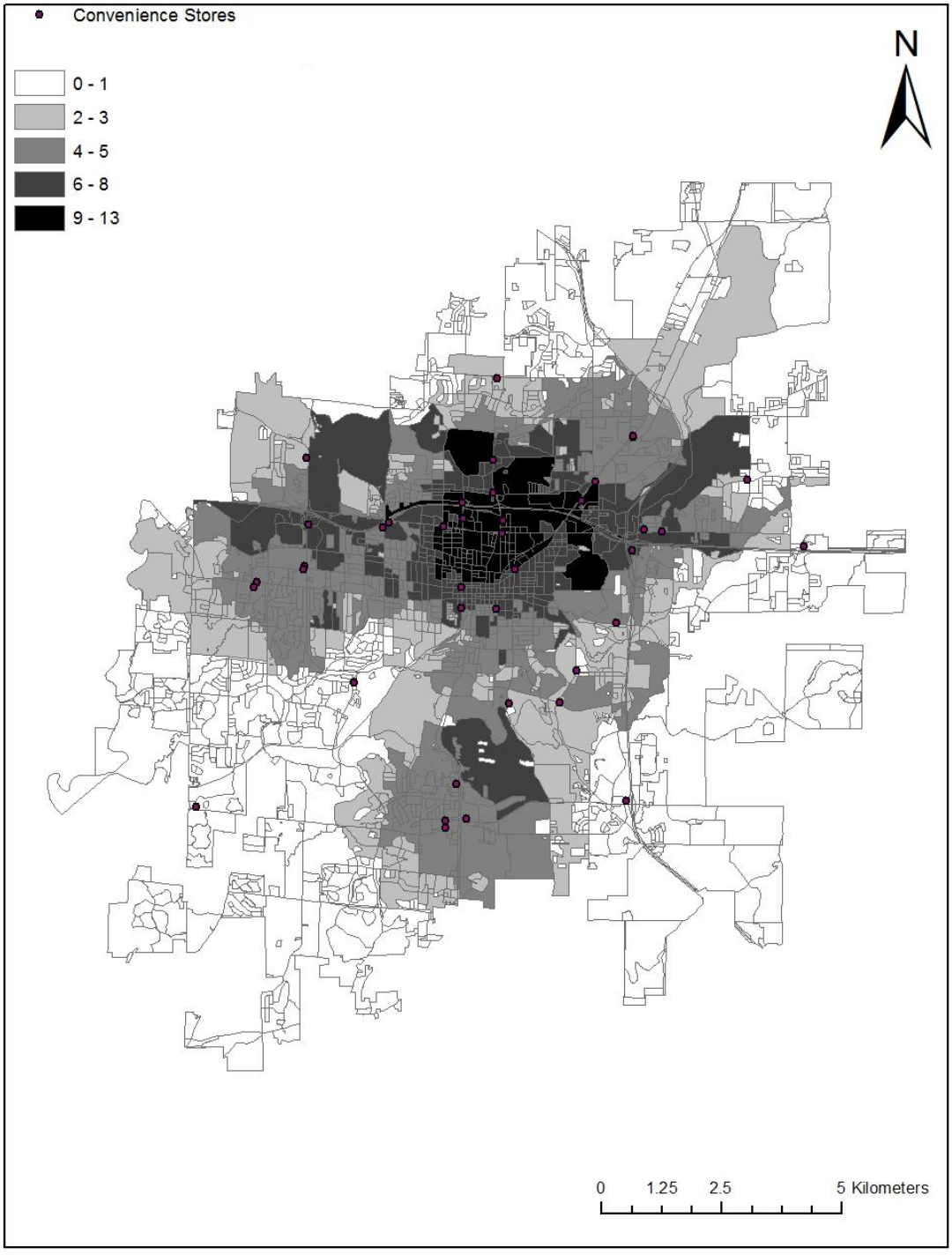

Figure 31. Number of convenience stores within 2000m of Census blocks

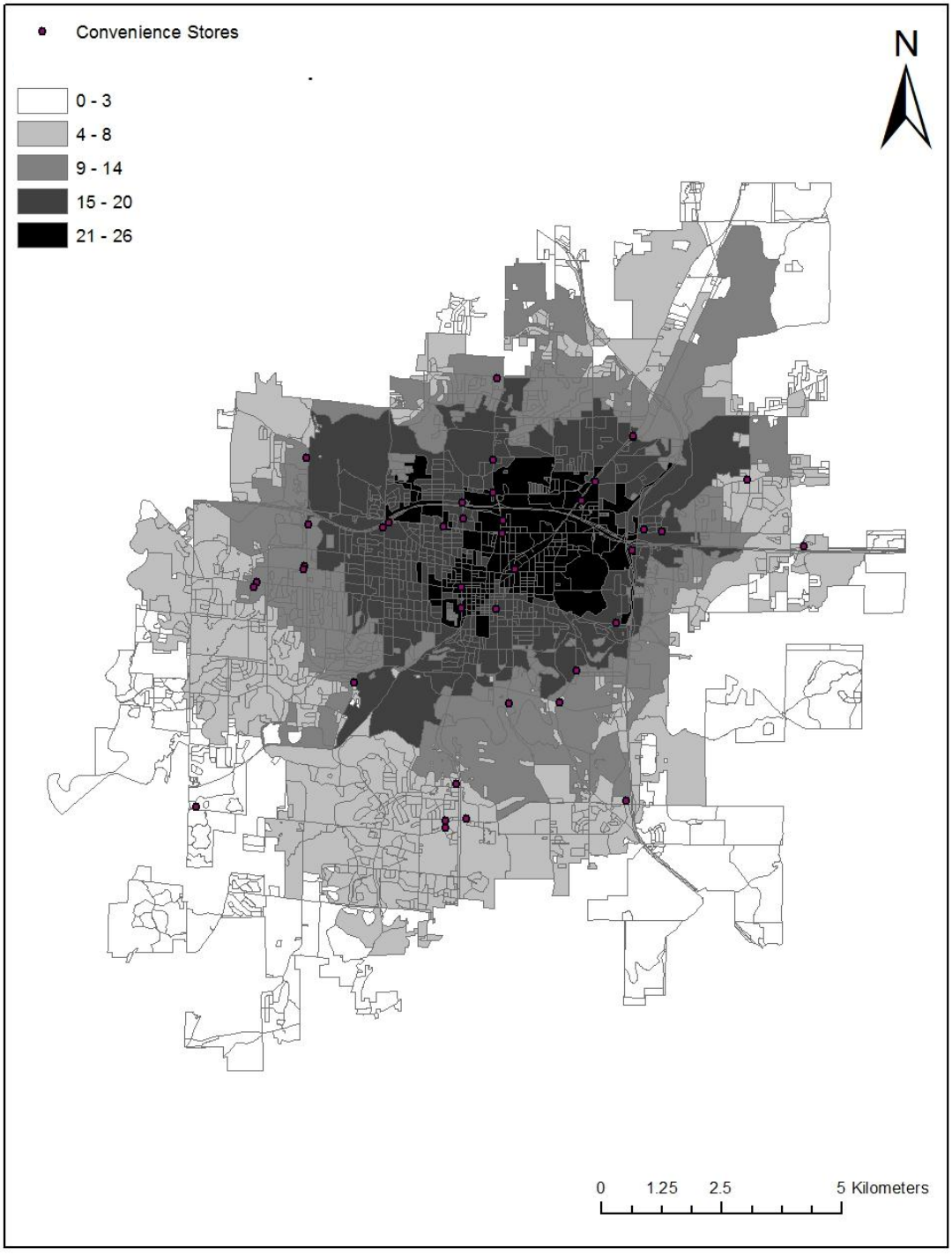

Figure 32. Number of convenience stores within 4000m of Census blocks

5.2.5 Liquor store access

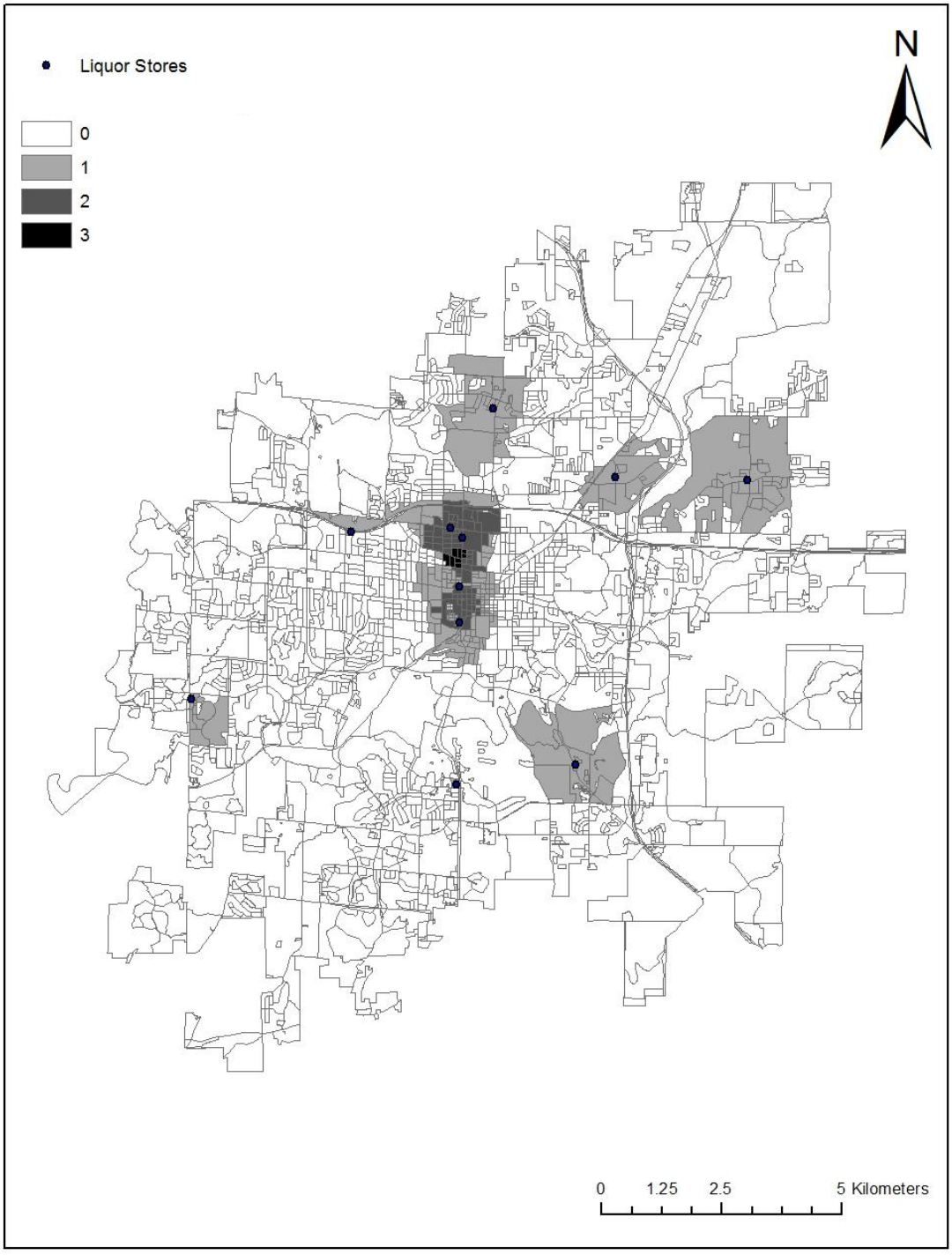

Figure 33. Number of liquor stores within 800m of Census blocks

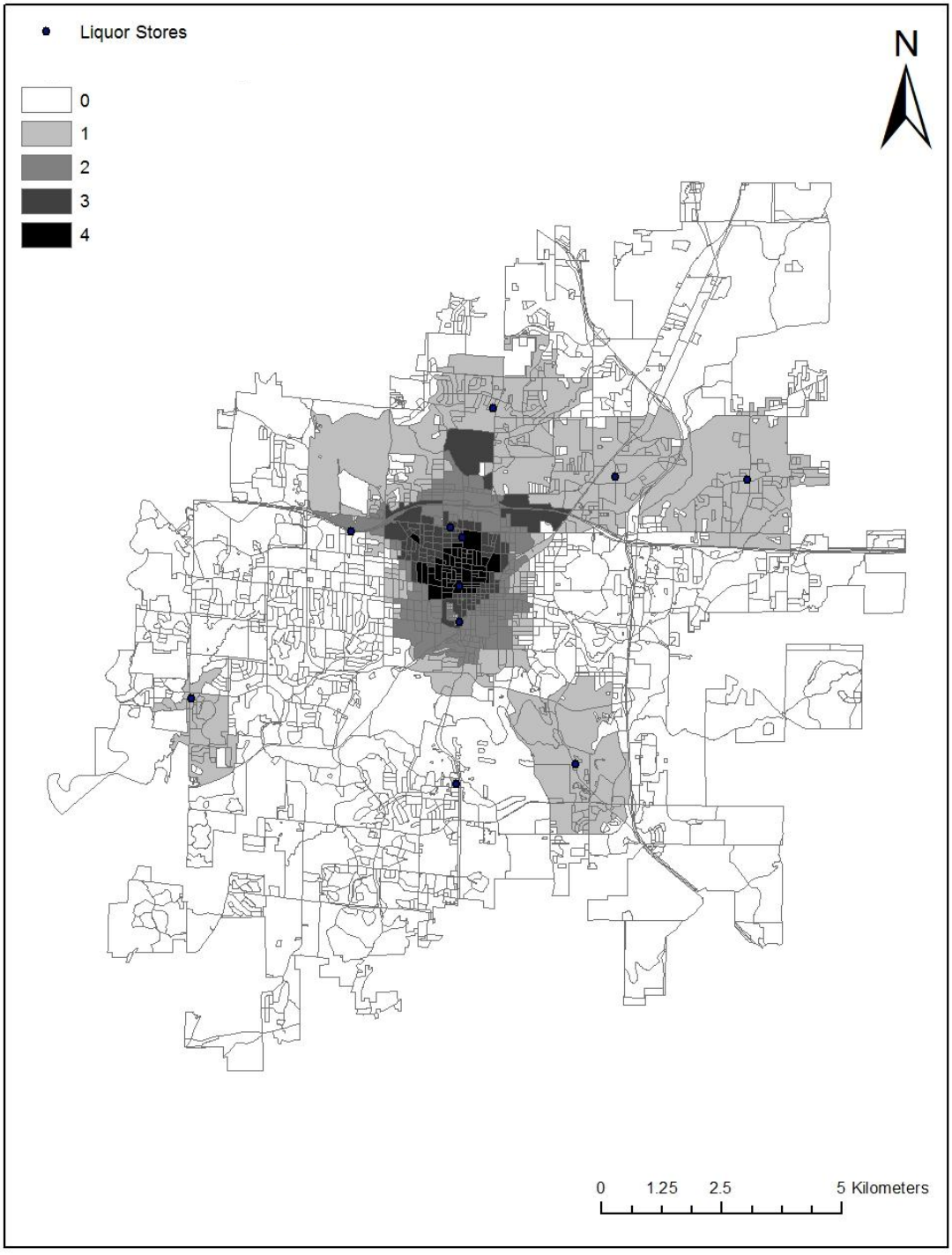

Figure 34. Number of liquor stores within 1600m of Census blocks

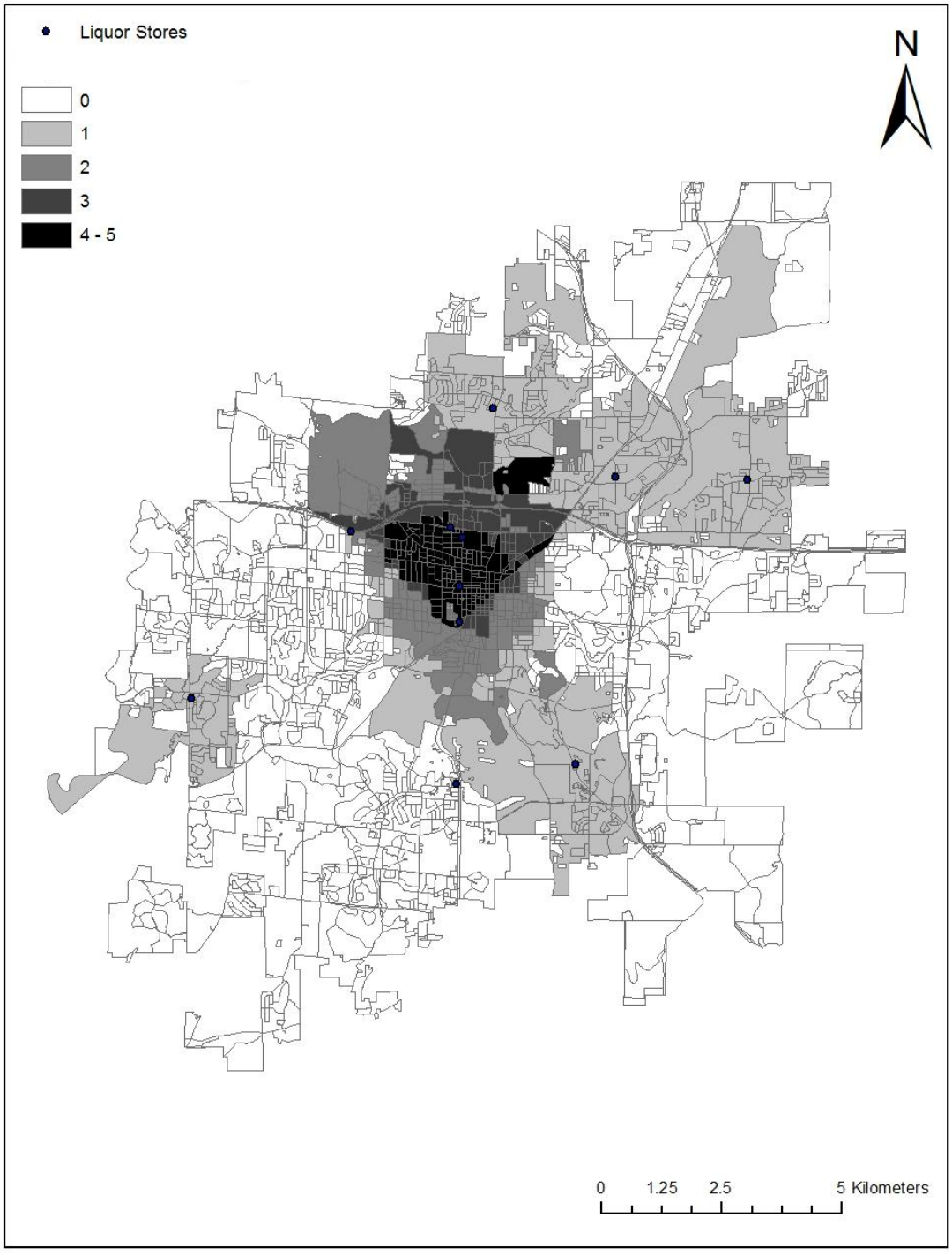

Figure 35. Number of liquor stores within 2000m of Census blocks

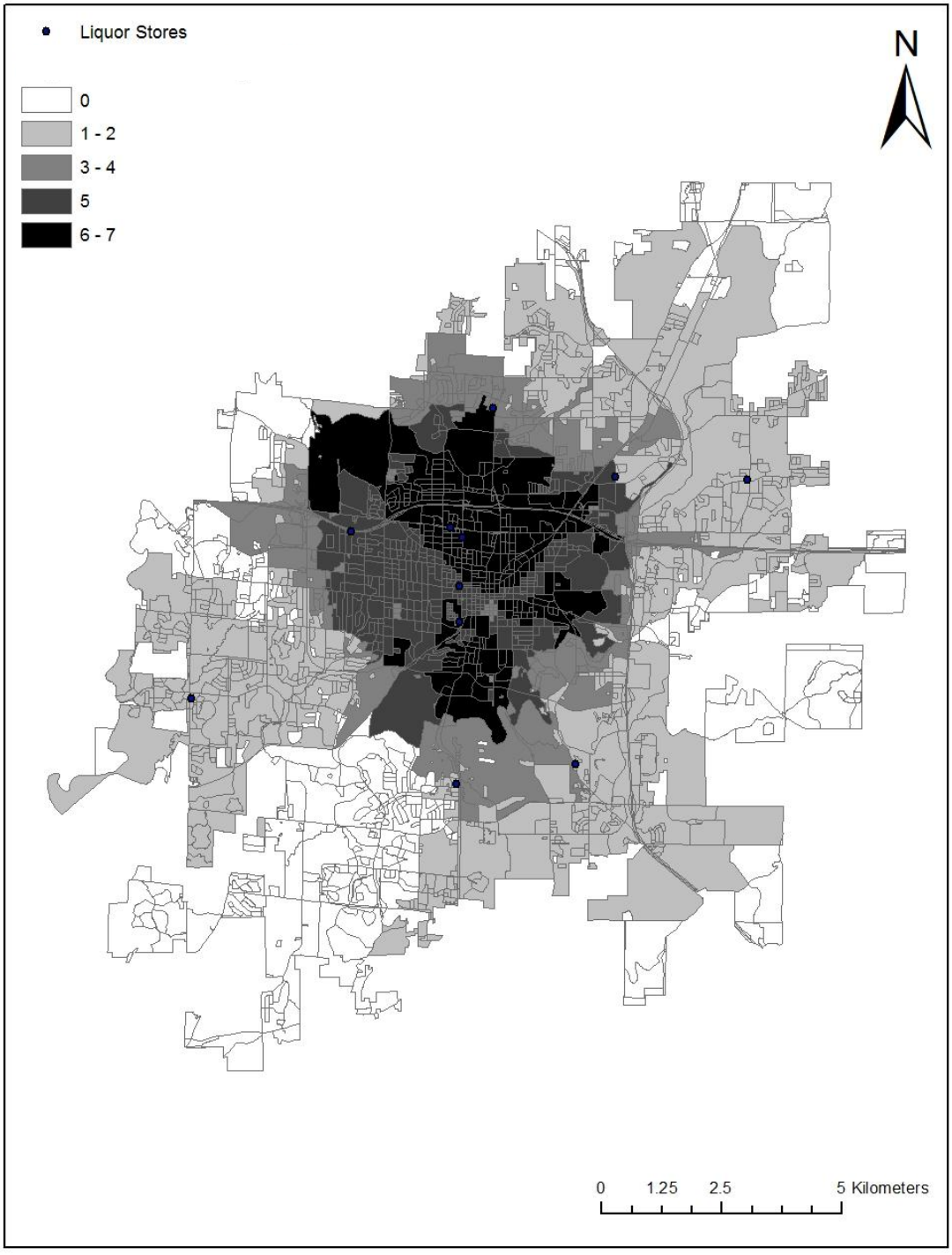

Figure 36. Number of liquor stores within 4000m of Census blocks

5.2.6 Fast food restaurant access

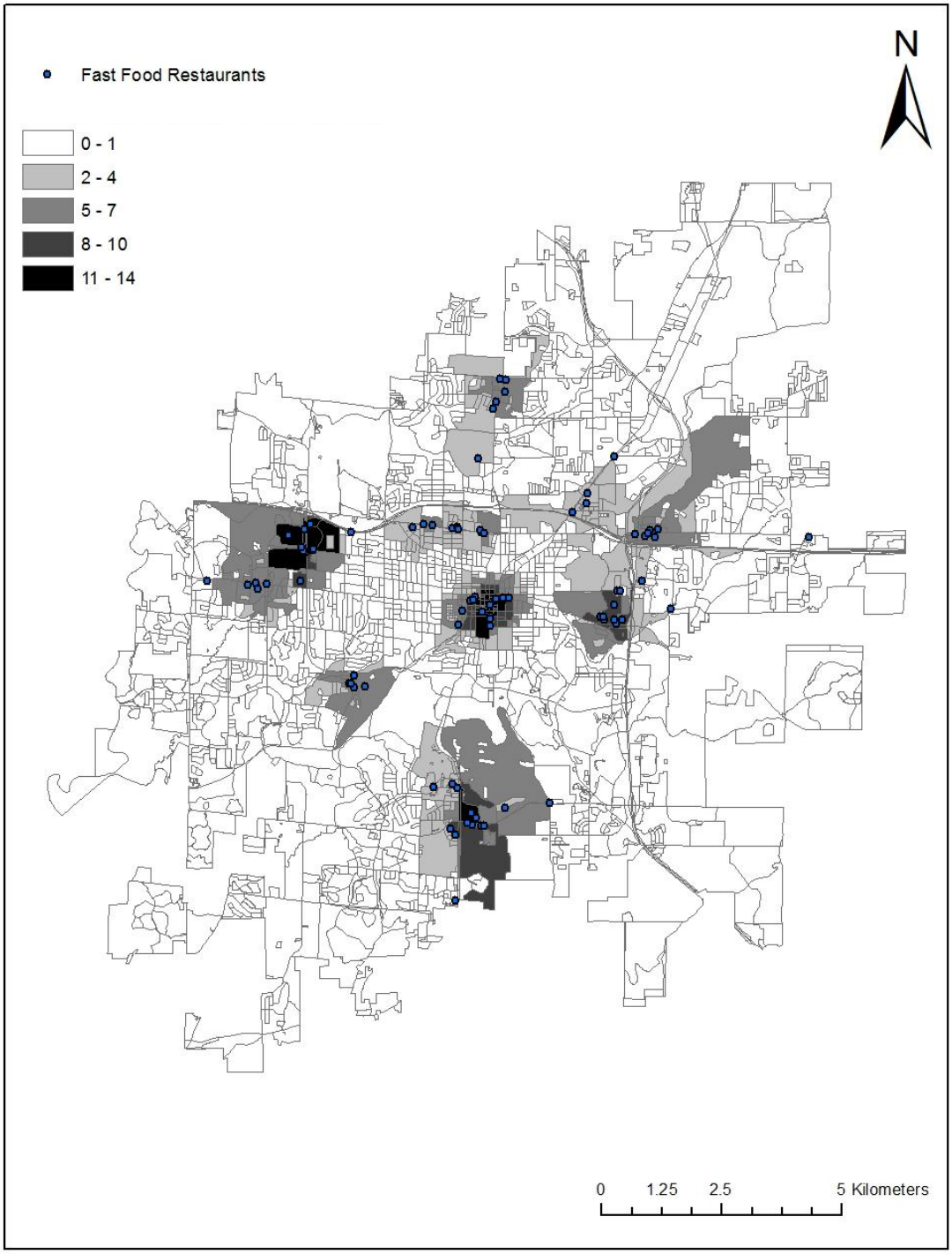

Figure 37. Number of fast food restaurants within 600m of Census blocks

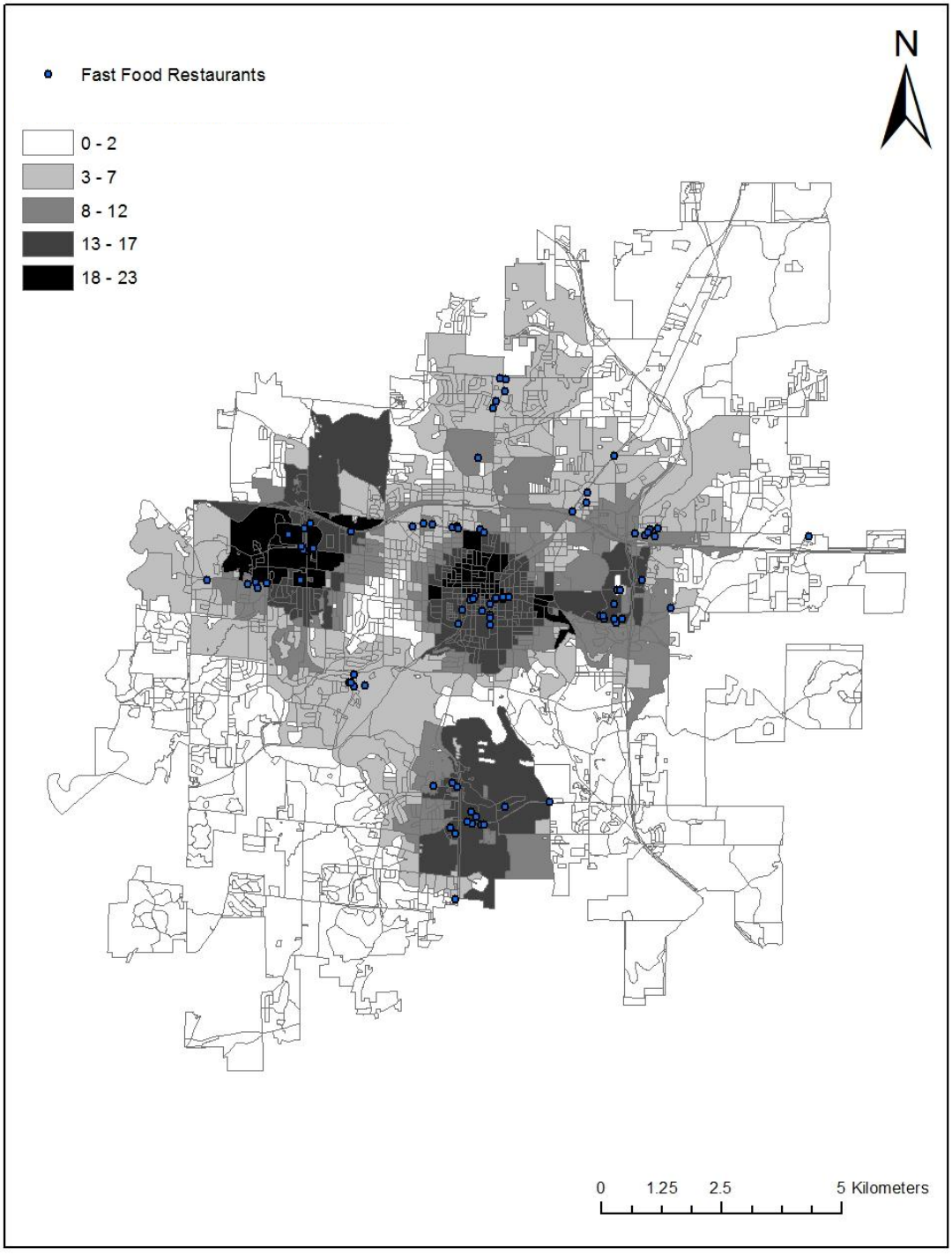

Figure 38. Number of fast food restaurants within 1600m of Census blocks

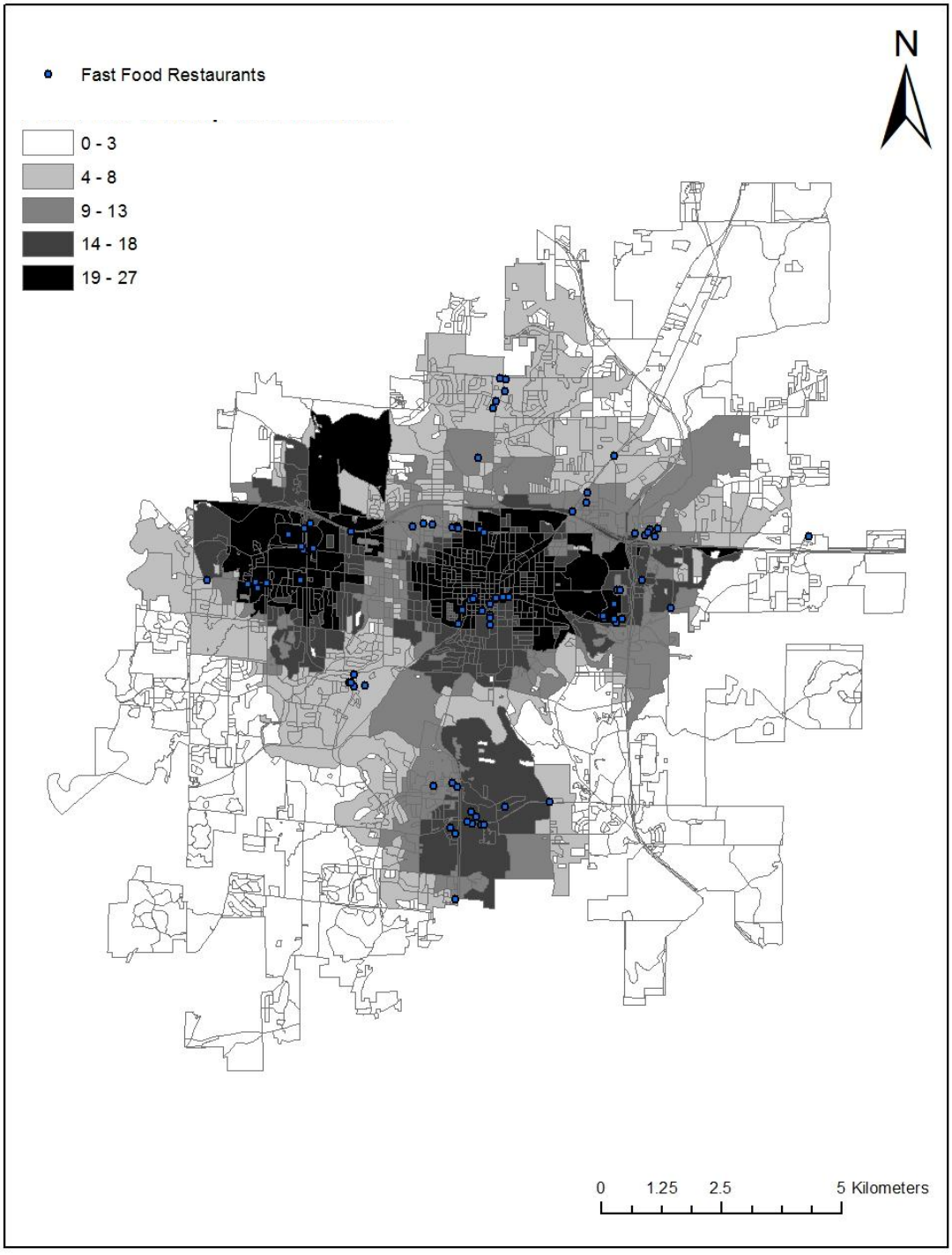

Figure 39. Number of fast food restaurants within 2100m of Census blocks

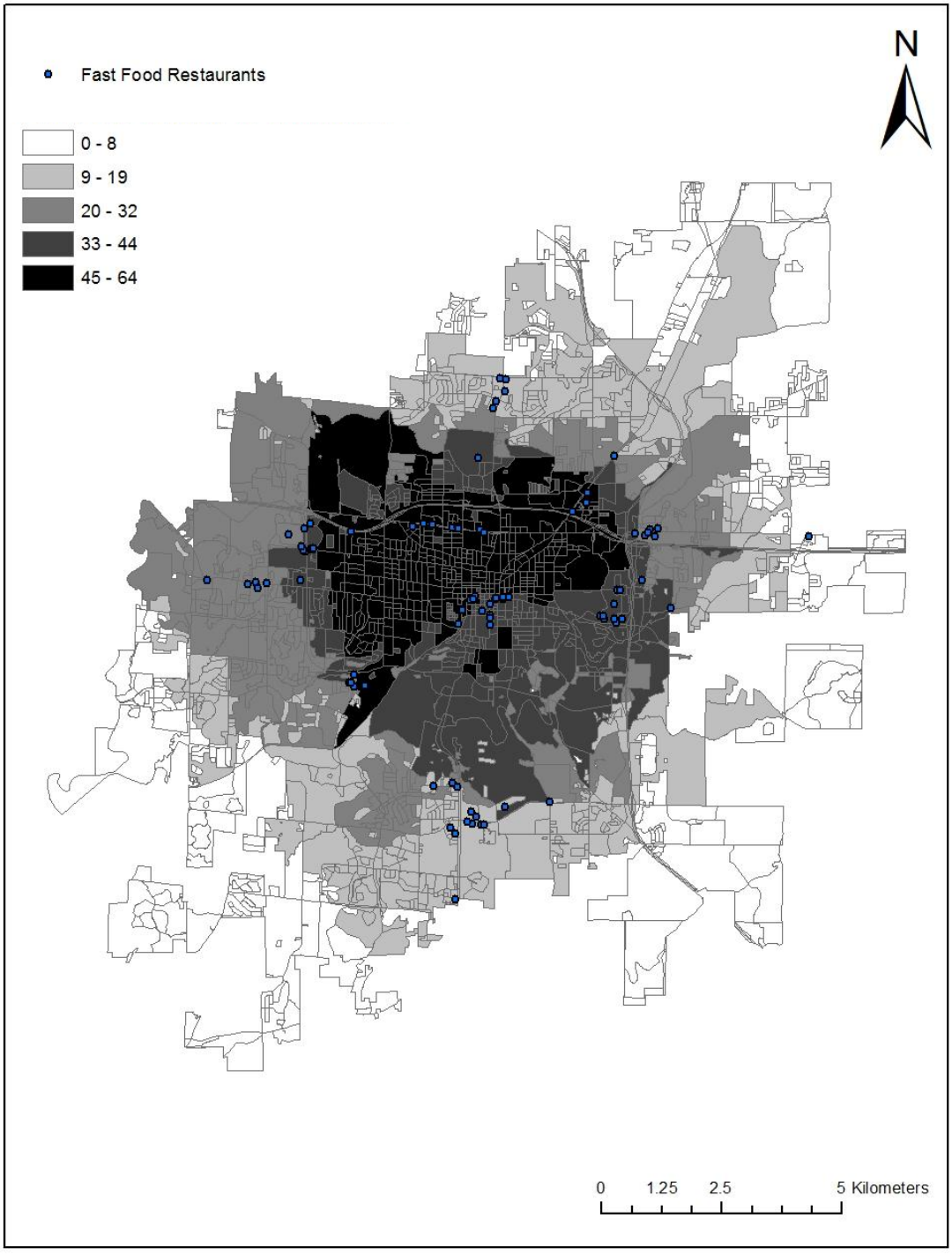

Figure 40. Number of fast food restaurants within 4100m of Census blocks

5.2.7 Store access at 4000 meters

In order to assess access to food considering combinations of multiple food sources some analysis using a 4,000 meter access standard is provided. Figures 39 – 44 show access at this distance standard when considering multiple food source types. This helps highlight areas that even at the relatively large distance of 4 kilometers do not have access to any type of food source considered. The results show that there are indeed a small number of blocks at the edges of Columbia that do not have access to supermarkets, other stores (smaller groceries, drug stores), convenience stores, food pantries, or community gardens.

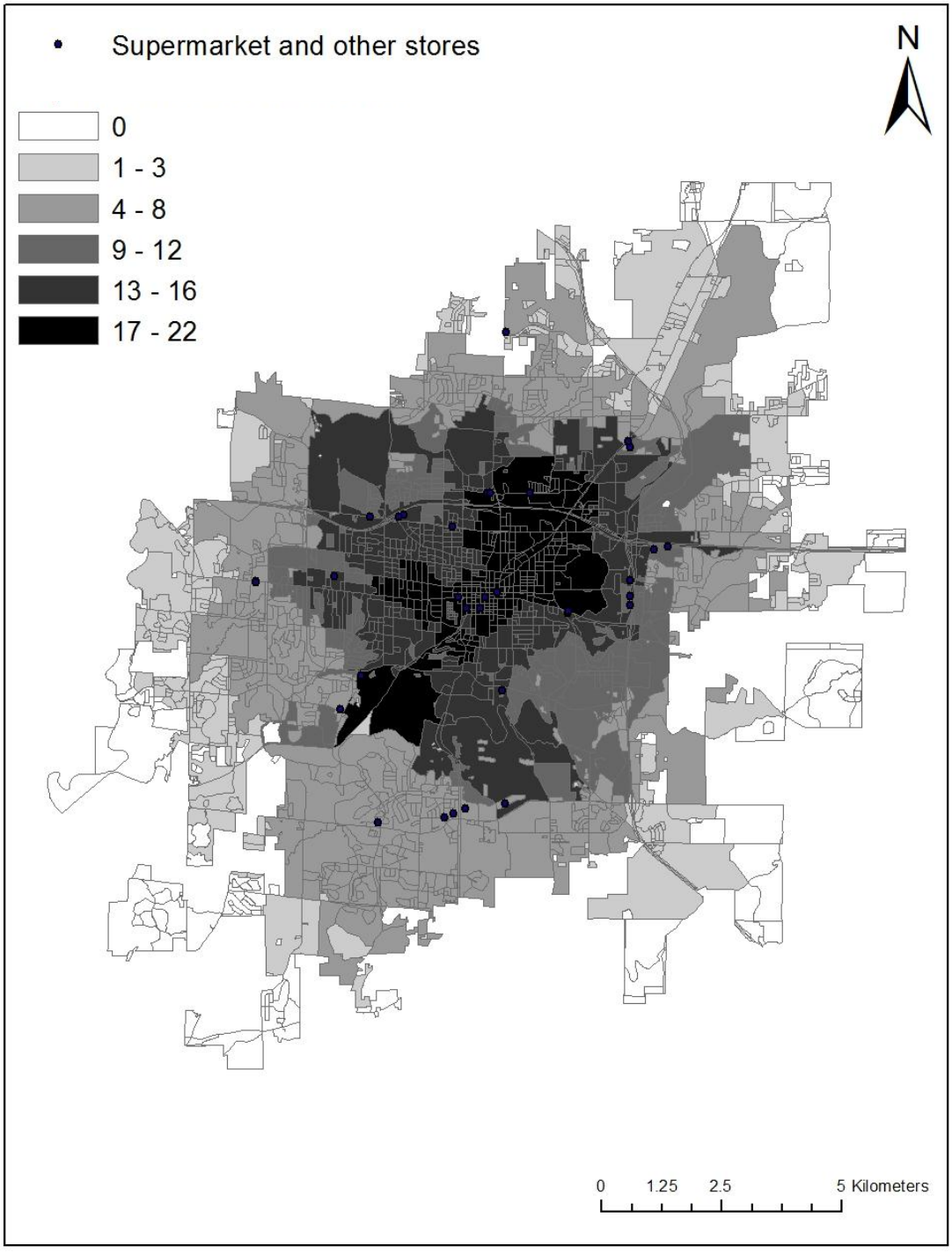

Figure 41. Number of supermarkets and other stores within 4,000 meters of Census blocks

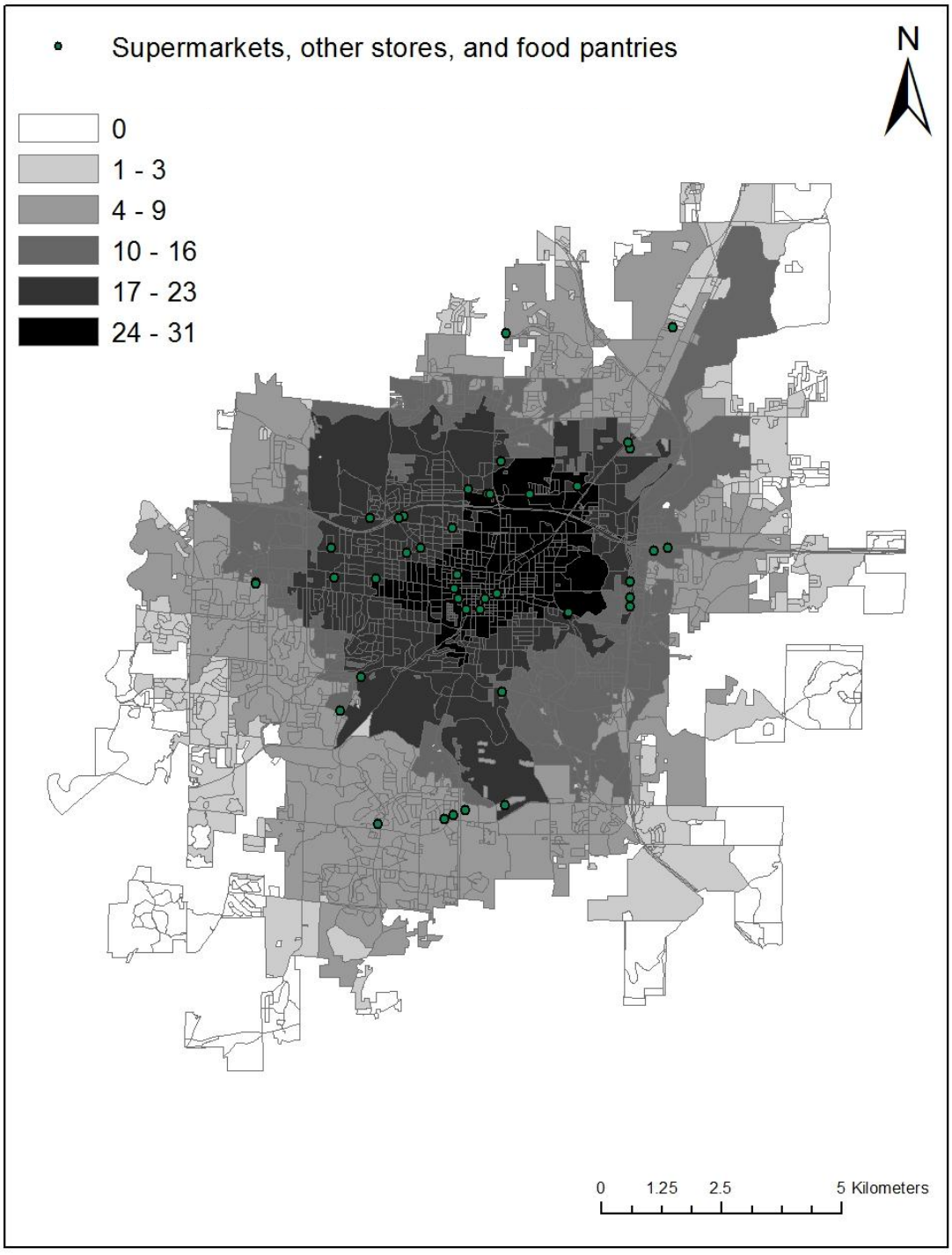

Figure 42. Number of supermarkets, food pantries, and other stores within 4,000 meters of Census blocks

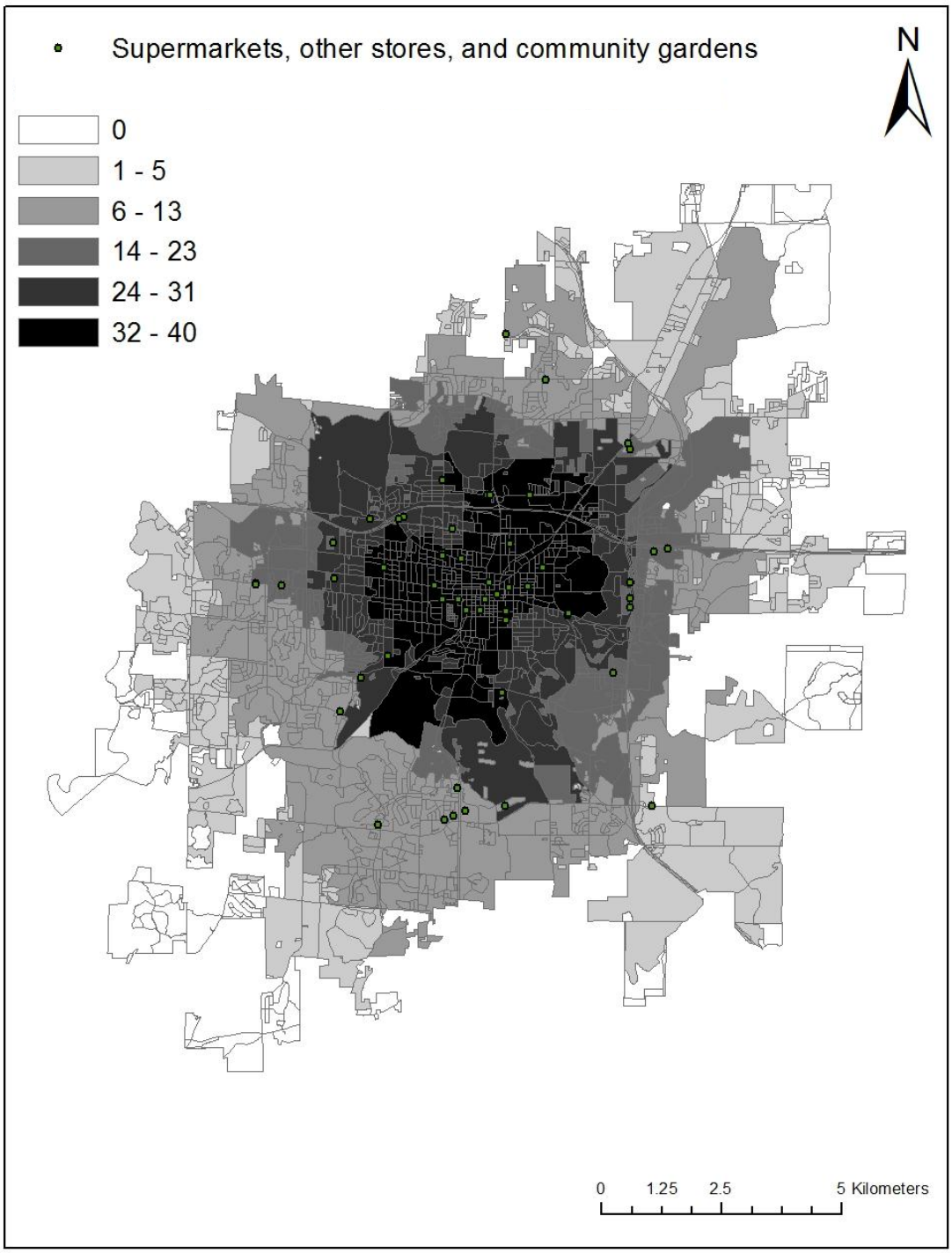

Figure 43. Number of supermarkets, community gardens, and other stores within 4,000 meters of Census blocks

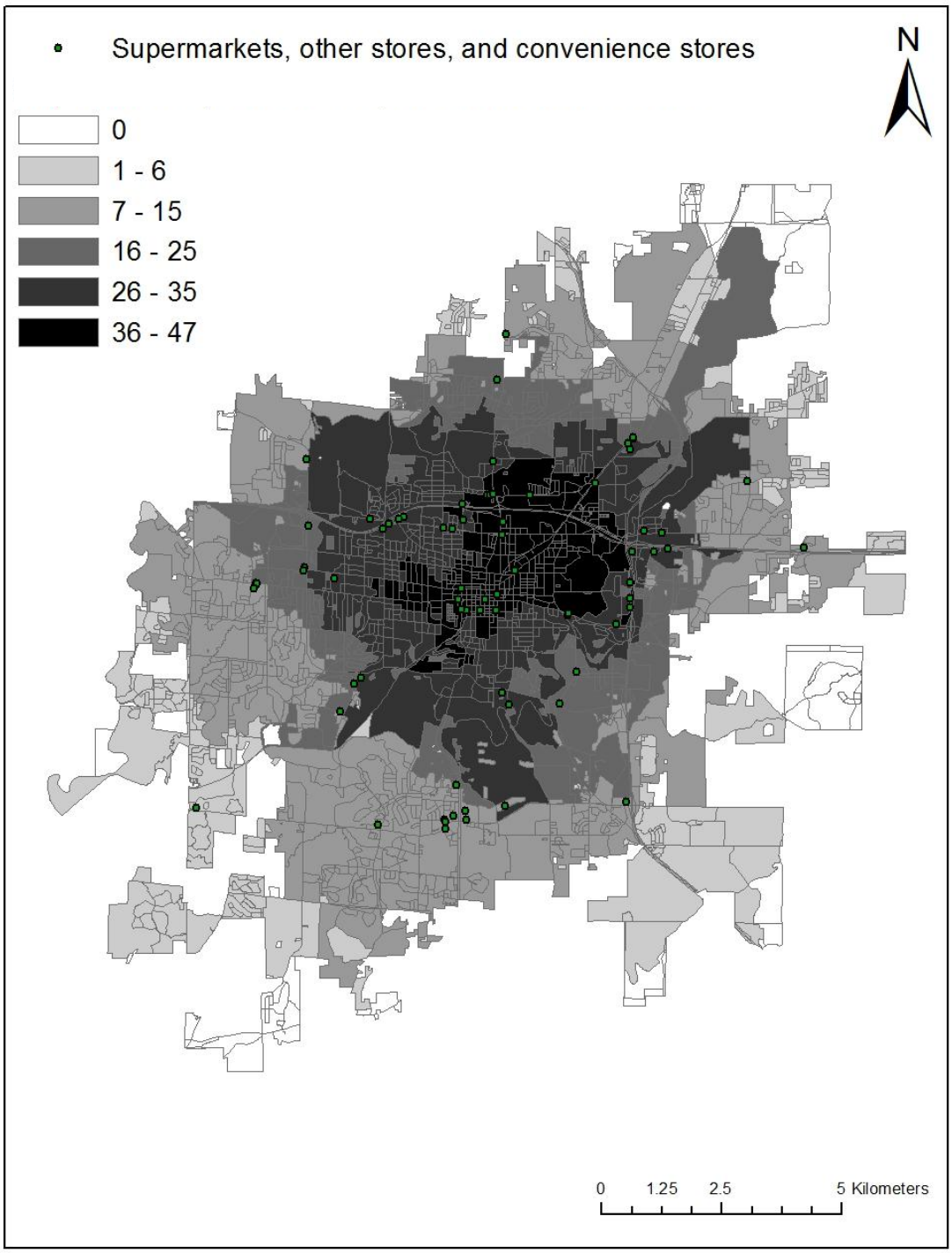

Figure 44. Number of supermarkets, convenience stores, and other stores within 4,000 meters of Census blocks

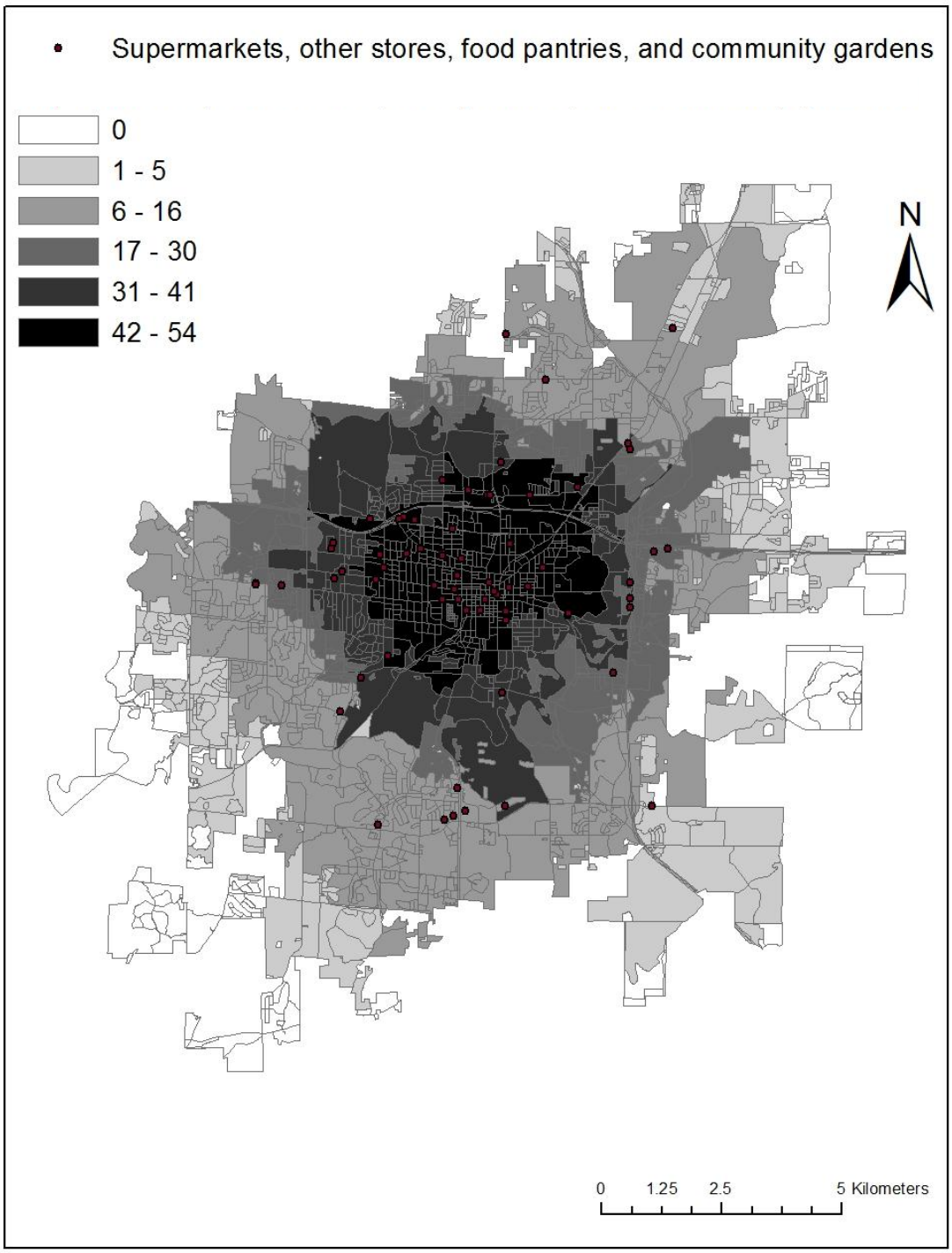

Figure 45. Number of supermarkets, community gardens, food pantries, and other stores within 4,000 meters of Census blocks

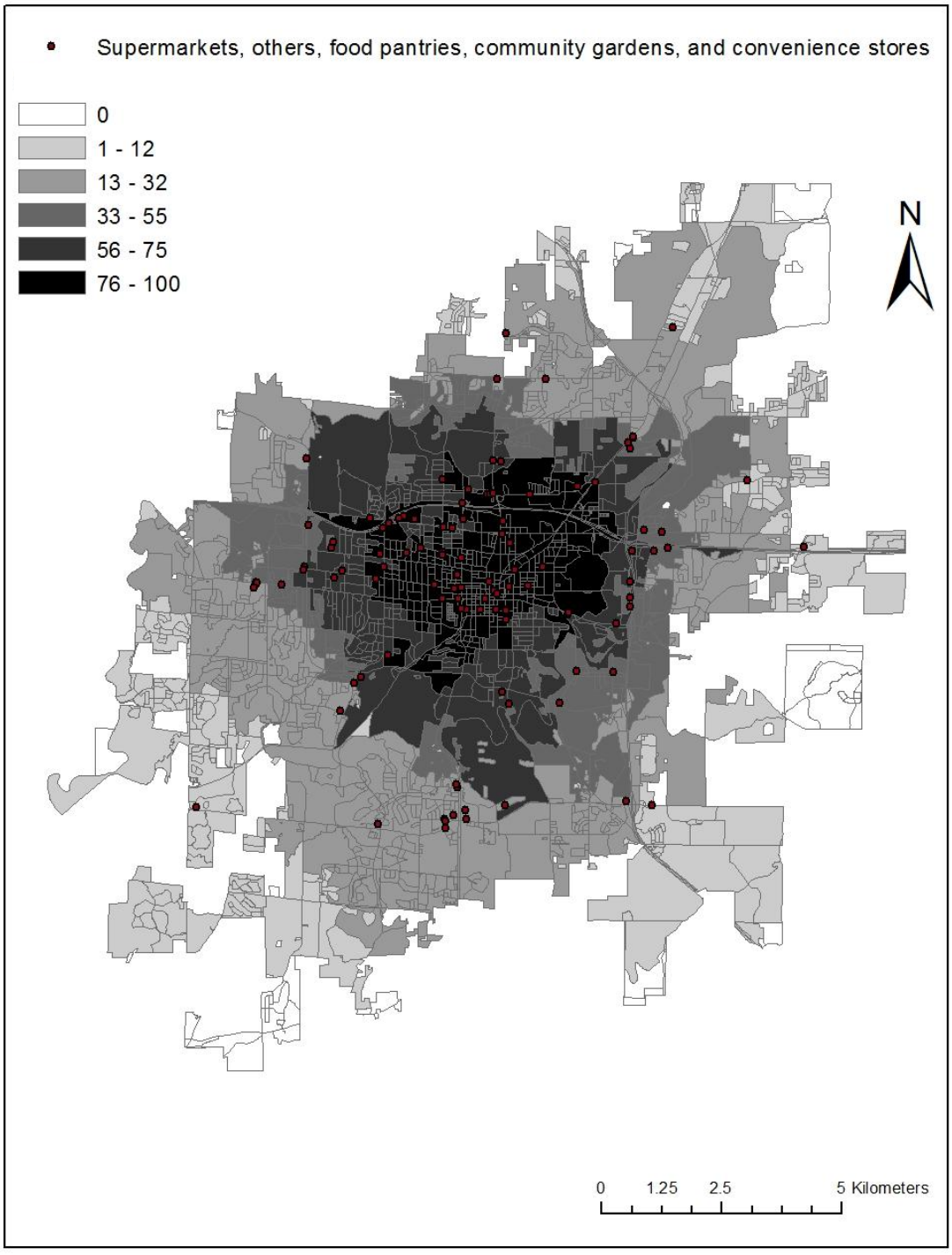

Figure 46. Number of supermarkets, community gardens, food pantries, convenience stores and other stores within 4,000 meters of Census blocks

5.3 Locally Calculated Food Deserts versus USDA Food Deserts

Figure 47 shows the food deserts calculated in this thesis in orange. These food deserts were identified by selecting blocks that were more than 1 mile from supermarkets having greater than 20% impoverished population. These criteria were based off the methods used by the USDA food desert finder. The Census tracts that the USDA(2011 a) designated as food deserts are shown for comparison in pink. Given these same criteria, many more areas of Columbia qualifying as food deserts are identified in this thesis than in the USDA(2011 a) analysis. The USDA (2011 a) reported three census tracts containing 8,823 individuals lived in food deserts in Columbia, MO. The Census block level analysis done for this thesis found portions of 16 more Census tracts (a total of 329 Census blocks), containing 24,524 individuals, that qualified as food deserts. This is a difference of 15,701 people. In other words, the number of individuals found to be living in food desert conditions in this thesis was approximately 278% greater than the number of individuals reported by the USDA (2011 a). The majority of the areas identified are on the East side of Columbia, to the North and South of the USDA food deserts.

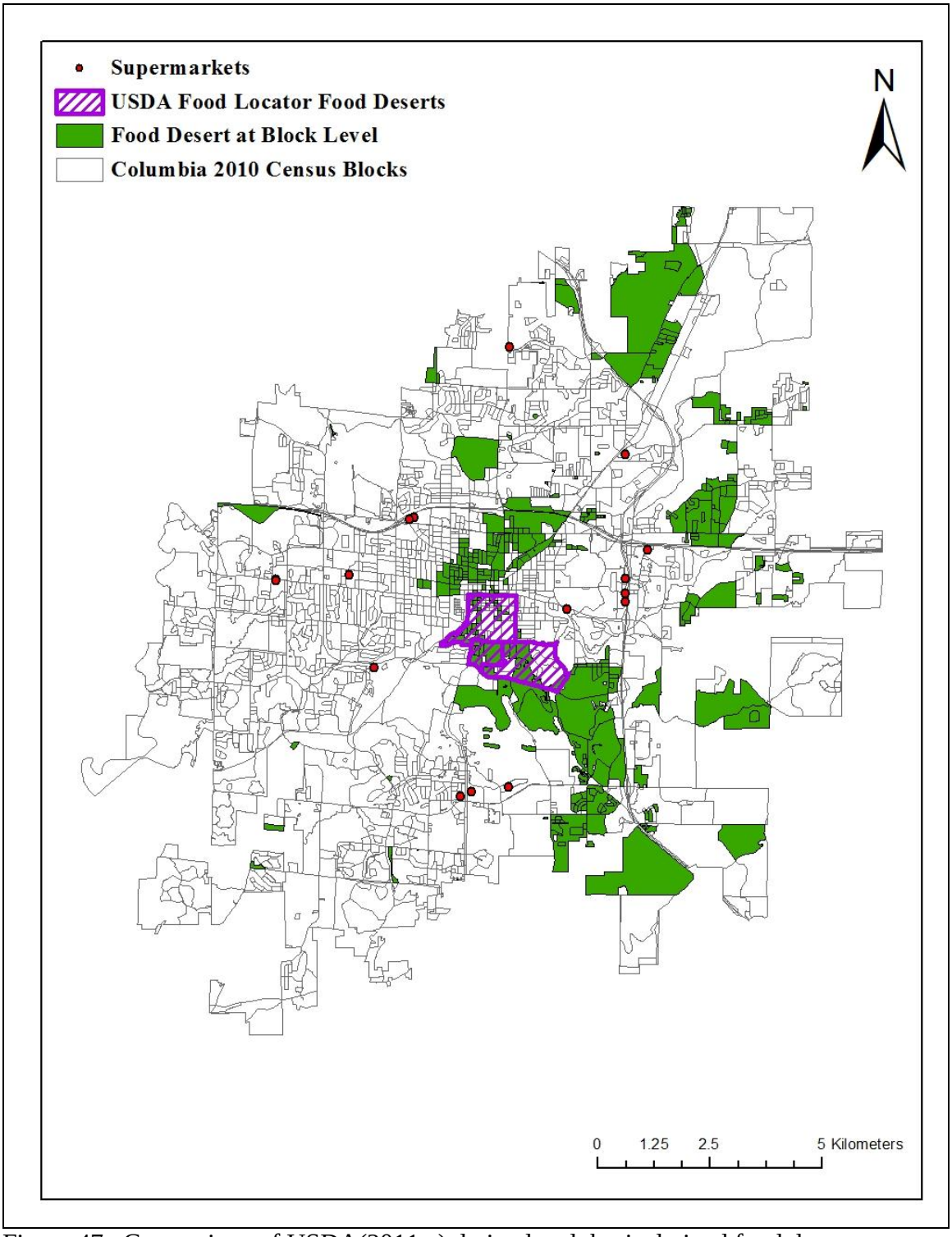

Figure 47. Comparison of USDA(2011 a) derived and thesis derived food deserts

CHAPTER 6: DISCUSSION

The results indicate that the spatial arrangement of supermarkets in Columbia gives rise to patterns of access similar to those described in other food desert studies (Apparicio et al. 2007, Beaulac et al. 2009, USDA 2009, Walker et al 2010). Based on the criteria used, which are comparable to those used by the USDA (2009), there many areas that lack access to supermarkets. The stores are arranged in a ring on the periphery of the urban center and under the USDA 1 mile standard of access the central areas of the city lack sufficient access to supermarkets. Combined with the higher cost and decreased availability of goods in supermarkets and secondary stores there is an apparent difference in access, both geographic and economic, between the center of the city and other areas. However, the areas with the worst geographic access to supermarkets are not in the center of the city but on the very outer edges of Columbia. Based on a purely geographic standard the areas to the southwest, southeast, and northeast of Columbia have the lowest access to supermarkets.

However, other factors are usually incorporated into the designation of food deserts. These other factors are usually places that are negatively impacted by things like poverty, lack of a vehicle, or disability. The USDA(2011 a) included criteria that 20% of the population of an areal unit should be at or below the poverty level and over 1 mile from a supermarket to be considered a food desert. The orange areas in Figure 47 show the Census blocks of Columbia that are further than a mile from a supermarket and are estimated to contain 20% or more of the people at or below the poverty level. The pink areas of Figure 47 show the Census tracts designated by the USDA as food deserts. It is

apparent than the analysis in this study identifies many more areas that could be considered food deserts based on the criteria of income and distance.

Another major area categorized as a food desert is the Southeastern part of the city. This area may be home to a large number of students and therefore the income information reported to the Census could be misleading since presumably a large number of them are being supported by their families. Other significant areas appear to be in the Eastern side of the city. There are some scattered areas to the west and southwest as well. A population filter was not used to identify the areas shown in Figure 47 so many of the smaller, scattered blocks selected have only a handful of people. Nonetheless, they are included in the results since they did meet the distance and income criteria for being a food desert. It is important to note that low income areas can exist even in areas that are high income on average and conversely, high income households can exist in areas of low income.

While the central area of Columbia lacks supermarkets at the Census block level it is close to food pantries and community gardens. This suggests at the least that alternative means of obtaining fruits and vegetables may be possible for people living in this area of the city. If these sources of food are utilized they could be a way for residents to obtain fresh produce without relying on a supermarket. However, community gardens are seasonal and require an investment of time that many households may not have. Similarly pantries that rely on donations may not be a consistent or reliable source of fresh produce. Other parts of the city, such as the Northeast, lack access to pantries and community gardens and thus may be in a more precarious environment than the central area of the city.

This study did not find evidence of minorities having worse access to supermarkets, community gardens, or food pantries based on ethnicity. The portion of the population that identified as White in the Census had the highest average distance from these food sources. Some demographic categories (e.g. American Indian) of the Census were not investigated since they constituted a much smaller percentage of the population than the other categories. However, those who identified as Black in the Census were found to be closer on average to fast food restaurants, convenience stores, and liquor stores which are sometimes considered to be negative sources of food or "food swamps" (Rose et al. 2009).

The results for the food store surveys (Table 4) support the previous literature that assumed that supermarkets had the most abundant selection of goods at the cheapest prices. Coupled with the year-round availability of produce they offer, these results suggest that having access to supermarkets makes it easier to obtain fresh fruits and produce. However, the market basket price of the TFP includes the cost of many goods that are not fresh or even frozen produce. Access to fruits and vegetables is the main component of access to healthy foods (according to the literature). Therefore an alternative basket of only fresh and frozen (or otherwise preserved) produce may be useful for determining if there is a significant difference between the costs of just produce.

While not all specialty stores and smaller groceries in Columbia were surveyed in this study, the results from the selection of those stores surveyed suggests that food at these stores is more expensive in general than that found at supermarkets.

The supermarket with the highest market basket price ($305.81) was Schnuck's which had 87 of the 87 total items on the market basket list. Clover's (considered a specialty store) had 70 out of 87 items but had a market basket cost of $395.54. Other specialty stores (World Harvest and Root Cellar) had a lower number of the market basket items (both had 32 items out of 87) but had average item prices higher than any other store type. Convenience stores had the lowest number of items available (28 for Casey's, 11 items for Fastlane, and 9 items for Petro Mart and the second highest average item prices. Average item price is a rough measure of costliness, however, because not all items are the same cost and so the inclusion or exclusion of items could potentially influence the average price, especially when the number of items is low and a high or low price on any one item affects the average considerably. Figure 15 suggests that the location of the secondary stores would increase access for the general population. However, given the higher costs associated with these stores it is uncertain whether they would be attractive to low income consumers.

The supermarket store access results (Figure 4) reveal the tendency for supermarkets in Columbia to cluster near each other. On the West, East, and South of the city there are clusters of two or three major supermarkets in close proximity to each other. This results in areas of highly overlapping service areas in some places while other parts of the city, such as the center of the city and the outer edges, are only covered by a single store, if at all. The results of these overlapping service areas are dependent on the distance used. At 1,600 m (~1 mi) the center of the city has very low access and is designated as vulnerable. Increasing the access distance can give different results and at the extreme service distance of 10,000 m the center of the city is designated as one of the

least susceptible areas of the city in regards to supermarket access. This suggests that the results of analysis are highly sensitive to the definition of access chosen.

This study attempted in some ways to address the influence that somewhat subjective measures of access can have on the results. This was the reasoning behind not choosing a single service standard but rather stepping through a series of them. Doing so allowed for the creation of access curves as seen in Figures 3-14. These curves allow one to see how rapidly (or not) access to a food source changes with distance. Steep curves, such as the one in Figure 5, suggest that any improvement in accessibility will benefit a relatively large number of people. Flatter curves, such as in Figure 7, suggest that improving accessibility will only benefit a more modest amount of people. Often times a point of inclination can be seen where the rate of people with access at a given distance decreases. This change suggests that improving access for people beyond this distance will be more difficult since any improvement in accessibility will benefit fewer people than before that distance was reached.

One of the benefits of the methodology used to measure access in this study is that it provides insight toward which areas are at a locational disadvantage to store access. The results of this method can be used to understand the variability of access throughout the entire city. Furthermore, having a measure of access available throughout the entire city allows any chosen measure of access to be selected and matched rapidly to its corresponding, pre-calculated, results. This enables the application of many different access standards, which is useful since the distance at which an individual can access a food source often varies for different segments of the population. For example, elderly populations will be more likely to have a lower access standard for walking to a store

than a young adult and an individual with access to a vehicle will be able to travel further to a store than an individual without a vehicle would be able to in the same amount of time.

CHAPTER 7: CONCLUSION

The results of this paper cast doubt on the utility of national level studies for application at the local level. Using similar criteria as the USDA(2009, 2011 a) studies, the research presented here has identified a completely different geographic distribution of food deserts. The main differences in methods applied was the use of smaller geographical units for analysis (blocks instead of Census tracts), as well as a more complete, locally collected set of food suppliers, better representation of access cost (i.e. network distance), enhanced understanding of food price variation (i.e. market basket survey), and avoidance of specific socio-economic classifiers.

As opposed to other studies that chose a service standard for access before performing the analysis this study assumed no criteria for access at the outset and instead applied a range of service standards that could then be used afterwards to examine access at any chosen standard and to understand how access changed for the population throughout that range. This provides a more flexible measure that can be applied to various groups that may have different capabilities to access food sources.

The market basket assessment is a unique aspect of this thesis that is rarely replicated in other studies due to the time and effort involved with conducting it. The information gained from it can be used to understand differences between various stores. As the results show, there are considerable differences in prices even between large chain supermarkets.

The results of this thesis support other studies that show there are considerable differences in access to food in the U.S. The methods used go further than many other studies in measuring access throughout the geographic area, rather than at a few,

somewhat arbitrarily chosen, access standards. The importance of the areal unit representing demand for food for which access is assess is highlighted by the large deviations in access observed given the use of Census tracts, block groups, and blocks. The measure showing magnitude (i.e. number of stores) of access for areas of analysis can help identify areas that may have access yet still be vulnerable to the loss of a store. Finally, the market basket assessment provides an added measure of economic cost of food and availability.

Together, these results support other studies that show differences in access to food in the U.S. but also raise questions about the accuracy of large, national-scale, studies when applied at a local level.

7.1 Future Study

This study is an exploration of Columbia's food environment and a comparison of access to food as measured at a national level by the USDA with a local analysis of access to food. Future opportunities for study could move beyond that by performing an analysis of where the construction of a new supermarket would improve access for the greatest number of people. Higher level statistical analysis might be beneficial in describing the differences in the food environment as well. Tests for significant differences in the data might allow researchers to focus on the most important differences between demographic groups.

The bus routes in the city were not included as part of the analysis because they run on the same road network provided in the transportation layer used. Cost in this application is measured by distance rather than time so incorporating public transportation routes does not add to the achieved results. However, the existence of bus

routes could be used in a subsequent study that focuses on potential benefits provided by various types of transportation modes. This type of study could incorporate the access values calculated for the city with a suitable access standard for travel by public transportation. This access standard would presumably be based off the average speed of travel by public transportation relative to other modes of travel like walking or automobile.

Results from studies on food access such as this thesis could be used to inform decisions on how to improve community access to food. For example, PedNet (PedNet 2008) is a non-profit organization operating in Columbia that focuses on improving infrastructure for non-motorized modes of transportation. PedNet has received funding to study and make recommendations on how to improve access to food in Columbia. The results of this study could be useful in helping them identify underprivileged areas of the city and prioritize the improvement of infrastructure to enhance access for these population. PedNet and other organizations likely are potential actors within Columbia that may be able to utilize and build upon these results to achieve their goals of benefitting Columbia residents.

Additionally it would also be beneficial to subsequently compare these findings with the results of focus groups and individual surveys to gain greater insight into how the built environment influences choice and how the assumptions about access made in this study match up with the realities experienced by the residents. The matters of whether the disparities in access reported here correspond to higher incidences of poor health. Information regarding this might be found in data on childhood obesity in the area. Alternatively, a local study could be done to survey individuals about their health,

dietary habits, and well-being. Combined with information about what area of the city they reside in, the results of such a survey could be useful for understanding the role access to food plays in the health of the community.

APPENDIX A- MARKET BASKET

Food Item	Brand	Item weight/unit (desired)	Item weight/ Unit (Actual)	Price (Lowest Cost)
Fruit—fresh				
Apples, any variety (bagged or loose)		Per lb		
Bananas		Per lb		
Grapes (green or red)		Per lb		
Melon (cantaloupe,honeydew, or watermelon)		Per lb		
Oranges, any variety (bagged or loose)		Per lb		
Vegetables—fresh				
Carrots, unpeeled (bagged or loose)		1-lb bag		
Celery, bunch		Per lb		
Green pepper		Per lb		
Lettuce, leaf (green or red)		Per lb		
Onions, yellow (bagged or loose)		Per lb		
Tomatoes (any variety)		Per lb		
Potatoes, any variety		5-lb bag		
Fruit, canned				
Oranges, mandarin(juice or light syrup)		15-oz can		
Peaches, any variety(light syrup)		29-oz can		
Vegetables, canned				
Mushrooms, pieces		4-oz can		
Spaghetti sauce, any variety		26-oz jar		
Tomato sauce, any variety		8-oz can		
Fruits and Vegetables, frozen				

Orange juice, concentrate		12-oz can		
Broccoli, chopped		16-oz bag		
Green beans—any variety		16-oz bag		
Green peas—any variety		16-oz bag		
French fries—any variety		32-oz bag		
Breads, Cereals, and Other Grain Products, fresh				
Bread, white, enriched		1-lb loaf		
Bread, whole wheat		24-oz loaf		
Hamburger buns, enriched		Package of 8		
Rolls, dinner, enriched		Package of 12		
French or Italian Bread,enriched		Per 1-lb loaf		
Bagels, plain, enriched		Package of 6		
Bread crumbs, plain		10-oz can		
Breads, Cereals, and Other Grain Products, dry				
Ready-to-eat cereal—corn flakes		18-oz box		
Ready-to-eat cereal—toasted oats		20-oz box		
Flour, white, all-purpose,enriched		5-lb bag		
Macaroni, elbow-style,enriched		1-lb box		
Noodles, yolk-free, enriched		1-lb bag		
Popcorn, microwave, any variety (unpopped)		9 oz package		
Rice, white, long-grain, enriched		5-lb bag		
Spaghetti, any variety, enriched		1-lb box		
Dairy Products, fresh				
Milk, 1% lowfat		1 gal		
Milk, whole		1 gal		

Cheese, cheddar, any variety		Per lb		
Cheese, cottage, any variety		16-oz carton		
Cheese, mozzarella, whole		16-oz package		
Dairy Products, canned				
Evaporated milk, any variety		12-oz can		
Meat and Meat Alternates, fresh				
Beef, ground, lean		Per lb		
Chicken, fryer, cut-up or whole		Per lb		
Chicken, thighs		Per lb		
Turkey, ground		Per lb		
Pork, ground		Per lb		
Turkey ham (packaged luncheon meat)		Per lb		
Eggs, grade A, large		1 doz		
Meat and Meat Alternates, frozen and canned				
Fish, flounder or cod, frozen		Per lb		
Tuna fish, chunk-style, water packed		6-oz can		
Beans, garbanzo (chick peas), canned		15-oz can		
Beans, kidney, canned		15.5-oz can		
Beans, baked, vegetarian		16-oz can		
Fats and Oils				
Margarine, stick		1-lb box		
Shortening, vegetable		3-lb can		
Salad dressing, mayonnaisetype		32-oz jar		
Vegetable oil, any type		48-oz bottle		
Sugars and Sweets				
Sugar, brown (dark or light)		1-lb bag or box		
Sugar, powdered		1-lb bag		

Sugar, white, granulated		5-lb bag		
Jelly, grape		32-oz jar		
Molasses, any type		12-oz jar		
Pancake syrup, any type		24-oz bottle		
Chocolate chips, semi-sweet		12-oz package		
Fruit drink, refrigerated, any flavor		1 gal		
Fudgesicles, ice milk		Box of 12		
Other Food Items, optional				
Baking powder		10-oz can		
Baking soda		16-oz box		
Chile powder		3.25-oz jar		
Cinnamon		3-oz jar		
Cumin		2-oz jar		
Onion powder		3.5-oz jar		
Garlic powder		4.25-oz jar		
Italian herb seasoning		2-oz jar		
Oregano		0.56-oz jar		
Paprika		2.9-oz jar		
Black pepper, ground		4-oz jar		
Salt, any type		26-oz carton		
Vanilla, any type		6-oz jar		
Chicken bouillon, reducedsodium, cubes		3.75-oz jar		
Catsup, any type		28-oz bottle		
Soy sauce, reduced-sodium		10-oz bottle		
Lemon juice, bottled		32-oz bottle		
Gelatin, powdered, unflavored		Box of 4 envelopes		
Chocolate drink mix, powdered		32-oz can		

Table 6 Thrifty Food Plan market basket(USDA 2002)

APPENDIX B – SUMMARY OUTPUT FOR SUPERMARKETS

Service Standard	Total Pop.	Total Demand Zones	Total Pop. Served	%DemPop Served	Sum Distance	% of Pop with access to one store	% of zones with access to one store	% of Pop with access to two store	% of zones with access to two store
100	108,498	2,698	2,382	0.0219	238,200	0.0214	0.0107	0.0005	0.005
1,000	108,498	2,698	22,875	0.2108	3,511,000	0.1498	0.1178	0.0424	0.0497
2,000	108,498	2,698	60,769	0.5600	6,024,000	0.3113	0.2542	0.1298	0.1471
3,000	108,498	2,698	90,748	0.8364	3,321,000	0.2395	0.2105	0.1993	0.1579
4,000	108,498	2,698	101,180	0.9325	4,408,000	0.0593	0.0896	0.1182	0.1023
5,000	108,498	2,698	105,071	0.9684	2,055,000	0.0268	0.0474	0.0582	0.0701
6,000	108,498	2,698	105,637	0.9736	1,008,000	0.0095	0.0292	0.0115	0.0393
7,000	108,498	2,698	106,585	0.9823	1,225,000	0.0063	0.0144	0.0050	0.0293
8,000	108,498	2,698	107,598	0.9917	0	0.0018	0.0051	0.0124	0.0256
9,000	108,498	2,698	108,489	0.9999	0	0.0005	0.0055	0.0019	0.0130
9,700	108,498	2,698	108,498	1	19,400	3.6867E-05	0.0033	0.0006	0.0056

Service Standard	% of Pop with access to three store	% of zones with access to three store	% of Pop with access to four store	% of zones with access to four store	% of Pop with access to five store	% of zones with access to five store	% of Pop with access to six store	% of zones with access to six store
100	0	0.0004	0	0	0	0	0	0
1,000	0.0185	0.0085	1.84335E-05	0.0015	0	0	0	0
2,000	0.0869	0.0697	0.0235	0.0297	0.0084	0.0085	0	0
3,000	0.205441575	0.2020	0.1187	0.1008	0.0624	0.0648	0.0099	0.0174
4,000	0.239488285	0.22164566	0.156887685	0.1267605	0.19281	0.1549	0.0906	0.0856

		3		63				
5,000	0.1489	0.1434	0.1666	0.1442	0.0934	0.1056	0.1911	0.1616
6,000	0.0437	0.0563	0.1717	0.1749	0.0747	0.0670	0.1661	0.1441
7,000	0.0040	0.0170	0.11621	0.1245	0.0306	0.0481	0.1252	0.1189
8,000	0.0069	0.0118	0.0593	0.0630	0.0127	0.0315	0.0625	0.0852
9,000	0.0084	0.0114	0.0219	0.0174	0.0050	0.0200	0.0347	0.0552
9,700	0.0017	0.0070	0.0092	0.0155	0.0048	0.0122	0.0180	0.0274

Service Standard	% of Pop with access to seven store	% of zones with access to seven store	% of Pop with access to eight store	% of zones with access to eight store	% of Pop with access to nine store	% of zones with access to nine store	% of Pop with access to ten store	% of zones with access to ten store
100	0	0	0	0	0	0	0	0
1,000	0	0	0	0	0	0	0	0
2,000	0	0	0	0	0	0	0	0
3,000	2.76503E-05	0.0007	0.0009	0.0003	0	0	0	0
4,000	0.0341	0.0318	0.0352	0.0418	0.0056	0.0044	0	0
5,000	0.0312	0.0281	0.0507	0.0559	0.0480	0.0489	0.06229	0.0607
6,000	0.0680	0.0670	0.0556	0.0730	0.0940	0.0670	0.04725	0.0478
7,000	0.0757	0.0715	0.0860	0.0837	0.1217	0.0978	0.0651	0.0730
8,000	0.0632	0.0633	0.0665	0.0681	0.1417	0.1286	0.0991	0.084
9,000	0.0444	0.0533	0.0389	0.0507	0.1200	0.1168	0.0864	0.0722
9,700	0.0204	0.0366	0.0310	0.0518	0.0884	0.0956	0.0867	0.0733

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