HHS Public Access

Author manuscript

Trans GIS. Author manuscript; available in PMC 2016 March 29.

Published in final edited form as:

Trans GIS. 2016 February ; 20(1): 79–100. doi:10.1111/tgis.12142.

Spatial Supermarket Redlining and Neighborhood Vulnerability: A Case Study of Hartford, Connecticut

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Abstract

The disinclination of chain supermarkets to locate or pull out existing stores from impoverished neighborhoods is termed as “supermarket redlining”. This paper attempts to map and understand the spatial effects of potential supermarket redlining on food vulnerability in urban disadvantaged neighborhoods of Hartford, Connecticut. Using a combination of statistical and spatial analysis functions, we first, built a Supermarket Redlining Index (SuRI) from five indicators such as sales volume, employee count, accepts food coupons from federally assisted programs, and size and population density of the service area to rank supermarkets in the order of their importance. Second, to understand the effect of redlining, a Supermarket Redlining Impact Model (SuRIM) was built with eleven indicators describing both the socioeconomic and food access vulnerabilities. The interaction of these vulnerabilities would identify the final outcome: neighborhoods where the impact of supermarket redlining would be critical. Results mapped critical areas in the inner-city of Hartford where if a nearby supermarket closes or relocates to a suburb with limited mitigation efforts to gill the grocery gap, a large number of minority, poor, and disadvantaged residents will experience difficulties to access healthy food leading to food insecurity or perhaps a food desert. We also suggest mitigation efforts to reduce the impact of large supermarket closures.

Keywords

Supermarket redlining; Food insecurity; Supermarket Redlining Index; Supermarket Redlining Impact Model; Vulnerability; Geographic Informaiton Systems

1 Introduction

“Supermarket redlining” is a term used to describe a phenomenon when major chain supermarkets are disinclined to locate their stores in inner cities or low-income neighborhoods and usually pull their existing stores out and relocate them to suburbs (Eisenhauer 2001). As with more familier forms of banking and residential redlining, the

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driving force behind supermarket redlining is also an abstraction based on perceived ‘urban obstacles’ (Eisenhauer 2001). These obstacles are lower demand, higher costs of urban land, labor, and utilities, lower profit margins from perishable food items, or risk of thefts in inner cities (Eisenhauer 2001). Coupled with these perceptions, other drivers of supermarket redlining are difficulties of finding locations for new supermarkets (typically 50,000 square feet or more), purchasing multiple adjacent plots, or competition from other investments. For example, a proposal for a minor league baseball stadium is threatening plans for a much needed supermarket just north of Downtown. The City officials argue that the approximately $60 million stadium will boost city's economy, however, opening a supermarket addresses a much greater and critical public health issue related to obesity in Connecticut's capital city (Ghosh 2014). If a neighborhood’s supermarket closes with limited chances of a new one opening, only vacant buildings and demoralized residents are left behind. Supermarkets also tend to drive smaller grocery stores out of business when they move in; so when they relocate or close down, residents face difficulties in accessing healthy and affordable food—thus widening the *grocery gap*, increasing *food insecurity*, and perhaps creating a *food desert*.

In Connecticut, according to the Federal Government’s survey, the percentage of household with food insecurity rose by approximately 33% from 7.6% in 2000–2002 to 11.4% in 2007–2009 (HartfordFoodSystem 2013). During 2010–2012, the value further increased to 13.4% of households. Out of these households, 36.6% were categorized with critical level of food insecurity (Coleman, Nord, and Singh 2012). Recently, Russell and Heidkamp (Russell and Heidkamp 2011) found that a food desert was created when Shaw’s (http://www.shaws.com) closed down in New Haven, a city with similar indicators of income inequality and health disparities as that of Hartford. The Shaw’s supermarket, located in an urban neighborhood, was the most successful retail anchor for the surrounding Dwight Street neighborhood since 1998 to over a decade. It was the *only* full-service supermarket in the nearby residential area with walking distance from hundreds of households with limited or no access to cars. The other retail stores were in the suburban area, which could only be accessible by a car. In Hartford, in the past, 11 out 13 chain supermarkets (almost 85% of the stores) left the city between 1968 to 1984 (Kane 1984) and few supermarkets opened since then to lessen the grocery gap. Even today, residents living in Downtown Hartford and Dowtown North (or DoNo) neighborhoods are at a distance of more than a mile from large to medium sized stores indicating an urban food desert (Martin et al. 2014). In some areas, especially in the neighborhoods of Blue Hills in the north and South End in the south, there is not a single full service grocery store within a distance of 2 miles (Martin et al. 2014).

There is plethora of studies identifying food deserts - both in rural (Hendrickson, Smith, and Eikenberry 2006, Smith and Morton 2009, Hubley 2011) and urban settings (Whelan et al. 2002, Wrigley 2002, Gallagher 2006, Hendrickson, Smith, and Eikenberry 2006, Larsen and Gilliland 2008, Hallett and McDermott 2011) and at different geographies (Cummins and Macintyre 2002, Wrigley et al. 2002, Morton et al. 2005, Pearson et al. 2005, Zenk et al. 2005, Smoyer-Tomic, Spence, and Amrhein 2006, Apparicio, Cloutier, and Shearmur 2007, McClintock 2008, Raja, Ma, and Yadav 2008, Ball, Timperio, and Crawford 2009, Coveney and O'Dwyer 2009, Sparks, Bania, and Leete 2011). Similarly there are studies measuring

food insecurity (Kendall, Olson, and Frongillo 1996, Carlson, Andrews, and Bickel 1999, Olson 1999, Alaimo, Olson, and Frongillo 2001, Hamelin, Beaudry, and Habicht 2002, T.Vozoris and Tarasuk 2003, Drewnowski 2004, Lopez et al. 2005, Tchumtchoua and Lopez 2005, Center 2011); however, there is no study to our knowledge, particularly from an empirical approach that focuses on supermarket redlining as an early indicator of risk for food deserts and food insecurity. The objective of this study, therefore, is to understand the spatial effects of potential supermarket redlining on food vulnerability in disadvantaged neighborhoods of Hartford, Connecticut.

The organization of the paper is as follows. Section 2 briefly discusses the background literature of supermarket redlining in relation to food deserts and food insecurity and section 3 describes the underlying conceptual framework of the proposed methodology. The details of study area, data, and methods employed in this paper are explained in section 4. Sections 5 and 6 then follow with results, discussion, and final conclusions respectively. Limitations and future studies are reported in Section 7.

2 Background Literature

The literature on food desert and food insecurity have increased tremendously in the last decade with several prominent studies, systematic reviews, and case studies (Avilés-Vázquez and Bussmann 2009, Beaulac, Kristjansson, and Cummins 2009, Larson, Story, and Nelson 2009, McKinnon et al. 2009, Walker, Keane, and Burke 2010). In this section we will briefly review these topics with the primary focus on supermarket redlining.

2.1 Food Desert and Food Insecurity

“Food desert” describes a phenomenon where affordable and healthy food is difficult to access. The concept of food desert was first used in the United Kingdom (T.Vozoris and Tarasuk 2003) in the 1990s to describe the rapidly decreasing number of grocers in urban, low income neighborhoods after World War II (Whelan et al. 2002). Th term was first used in the context of public sector housing schemes in Scotland in the early 1990s for the Low Income Project Team of the Nutrition Task Force (Beaumont et al. 1995). Since then, several researchers attempted to define food deserts from different perspectives. Earlier Acheson (1998) defined it as where “*cheap and varied food is only accessible to those who have private transport or are able to pay the cost of public transport*” (p.65). Some of the recent literature identify socioeconomically disadvantaged neighborhoods with limited or inadequate physical or economic access to healthy and affordable food as food deserts (Whelan et al. 2002, Wrigley et al. 2002, Wrigley, Warm, and Margetts 2003, Smoyer-Tomic, Spence, and Amrhein 2006, Apparicio, Cloutier, and Shearmur 2007, Larsen and Gilliland 2008). The United States Department of Agriculture (USDA) measures food desert in the following way: A census tract is considered a food desert if it meets a certain threshold of poverty, and if at least 500 people or one-third of the population reside more than a mile from a large grocery store (USDA). USDA’s definition of food desert is the most widely used. In terms of methodological exploration, researchers use different techniques to delineate food desert and there is no clear agreement on what measures are absolutely necessary in identifying food deserts. Initially researchers focused on the number of food stores, ratio of stores per unit area in a neighborhood (Cummins and Macintyre 2002,

Morland et al. 2002, Moore and Roux 2006, Block and Kouba 2006), or the minimum distance to the nearest food stores (Zenk et al. 2005). Researchers who argue that food deserts do not have clear boundaries began using GIS, remote sensing, and complex modeling techniques to dilineate food deserts (Hallett and McDermott 2011, Sparks, Bania, and Leete 2011, Sadler, Gilliland, and Arku 2011). Some have also used mixed methods to measure accessibility to food stores (Hallett and McDermott 2011).

"Food insecurity" describes a condition where people have limited access to sufficient, safe, and nutritious food to meet their daily need for healthy living (Olson 1999, Hamelin, Beaudry, and Habicht 2002, Lopez et al. 2005). Typically residents living in a food desert with limited access to healthy food experience issues of food insecurity but the impact is disproportionaelty higher among vulnerable populations due to lower socioeconomic status, ethnic minority status, old age, and existing negative health coutcomes (Morland et al. 2002, Zenk et al. 2005, Raja, Ma, and Yadav 2008). Zenk et al. (2005) found that even within low-income neighborhoods, residents living in areas with higher proportion of African-American population had to travel on an average 1 to 1.25 miles more to the nearest supermarket than neighborhoods with predominantly white population. White neighborhoods, on the other hand, had almost 4 times more supermarkets compared to neighborhoods with significantly higher balck population (Morland et al. 2002). In tems of prices, majority of research showed that the poor had to pay more for healthy foods (Chung and Myers 1999, Morland et al. 2002, Hendrickson, Smith, and Eikenberry 2006, Jetter and Cassady 2006). In a case study conducted in the Twin Cities Metropolitan Area of Minnesota, Chung and Myers pointed out that big chain supermarkets had much lower price but were not likely to locate in poor areas (Chung and Myers 1999). Non-chains and small stores were more likely to locate in impoverished areas where typically choices for fresh food were limited with abundant varierty of high-calorie packaged foods at higher prices (Chung and Myers 1999). Researchers, however, from other countries had different findings. Unlike in the United States, study sites in Canada, Australia and New Zealand (Smoyer-Tomic, Spence, and Amrhein 2006, Apparicio, Cloutier, and Shearmur 2007) showed that middle-income communities had the most access to supermarkets and were better served by food stores. Cummins and Macintyre (2002) argued that in United Kingdom, wealthier and poor neighborhoods had no statistically significant differences in access to supermarkets, food prices, or food availability.

2.2 Supermarket Redlining

The concept of retail redlining is less explored in the literature and adaptation of this abstract idea to "supermarket redlining" is even more limited and perhaps challenging and controversial. Redlining, in general, is a practice in banking and insurance companies when they decide to deny, stop, or charge higher from residents living in marginalized and vulnerable neighborhoods (Kane 1984). Typically, a "red-line" will be marked on a map to delineate those specific areas (Sagawa 1999). Later D'Rozario (2005) defined retail redlining as "*A spatially discriminatory practice among retailers, of not serving certain areas, based on their ethnici-minority composition, rather than on economnic criteria, such as the potential profitability of operating in those area*" (p.175). In our study, we extend the definition of redlining to supermarket redlining where chain supermarkets either – i) close

down, ii) relocate to suburban areas, or iii) new stores do not open in urban areas not only to due to discriminatory reasons but also for a host of other related factors. These factors can be broadly divided into two categories – i) stereotypes as "perceived urban obstacles" (Eisenhauer 2001) and ii) "logistical obstacles" related to retail business (Shaffer 2002, Raja, Ma, and Yadav 2008).

Examples of perceived urban obstacles in a city are as follows. i) *Profitability:* Supermarket chains often cite that low rates of profit margin and higher cost of overheads as barriers to investment in neighborhoods where demand for food items is low due to low-income shoppers, lower volume of sales per customer, and smaller per trip purchases (Eisenhauer 2001, Shaffer 2002). ii) *Crime*: Higher crime rates in low income urban neighborhoods including employee theft, shoplifting, and dishonesty are also central to the reasons of supermarket closures (Shaffer 2002). High crime is also related to higher rates of insurance and greater difficulty of getting loan approvals to open new stores. iii) *Cultural Biases*: Another important reason why supermarkets avoid inner-city neighborhoods is a perveived anxiety based on cultural biases about the inner city and minorities (Zenk et al. 2005, Raja, Ma, and Yadav 2008, Ball, Timperio, and Crawford 2009, Sugrue 2014). In Moreland et al's multi-site study (Morland et al. 2002) the racial discrepancy was evident from their findings that predominantly white neighborhoods had 4-times as many supermarkets than black neighborhoods. Mark Green – former New York Consumer Affairs Commissioner (Shaffer 2002) said there is a "*knee-jerk premise that blacks are poor and poor people are a poor market*"(p.25). Logistical obstacles on other hand include: i) difficulties of finding locations for new stores, which are typically 50,000 square feet or more, ii) purchasing multiple adjacent plots, iii) higher cost of tax rates, insurance, and utilities (Eisenhauer 2001, Shaffer 2002), iv) zoning restrctions and contamination of sites that may require remediation before new stores can be constructed (Shaffer 2002), v) investors may not understand the diversity of food needs and desires of the racially mixed population, and v) hindrances from local politics (Shaffer 2002).

In the United States, isolated incidents of supermarket redlining (i.e. one of three scenario mentioned above) began in 1960s and since then the trend has been on the rise (IFDP 1997). For example, in Boston, Massachusetts, 34 out of 50 big chain supermarkets had closed since 1970s. In Los Angeles county in California, the number of supermarkets decreased from 1068 in 1970 to 694 in 1990 (Turque 1992). Safeway, a well known supermarket chain, closed more than 600 stores in the country from 1978 to 1984 (Eisenhauer 2001). Many of these stores were the primary or only source of affordable, safe, and acceptable quality of meat and produce in their neighborhoods. In Hartford, 11 out 13 chain supermarkets (almost 85% of the stores) left the city between 1968 to 1984 (Kane 1984). Incidents of such kind are still happening today (Eisenhauer 2001, Raja, Ma, and Yadav 2008, Russell and Heidkamp 2011).

In recent years, city of Hartford also experienced several supermarket closures leaving behind unhappy residents and an even wider grocery gap than the past. Market at Hartford 21, an upscale grocery store located in Downtown Hartford was *only* open for six months when it finally closed in September 2011 (Haar 2011). It used to provide various healthy and nutritious ready-to-eat meals, some fresh produce, and even few organic items. It was

becoming “a downtown favorite” as quoted by Tiff (2011) and *“it’s very nice having a basic grocery store with some basic needs close by”* (Jimmy 2011). Central supermarket, located in the Farmington Avenue of Hartford, was closed on May 2014 which had been described as “*a huge loss to the West End since this area does need a grocery store”* (Emily 2012). West Hartford’s Crown Supmerkaret also plans to close after more than seven decades of service to the community. A local resident, who had shopped at Crown for her entire life said, *“I don’t know what I’ll do. I’ll be devastated if it closes. I am there once a week for a big order”* (Jacobson 2014).

Incidents of supermarket redlining caused due to either closing down of existing supermarkets, relocation of supermarkets in the suburbs, lack of investments to construct new ones, or combination of these scenarios will disproportionaelty affect neighborhoods with low-income vulnerable residents. It will increase the difficulty of accessibility and availailty of healthy food choices. Low-income residents usually do not have enough economic support and/or access to transportation (e.g. personal cars) to travel that “extra” distance to buy healthy food from other stores or from chain supermarkets in the suburbs. In terms of affordability, low-income consumers often have to pay more for shopping at the local stores where stock is limited and sometimes of poor quality (Kaufman et al. 1997, Morland et al. 2002, Hendrickson, Smith, and Eikenberry 2006, Andreyeva et al. 2008). Therefore as stores close, vulnerable urban residents are either traveling farther to purchase nutritious, competitively priced groceries or paying inflated prices for low quality, processed foods at the corner stores. These situations, affecting both individual health and health of a neighborhood, widen the urban grocery gap, increase food insecurity, and perhaps create a food desert.

3 Conceptual Framework

“Supermarket Redlining Index” (SuRI) is an index, which ranks the chain supermarkets based on certain parameters. These parameters are location, presense of local grocery stores in close proximity, sales volume, employee count, accepts SNAP (Supplemental Nutrition Assistance Program) and/or WIC (Women, Infants, and Children) coupons, size of the service area, and population density of the service area. Detailed specifications of the index with variable definitions are explained later in section 4.3. If a supermarket with high SuRI value closes or relocates to a suburb with limited possibilities of a new store opening, the risk of supermarket redlining increases. Given such risk, the “Supermarket Redlining Impact Model” or SuRIM identifies *places* or location of neighborhoods where the impact of food vulnariabilty will be critical. The model is an extension of Cutter’s hazards-of-place model of social vulnerability (Cutter 1996, Cutter, Mitchell, and Scott 2000, Cutter 2003). See Figure 1.

According to Cutter’s model, risk and mitigation interact to create an initial hazard potential (Cutter, Mitchell, and Scott 2000, Cutter 2003). In our framework, *risk* is the likehood of the occurrence of supermarket redlining i.e. scenarios where a supermarket closes down and/or relocates to suburban neighborhoods from inner cities. The magnitude of the risk will further depend upon parameters such as 1) the source of the potential risk (e.g. location of the store), 2) type of the risk (e.g. rank of the store calculated from SuRI), and 3) the impact of

the risk (high-consequence: if it is the only full-sized supermarket in the neighborhood, and low-consequence: if there are other alternatives to fill the grocery gap). Risk of supermarket redlining then interacts with *mitigation* (e.g. increasing investments to open new stores, increasing stocks of fresh produce in the existing corner stores of the neighborhood, open farmers') to produce the *hazard* potential of increasing food insecurity and food deserts. Risks can either be reduced by good mitigation policies or amplified by poor or nonexistent mitigation practices. This is typically the case for inner city urban areas where a combination of perceived and logistical obstacles creates disinvestment for new stores and increases the likelihood of supermarket redlining.

The hazard of increasing food security or difficult access to healthy food interacts with underlying *social fabric* of the neighborhoods to creare *social vulnerability*. The social fabric (including sociodemographic, economic, and cultural characteristics, awareness, perception, and experiences of the neighborhood residents) affects the overall capacity to respond to food insecurity. For example, if an important supermarket closes down in a neighborhood, the impact would be disporpotionately critical among low-income reisdents with limited access to cars compared to others who have the resources to travel farther for buying fresh produce. The *food access* filter includes indicators describing the food environment or foodscapes of the neighborhoods. The indicators are proximity to other smaller grocery and corner stores, availability of fresh produce in these stores, variety or diversity of food items to satisfy the need for ethnically diverse population, and alternative sources of healthy food at seasonal farmers' markets. With the risk of supermarket redlining, the presence or absence of these indicators ineteracts with the hazard of potential food insecurity and food deserts to produce food access vulnerability. Similar, to social vulnerability, the impact of the hazard will be disproportionely higher for the residents with fewer food access indicators to fill the grocery gap. Finally, the social and food vulnerability parameters mutually relate and produce the places-of-food vulnerability outcome or in other words *locations of disadvantaged neighborhoods with critical food vulnerability*. Similar to Cutter's model, the places-of-food vulnerability has a feedback loop to the initial risk (supermarket redlining) and mitigation (to reduce the risk of supermarket redlining), allowing for enhancement or reduction of both risk and mitigation, which in turn would lead to increased or decreased places-of-food vulnerability (Figure 1) (Cutter, Mitchell, and Scott 2000, Cutter 2003).

To operationalize the conceptual framework, we focused on one input element (risk) and three outcome elements (food access vulnerability, social vulnerability, and place-of-food vulnerability) of the model. SuRI measures the location and magnitude of risk from potential supermarket redlining; the social fabric and food access indicators contribute to social vulneraibility and food access vulnerability respectively. The final outcome of place-of-food vulnerability is the product of social and food access vulnerabilities (Figure 1 and 3).

4 Methodology

4.1 Study Area

Hartford, the capital city of Connecticut, has a diverse demographic, socioeconomic, and health disparity indicators. The total population in 2012 was 124,893, which were

predomidantly urban (ESRI 2011). The Hispanic population comprised the biggest ethnic group with 43.4%, followed by 34.1% of non-hispnic blacks and 15.8% of non-hispanic whites (City-Data 2012). Hartford has an estimated poverty rate of 32.9%, more than double the Unites States' poverty rate of 15% (Martin et al. 2012, United-States-Census-Bureau 2013b). The unemployment rate in Hartford in April 2013 was 14.8% (Connecticut-Department-of-Labor 2013), compared to approximately 7% nationally (US-Bureau-of-Labor-Statistics 2014). The 2011 median household income was estimated at $29,169, which is less than half of the estimated median household income for the Hartford County and below the median for the the Unites States ($50,502) (United-States-Census-Bureau 2013a, 2012). 47.9% of children in Hartford live below the poverty line compared to the Unites States' child poverty rate of 21.8%. The youngest members of Hartford are at increased risk of diet-related diseases due to nutritionally imbalanced access to foods in their neighborhoods. A 2012 study found that 37% of preschool children in Hartford were overweight or obese, making the prevalence of childhood obesity among preschoolers more than twice as high as Centers for Disease Control and Prevention (CDC) age and gender body mass index guidelines (University-of-Connecticut's-Center-for-Public-Health-and-Health-Policy 2012).

4.2 Data

The data for this study was grouped into four categories of food retail stores, relevant Geographic Information Systems (GIS) shapefiles, socioeconomic and demographic characteristics, and travel-time to stores. Food stores data were collected from two sources of Connecticut Department of Energy & Environmental Protection's (DEEP 2011) food residual generation mapping project and ESRI's Business Analysis (ESRI 2011). We followed the criteria used in DEEP's grocery store mapping project to categorize the stores included in our study into three groups: 1) large supermarkets with employee count greater than 15 persons (e.g. Shop and Stop), 2) small supermarkets with employee count between 4–14 persons (e.g. Carlos Supermarket), and 3) convenience stores (e.g. 7-Eleven). Based upon this criterion and within a 3-miles buffer around the city of Hartford, we identified 33 large supermarkets, 17 small supermarkets and 73 convenience stores. A 3-miles buffer were used for two reasons, first, the residents of Hartford often shop outside their town limits, and second, to minimize errors from edge effects in the subsequent mapping and spatial analysis (Haefner et al. 1991, Lawson, Biggeri, and Dreassi 1999, Laurance 2000). A variety of methods were used to ensure sample completeness, including online yellow pages, business listings, and more importantly "ground-truthing" of driving through neighborhoods to verify stores names. Out of the 33 identified large supermarkets within a 3-miles buffer around Hartford, 9 were located in the city (Figure 2). For each large supermarket we further obtained the following information: sales volume, employee count, SNAP/WIC coupon status, size of the service area, and population density of the service area.

The GIS shapefiles such as Connecticut's road was obtained from ESRI's Business Analysis dataset, and state, town, and census block-group boundary shapefiles from the Map and Geographic Information Center at University of Connecticut (MAGIC 2013). The socioeconomic and demographic variables were selected from ESRI's Business Analysis dataset at the block-group level. The variables selected for the social fabric indicator of the

SuRIM model were: percentage of elderly population (65+ years), minority and ethnic population (Black and Asian), diversity of race and ethnicity, population with less than high school education, renter occupied household units, unemployment rate, and low income population. The data on travel time by bus and by car from the population centroids of block groups to the retail food stores were obtained by using Google Direction API application. This is a free service provided by Google that calculates the direction (and distance) including the time between locations using an HTTP request with a limitation of 2,500 requests per 24-hour period. We will introduce the details of this technique in a future paper, which is currently under preparation.

4.3 Methodology

We first calculated the potential Supermarket Redlining Index (SuRI) at the store level using five variables (Figure 3A): sales volume ($), number of employee (count), whether the store accepts SNAP and/or WIC coupons (yes or no, will be coded as 1 and 0 respectively), size of the service area (number and area of all block-groups that were assigned to the store as the closest supermarket), and population density (number of person per square mile) of the service area. Sales volume and employee count were the characteristics of the supermarket, which indicated how important that particular supermarket was in serving the community. SNAP-WIC status indicated whether the supermarket accepted coupons from the federally funded food assistance programs designed for low-income households. The service area of the supermarket was determined by using ArcGIS 10.1's Network Analyst functions where a road-network database and the 'Closest Facility' tool were used to calculate the path from each block-group population centroid to its closest supermarket. The average population density of the service area was then calculated and assigned to each supermarket as the fourth variable. So neighborhoods with sparse supermarkets had larger service area and thus larger proportion of urban residents would be at risk if an existing store closed down.

Since the units of these variables were different, each variable was standardized by calculating the ratio of its value to the total value divided by the highest ratio among the block-groups (See formula 1).

$$SD(x)=\frac{x_i}{\Sigma x_i}\Big/\max\frac{x_i}{\Sigma x_i} \quad \text{(Formula 1)}$$

SD(*x*) *is the standardized Redlining Indicator; where*

i is the store

x_i is the variable value of each store;

Σx_i *is the sum of each variable;*

$\frac{x_i}{\Sigma x_i}$ *is the ratio of each variable.*

Value of each standardized variable ranged from zero to one. To generate an aggregate value for SuRI, standardized values were summed for each supermarket. Due to the lack of prior literature and statistical evidence needed to assign specific weights to calculate supermarket

redlining index, all indicators were given the same importance of equal weights (Wood, Burton, and Cutter 2009, Laurance 2000). Table 1 summarized the important steps. The final result was rescaled from 0–10 to be comparable with the values from the SuRIM.

Next, we built the Supermarket Redlining Impact Model (SuRIM) at the block-group level using 11 variables (Figure 3B). We used 7 socioeconomic and demographic variables to describe the *social vulnerability* (SoVI) component of the SuRIM (See Fig.3B). For the *food access vulnerability* (FaVI) component, 4 variables related to access to healthy food in a situation when existing supermarket closed down or relocated to suburbs were included. In figure 3B, variables with "+" and "−" represent positive and negative effect on the SuRIM respectively. The 7 socio-economic-demographic variables were percentage of elderly population (65+ years), minority and ethnic population (Black and Asian), diversity of race and ethnicity, population less than high school education; renter occupied household units, unemployment rate, and low income population. All these social fabric variables had positive impact and increased the value of SoVI or in other words increased the impact of risk (supermarket redlining) on the harzard of potential food insecurity and food deserts.

For FaVI, the transit-time variables were the *additional* travel time that the neighborhood residents would have to travel for groceries by a public transport or by a car in a situation of supermarket redlining. Google Direction API application was used to calculate these transit time variables (by bus and by car) for each block group from their closest supermarket to the second closest one with the assumption that longer transit time would increase the difficulties for accessing healthy food. Travel time by a bus included walking to a bus stop, time on the bus to the store, and then off the bus and walking to the store. The other two variables described the alternative sources of food items in a time of supermarket closures. The variables were the presence and absence of small sized local supermarkets with employee count between 4 and 14 persons and convenience stores. In a situation of redlining and when the second closest supermarket was too far away, these stores would become the primary or sometimes the *only* source of groceries. Local small supermarkets might still shelve limited fresh produce but the convenience stores would typically not have fresh food items at all. Small supermarkets were aggregated by block-groups and the count showed the availability of alternative access to limited healthy food (Martin et al. 2014). We assumed that these stores decreased the impact of the risk of supermarket redlining and used 1 minus the standardized value when calcylating the FaVI. To the opposite, convenient stores typically with no fresh food, increased the food vulberability. This variable was also aggregated at the block-group level and higher the count higher was the FaVI value indicating increase in the risk of exposure to low nutrition food environments.

All of these 11 variables were then standardized using the same method described for the SuRI to create the SoVI (social vulnerability) and the FaVI (food access vulnerability) components. The final outcome of place-food-vulnerability in the SuRIM was the product of FaVI and SoVI (FaVI * SoVI = place-food-vulnerability). Since there were no prior studies that modeled the impact of supermarket redlining and provide insight in choosing the weights, we assigned equal weights to FaVI and SoVI in calculating the product (Cutter 2003).

5 Results

Table 2 shows the descriptive statistics of SuRI values, which ranges from 2.1 to 6.2 with a mean value of 4.1. Based on these values, 33 large supermarkets were grouped into three categories of low (SuRI <3.0), medium (SuRI 3.00 – 4.99), and high (SuRI >= 5.00) SuRI values. There were 3 supermarkets with a service area of 4 block groups in the low category, 25 supermarkets with a service area of 192 block-groups in the medium category, and 5 supermarkets with a service area of 74 block-groups in the high category. Higher SuRI values indicated higher *risk* of supermarket redlining and resulting higher *hazard* of potential food insecurity and food deserts. To the opposite if in a neighborhood a store with low SuRI value closed down or relocated to suburb with limited mitigation efforts to fill the gap, the residents of that neighborhood would either had other supermarkets to shop from in that same neighborhood or had access to car (and or public transportation) to travel to distant stores. Figure 4 is a proportional circle map showing the spatial distribution of stores with SuRI values. Of the 33 large supermarkets, only 9 (27%) were located in Hartford and most of them were in the west and south. The supermarket with highest SuRI value (Bravo Supermarket) was located in northwest of Hartford in Albany Ave. Given there were no other supermarkets or even a small store; this supermarket played an important role as the only provider of fresh food for the residents of the surrounding 27 blockgroups in the northwest area of Hartford. A Walmart, which opened in 2013 at the border of Hartford and West Hartford, had a lower SuRI value, even with highest sales volume and employee count than the other stores. This was due to the presense of other large supermarkets such as Super Stop & Shop and Save-A-Lot in close proximity. Closure of any one of these stores, will therefore, not be a critical loss for the residents.

Figure 5 shows the spatial distribution of the two components of SuRIM – food access vulnerability index (FaVI) and social vulnerability index (SoVI) with SuRI values at the census block-group level. Although FaVI did not showed strong spatial clustering of either high or low values in the study area, several important findings still emerged. First, in north of Hartford and areas just outside the northern city boundary had higher food access vulnerability due to lack of large supermarkets or small-sized local stores and very limited public bus services. Second, block groups with higher FaVI values (5.1 – 7.6) were located in the downtown, DoNo, and northwest. Third, the supermarket with the highest SuRI value was located in a block group in DoNo with highest FaVI, indicating a positive correlation between SuRI (risk) and FaVI (one of the outcome of SuRIM). This supermarket was the closest store from the surrounding 27 blockgroups with no other alternative food stores in the vicinity. In overall, the SoVI was higher in Hartford than the surrounding suburbs. Within Hartford, the inner city areas in the central and north-central region had the highest values with 41–96% of Black population and 38–50% of low-income population. Blockgroups located in the downtown area with higher SoVI also had higher FaVI (5.6 – 7.6) and several supermarkets with medium (3.1–5.0) to high (5.1–6.2) values of SuRI. This indicated a stronger positive correlation between SoVI and FaVI, and a weaker positive correlation between SoVI and SuRI.

The final outcome of SuRIM or the place-food-vulnerability value (FaVI * SoVI = place-food-vulnerability) is shown along with the SuRI values in Figure 6. Based on the SuRIM

values, the 263 block-groups in the study area were divided into three categories of low (66 block-groups), medium (132 block-groups), and high (65 block-groups) values. Our first observation was that the *places* or neighborhoods of inner city Hartford had higher impact of place-food-vulnerability (higher SuRIM values) from the risk of potential supermarket redlining (higher SuRI values). The neighborhoods in the northwest of Hartford had the highest SuRIM values between 15 and 30 with only one supermarket. The impact on these places was further accentuated by the socioeconomic vulnerability of the residents and limited choice and access to healthy food. On the contrary, some affluent suburban areas (West Hartford, Newington and south of Wethersfield), located to the west of Hartford, had lower SuRIM values indicating that the residents living in these neighborhoods were less vulnerable to the hazard of potential food insecurity and food desert even if their large supermarket closed down. This was because the residents were not dependent on only 'one' store and had higher socioeconomic status and easy access to other alternative stores. The pattern, however, was different for the suburbs located east and northeast of Hartford. Towns and cities such as Bloomfiled, South Windsor, East Hartford, and Manchester had medium to high values of SuRIM (6.1–15.0) and lower values of SuRI (2.1–3.0).

The cross-tabulation between SuRI (risk) and SuRIM (place-food-vulnerability) are shown in Table 3. In the lower right cell (i.e. high SuRI and high SuRIM values), there are three large supermarkets, whose services are critical for providing fresh and healthy food to the residents of their service area (43 block-groups). Of these three stores, two (Bravo Supermarket) were located in Hartford and one store (Shop Rite Supermarket) was located on the western edge of Hartford. The socioeconomic status of the residents (approximately 62,000 population) living in these 43 block groups was critical: over half of the population (51%) lived in rented properties, 11% had less than high school education, high proportion of Black population (69%), average unemployment rate at 21%, and 26% with of low income. Therefore the continuation of business for these stores was critical because if any of these stores closed down or relocated to the suburbs and mitigittion efforts were slow or non-existent to close the grocery gap, a significant number of population who were socioeconomically vulnebrable would experience the hazard of food insecurity and food deserts. Residents would either had to drive long distances to another big supermarket or shop at the nearby small local stores, which might not be able to provide fresh fruits and vegetables at affordable prices.

6 Discussions and Conclusion

We highlight major findings of our study here. First, the service areas (block groups) of the supermarkets with higher risk of redlining (high SuRI values) were also the areas with higher impact of place-food-vulnerability (high SuRIM values) i.e. disproportionately affecting the access to healthy food among socioeconomically vulnerable residents. These areas, not surprisingly, were located in the inner-city neighborhoods of Hartford, especially in the north, east, central, and south-central parts. In these neighborhoods, once a nearby supermarket closes (or relocates) and if the mitigiation efforts are slow, a large proportion of vulnerable residents might face food insecurity and related negative health outcomes. However, residents who have the reosurces or the means to travel the 'extra' miles to an alternate supermarket will be less vulnerable to the hazard of food insecurity. The mitigation

efforts (e.g. increasing investments to open new stores, increasing stocks of fresh produce in the existing corner stores, encouraging seasonal farmer's markets) will also affect the severity of the hazard and the final outcome of place-food-vulnerability. Second, some suburban areas such as northwest of West Hartford, Newington and south of Wethersfield had low SuRI and SuRIM values. This indicates that residents living in these neighborhoods are less vulnerable and the existence of cluster of large supermarkets in close proximity provided choices and more options for buying fresh groceries. These places are typically affluent suburban neighborhoods (only 4% low income population and unemployment rate is around 5%) with predominantly white population (over 80%) and with easy access to a number of large chain supermarkets (average number is 4). Third, GIS methodologies particularly network analyses functions and travel-time data obtained from Google Direction API service aided in illustrating these major findings.

The correlation between supermarket redlining index and its impact model identified urban neighborhoods that will face increasing difficulty of accessing healthy and nutritious food if full-service supermarket closes. It raises concerns about food insecurity and food deserts and urges city officials to consider stronger but feasible mitigation policies to fill the grocery gap. Since it is not always possible to open a large supermarket in inner cities due to lack of investments, stable markets, and lack of infrastructure related to easy access to highways, large loading docks for large trucks to unload, or distribution networks (Shaffer 2002, Martin et al. 2014), we suggest other mitigation policies. These suggestions are: a) investing more in fresh food stocks at the exisiting local medium to small sized grocery stores and corner stores (Martin et al. 2012), b) encouraging more urban farms and community gardens to increase options for healthy foods for atleast few months of the year. Martin et. al. (2014) in their recent study using survey data indicated that improvement of quality of food and appearance of the existing smaller local stores can potentially impact the food purchasing decisions of low-income residents in Hartford and mitigate the negative impacts of food insecurity (Martin et al. 2014). Many of the storeowners from small and medium-sized markets in Hartford live locally. Therefore, efforts to improve the business infrastructure and sales of these markets will also support the local economy, which is in line with the principles of healthy, sustainable food systems. Studies have shown that storeowners' established friendships between owners and patrons fosters store loyalty, especially in neighborhoods without a large supermarket (Bloemer and De Ruyter 1998, Walker, Block, and Kawachi 2012). In comparison, large supermarkets tend to be owned by national or often international companies where revenues are not reinvested into the city and the owners might not be at the same level of enthusuam to develop friendship with the local patrons.

7 Limitations and Future Study

The study also had few limitations. First, due to insufficient literature and to our knowledge this being the first attempt to model the impact of supermarket redlining, we used equal weights of FaVI and SoVI in the SuRIM (SuRIM or place-food-vulnerability was the product of FaVI and SoVI) (Cutter 2003). It is possible that in a different study design, FaVI could be more critical than SoVI or vice versa. Second, we calculated accessibility to grocery stores by car and by public transportation. Due to high incidence of crime in some parts of the inner city neighborhoods of Hartford, residents were disinclined to walk to

services and therefore walking distance was not included It is however possible that some residents still walk to grocery stores. Third, we included small supermarkets (with employee count between 4 and 14) as an alternative source for access to fresh food in a situation of supermarket redlining i.e. when supermarket closes or relocates to other areas. However, some small supermarkets may not stock fresh produce or variety of food items for ethincially diverse population of Hartford. The prices of food items in these local stores may also vary significantly. If these small supermarkets have higher price and limited variety, will the residents consider these stores as an alternative for large chain supermarkets? If not, then these local supermarkets are not an alternate source for healthy foods and therefore will increase the impact of supermarket redlining instead of decreasing the impact. To answer this question empirically in a future follow-up study, we are currently conducting a survey to collect detailed data on price, quality, and variety of available food items, and external and internal appearances of the medium and small sized grocery stores in Hartford and adjacent towns.

Acknowledgments

Contributor Information: Debarchana Ghosh, The study is funded by the 'Fund for Innovative Education in Health and Society' awarded by College of Arts and Sciences, University of Connecticut and the National Institute of Health, NIDA K01 (K01DA037794).

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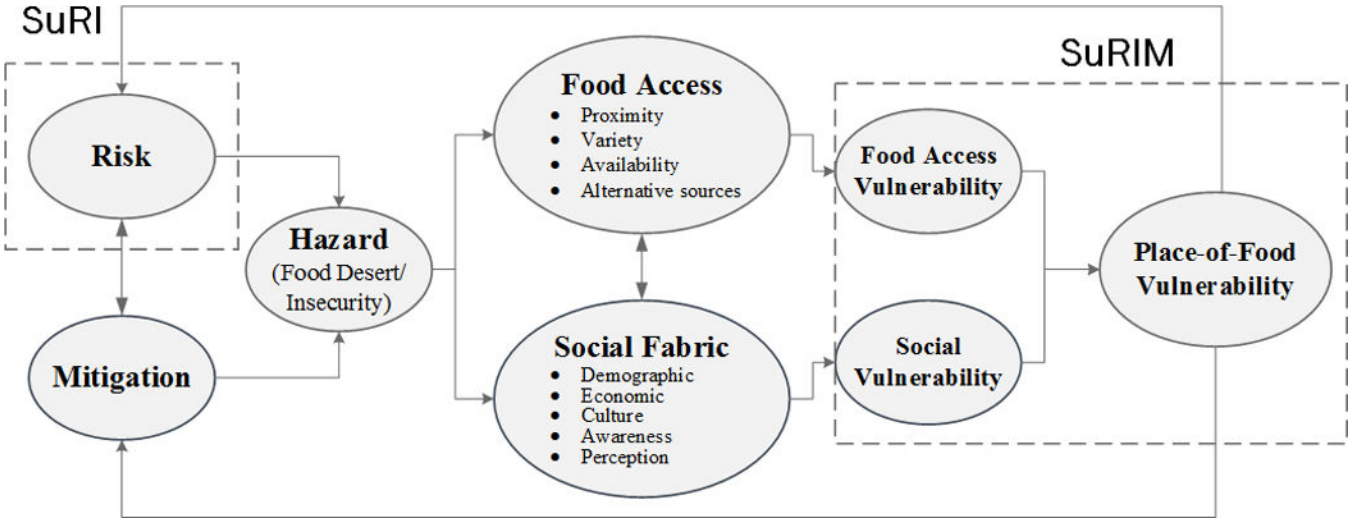

Figure 1.
Conceptual Framework

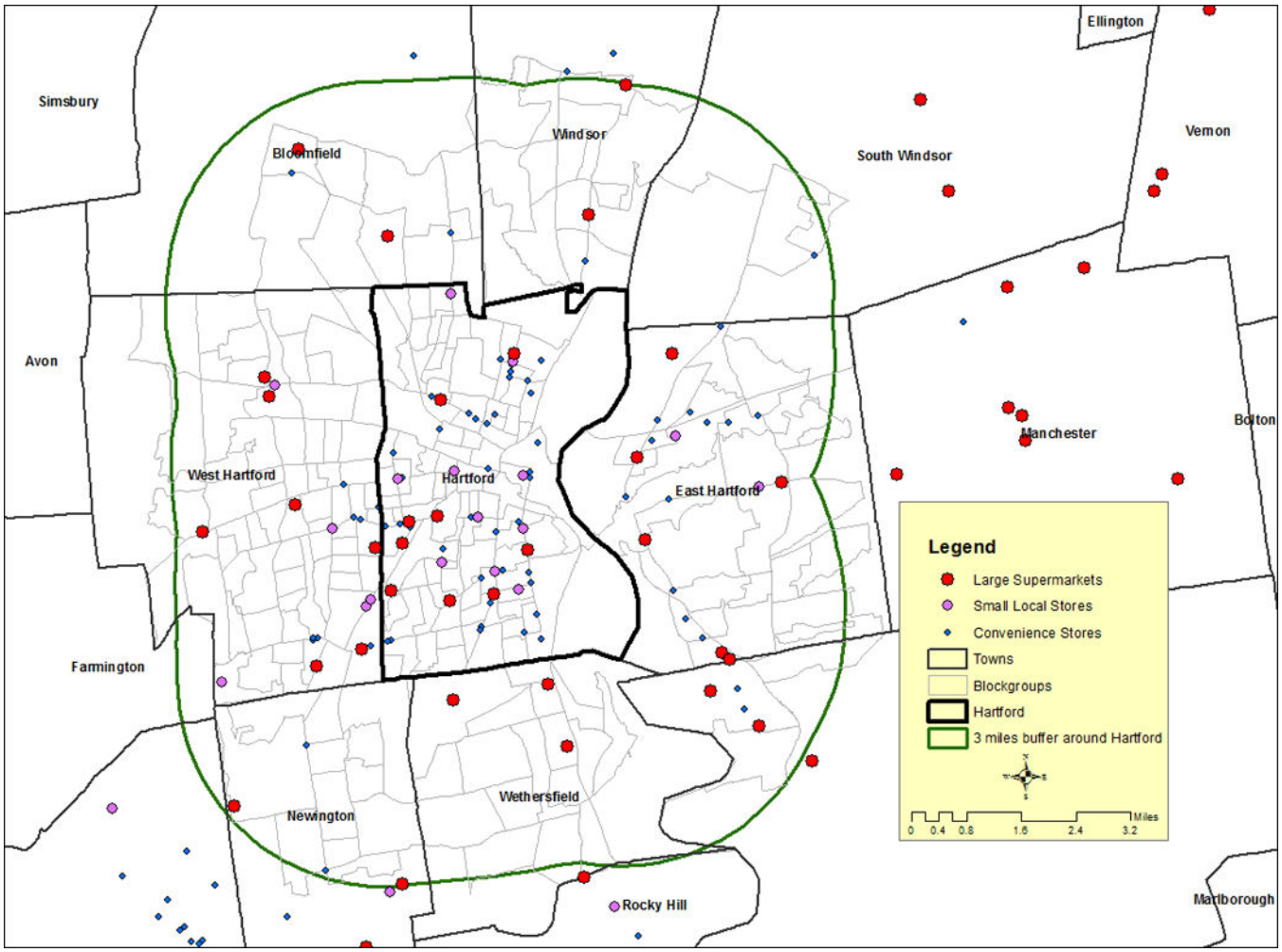

Figure 2.
Location of three categories of food retailing stores in Hartford with a 3-mile Buffer

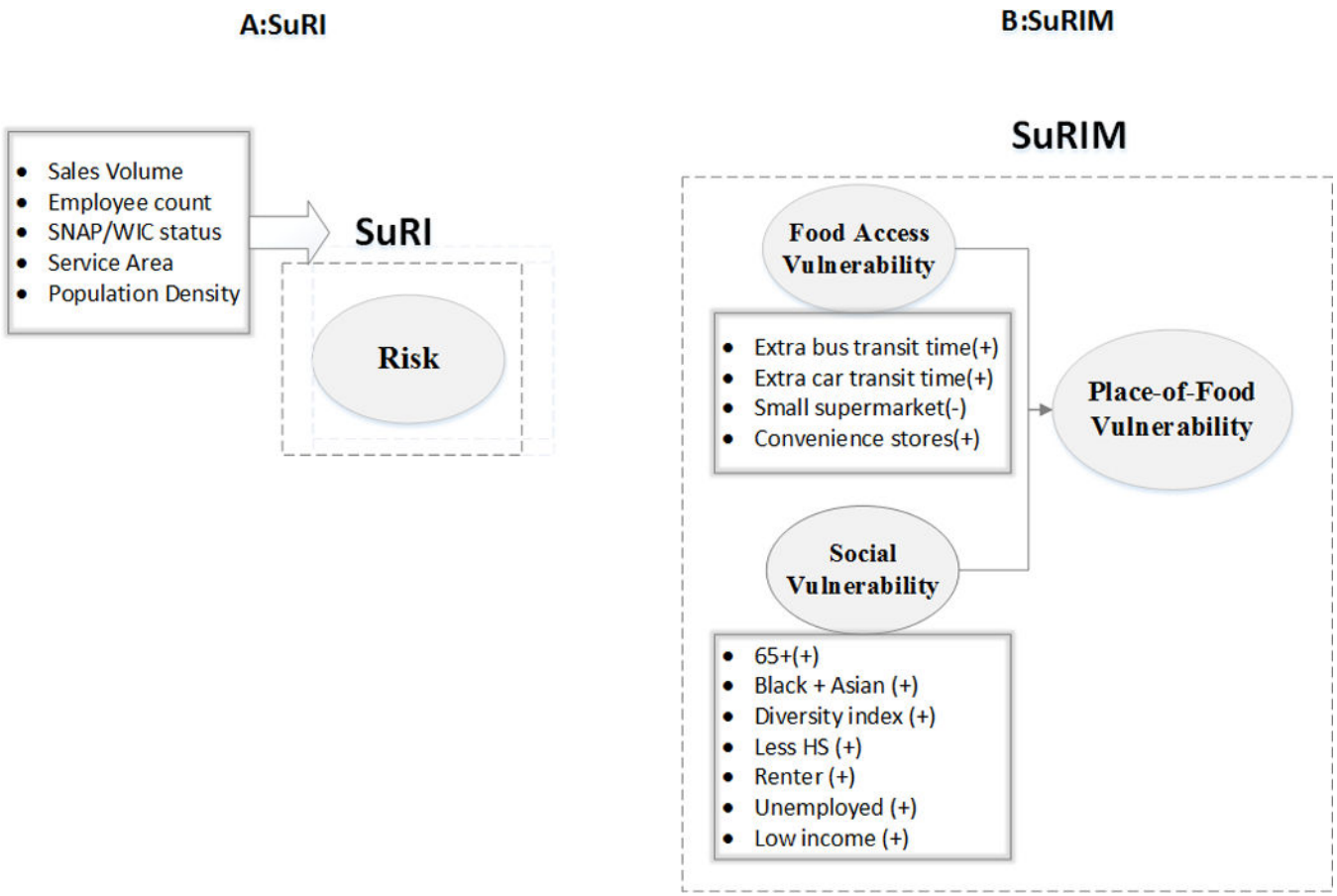

Figure 3.
Operational framework of Supermarket Redlining Index (SuRI) and Supermarket Redlining Impact Model (SuRIM)

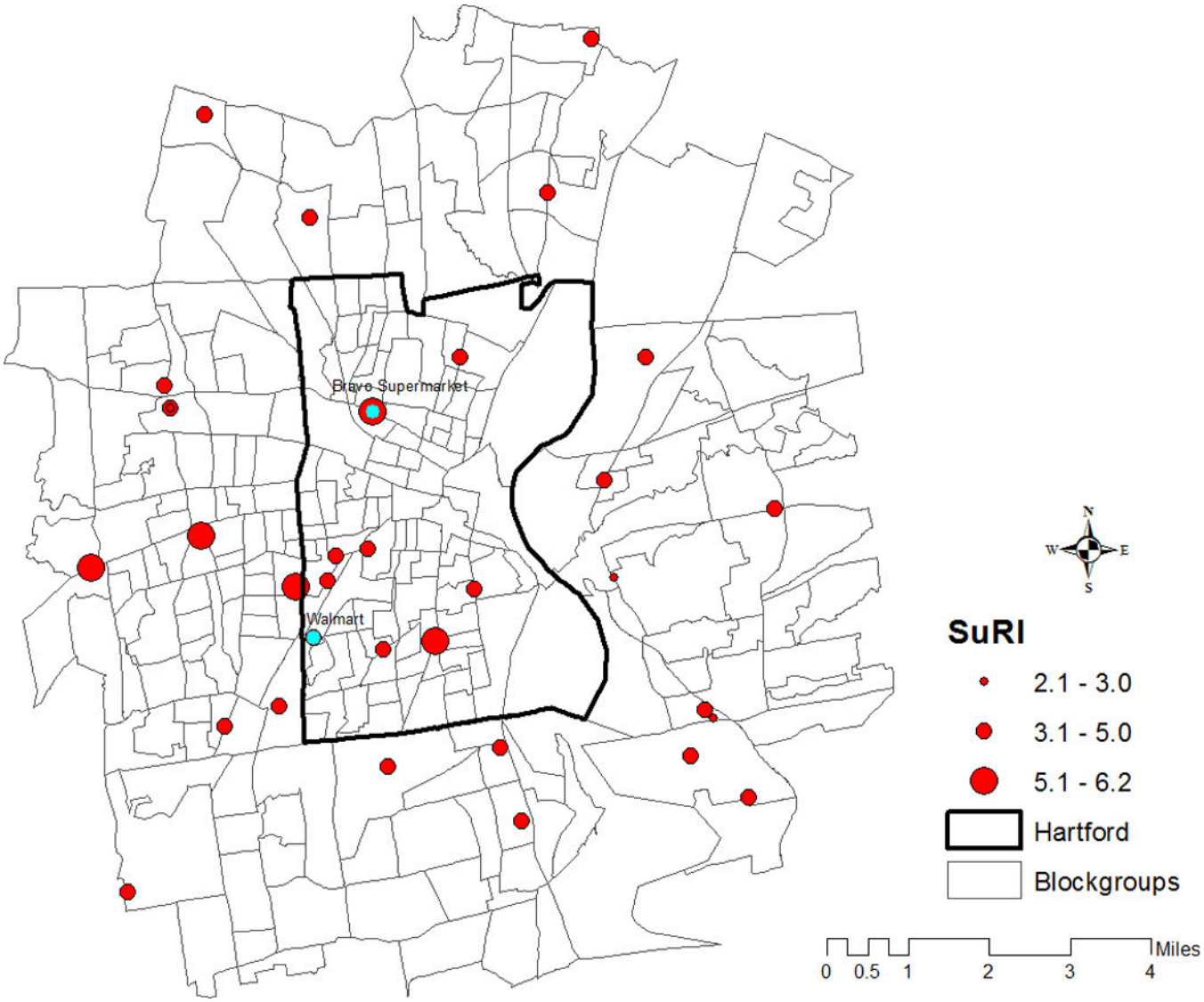

Figure 4.
Spatial distribution of Supermarket Redlining Index (SuRI)

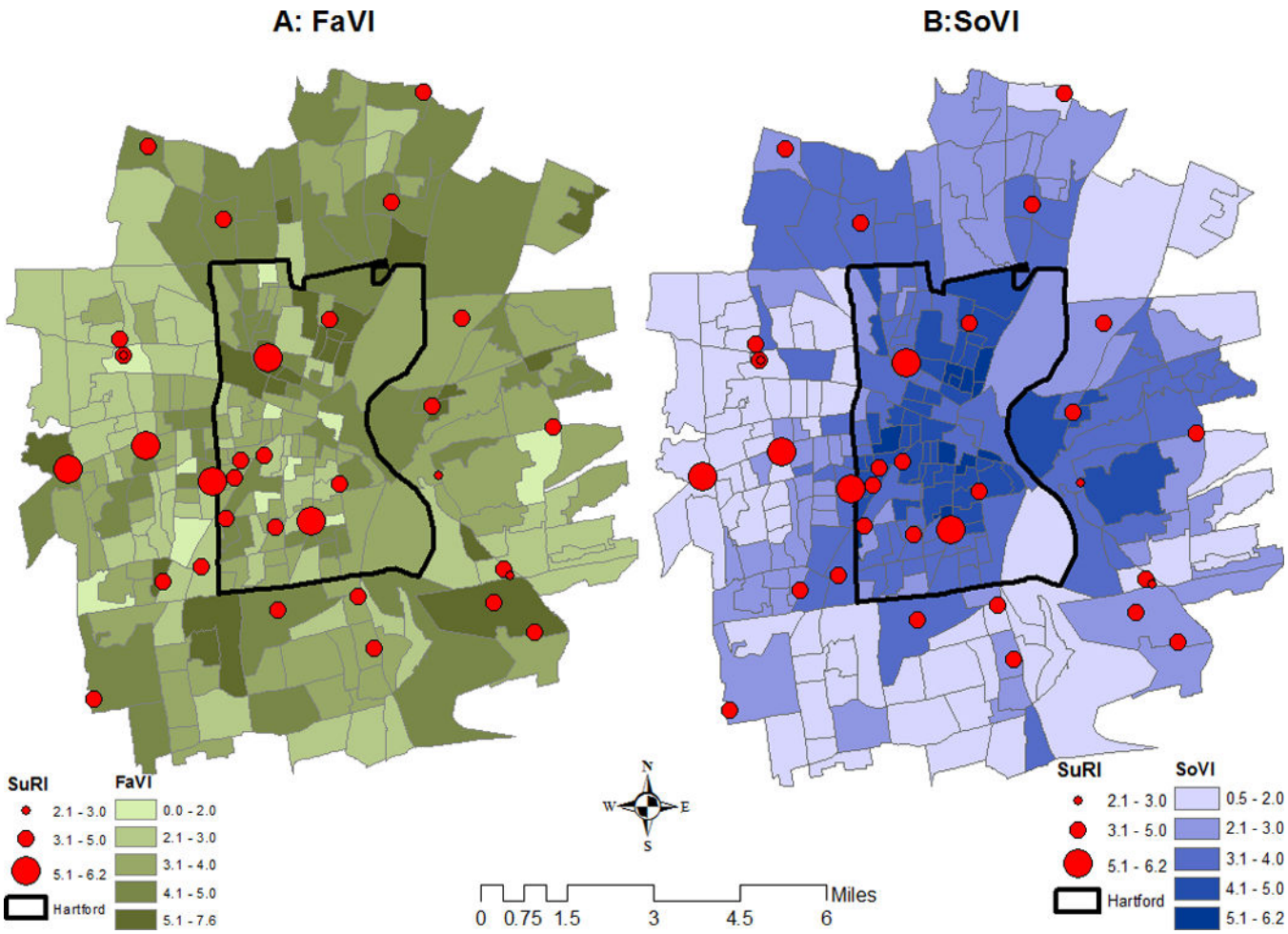

Figure 5.
Spatial distribution of Food Access Vulnerability Index and Social Vulnerability Index

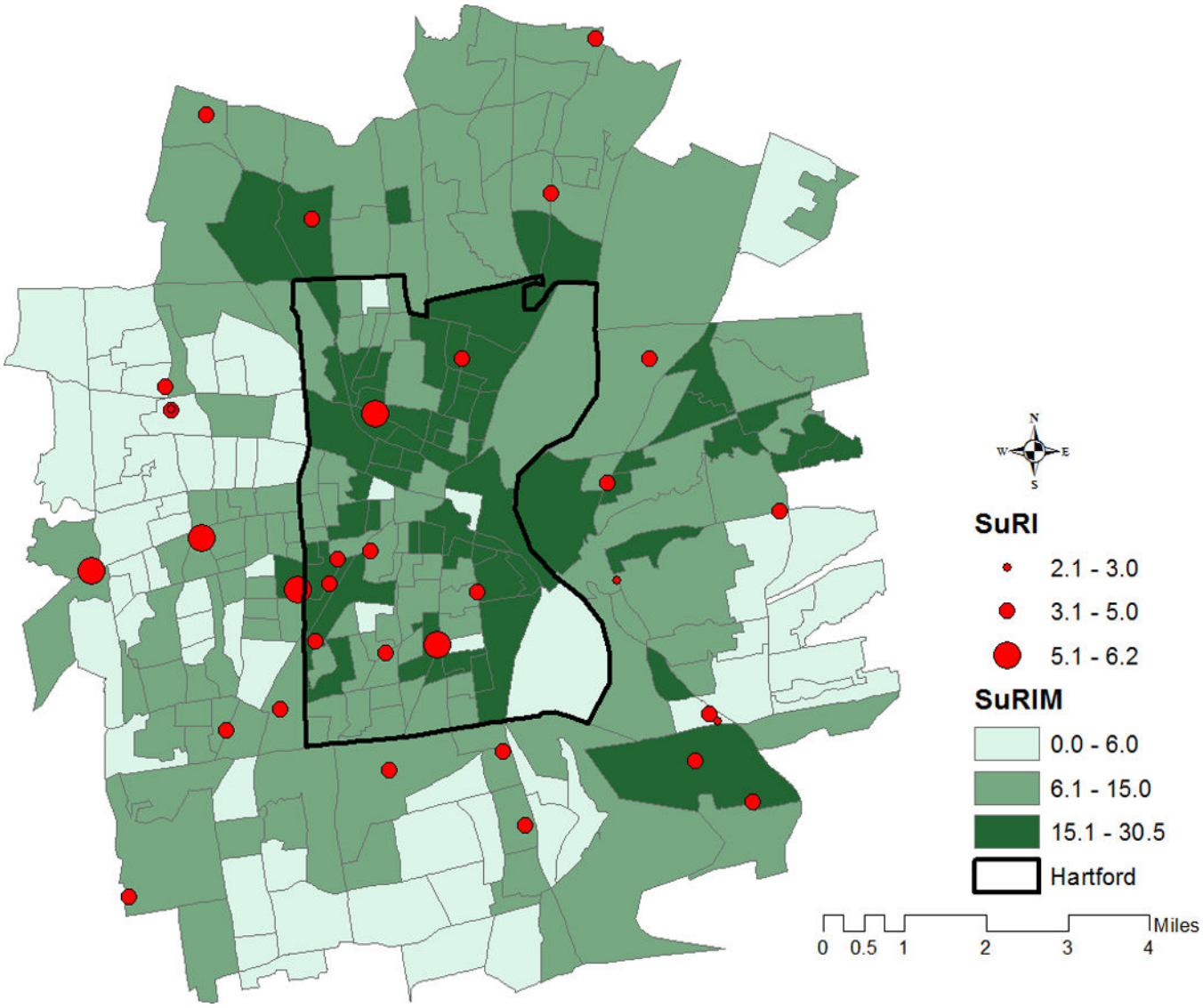

Figure 6.
Spatial distribution of Supermarket Redlining Impact Model (SuRIM)

Table 1

Methodology of Supermarket Redlining Index (SuRI)

Creating Supermarket Redlining Index	**Example using the 'Sales Volume' variable**
Step 1: Sum of each variable for all stores	Sum of sales volume ($)
Step 2: Computing the variable ratio for each store	Sales Ratio = sale volume of a store /sum of sales volume for all stores
Step 3: Calculating the Variable Indicator for each store	Sales indicator= Sales ratio/ maximum value of sales ratio
Step 4: Calculating a composite index of SuRI for each store including all the variable indicators	SuRI=[sales indicator + service area indicator + ……+ population density indicator]

Note: The left column lists the steps and the right column provides an example for each step.

Table 2

Descriptive Statistics of SuRI

	N	Min.	Max.	Mean	Std. Deviation	Percentiles		
						25	50	75
SuRI	33	2.1	6.20	4.11	0.86	3.55	3.80	4.62

Table 3

Cross-tabulation of SuRI and SuRIM

SuRIM	No. of Block-groups	SuRI					
		Low: < 3.0		Medium: 3.00–4.99		High: >=5.00	
		No. of Supermarket	No. of Block-groups in service area	No. of Supermarket	No. of Block-groups in service area	No. of Supermarket	No. of Block-groups in service area
Low: < 6	66	2	0	2	13	0	0
Medium: 6.0–14.99	132	1	4	17	144	2	31
High: >= 15	65	0	0	6	35	**3**	**43**
Total	263	3	4	25	192	5	74