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Food Deserts or Food Swamps? Using Geospatial Technologies to Explore Disparities in Food Access in Windsor, Canada

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ABSTRACT

Access to healthy, varied and affordable foods has a great impact on individual dietary patterns and diet-related health outcomes. Consequently, there is an increasing interest in identifying food deserts - areas with poor access to supermarkets or other food retailers that provide a wide range of healthy and affordable food. Using geographic information systems (GIS), this study examines geographic accessibility to both supermarkets and fast food outlets, and explores their relationship with neighbourhood socioeconomic and zoning characteristics to identify food deserts and food swamps in Windsor, Ontario, Canada. The results show that access to supermarkets and fast food outlets varied by neighbourhood-level socioeconomic deprivation in Windsor, with socioeconomically disadvantaged areas having better food access than advantaged areas. Consistent with previous findings in other Canadian cities, this study finds that food swamps were more prevalent than food deserts in Windsor.

Keywords: Food deserts, Food swamps, GIS, Food accessibility, Neighbourhood, Windsor

INTRODUCTION

Adequate consumption of nutritious foods is essential to overall health and can reduce the risk of nutrition-related chronic disease and obesity. In the past, theories in the public health field about food choice have tended to focus on factors that influence individual decisions (Health Canada, 2013). However, individuals are embedded within larger social systems. Increasingly, researchers and policy makers have come to recognize the influence of environments (e.g., physical, social and economic) on individual dietary patterns (Health Canada, 2013). In particular, a significant amount of research has focused on examining spatial disparities in the accessibility of food services that may have an effect upon individual food choices (e.g., Black et al., 2011; Smoyer-Tomic et al., 2008). Some argue that "food deserts" – areas with poor access to supermarkets or other food retailers that provide a wide range of healthy and affordable food - may contribute to social and spatial disparities in diet and diet-related health outcomes (Beaulac et al., 2009). People are likely to make food choices based on the food outlets that are available in their immediate neighborhoods (Furey et al., 2001; Walker et al., 2010), particularly for vulnerable groups (e.g. low-income, elderly persons, persons without a private vehicle) who often have limited financial and transportation resources for travelling outside the local area to purchase food (Smoyer-Tomic et al., 2006). The relatively poor access to supermarkets would therefore suggest that elderly, low-

income families without a private vehicle tend to shop in small local stores or fast food restaurants that only offer limited varieties of foods, and at higher prices (Apparicio et al., 2007). Since inexpensive, energy-dense, low nutritional foods are more accessible or affordable than those that are nutritious, it can be difficult for vulnerable populations to maintain a healthy diet (Drewnowski & Specter, 2004; Smoyer-Tomic et al., 2008). In fact, the poor access to healthy, varied and affordable foods has been found to be related to poor diets and poor health, even after controlling for individual socioeconomic factors (Apparicio et al., 2007).

Over the last two decades, considerable research has been conducted on food deserts in many developed countries including the United States, the United Kingdom, Canada, Australia, and New Zealand. Despite the growing interest in food deserts, there remains no consensus on a definition and what measures are relevant in identifying them (Apparicio et al., 2007). This has led to varied methodologies being used to identify food deserts as well as mixed and sometimes controversial results about their existence. For example, American studies have found strong and robust evidence regarding the existence of food deserts, while studies from other developed countries are inconclusive (Beaulac et al., 2009). Canadian research on food deserts is still in its early stages, yet a few quantitative studies have been conducted in several Canadian cities with mixed findings, including Toronto, Saskatoon, London, Edmonton, Montreal, Kingston and several others (e.g., Apparicio et al., 2007; Bedore, 2013; Cushon et al., 2013; Larsen & Gilliland, 2008; Smoyer-Tomic et al., 2006). Some cities appear to have significant food deserts, while others do not. Even though the literature shows little evidence of widespread food deserts in Canada, there is preliminary evidence that food access gaps still exist in some vulnerable neighbourhoods that warrants further research. As previous research has indicated, while Canada resembles the United States and United Kingdom in certain ways, “its geographic, demographic, political and economic characteristics suggest that in terms of food access, its experiences may be unique.” (Smoyer-Tomic et al., 2006).

This study examines geographic accessibility to both supermarkets and fast food outlets and explores their relationship with neighbourhood socioeconomic and zoning characteristics to identify food deserts in the city of Windsor, a geographic area which has so far received little empirical attention in this literature. The aim of this study is to provide additional empirical evidence to bring Canadian cities more formally into discussions about food deserts and food environments.

LITERATURE REVIEW

The term “food desert” reportedly originated in Scotland in the early 1990s and was used to describe “areas of relative exclusion” where residents experience “physical and economic barriers to accessing healthy foods” (Leete et al., 2012; Reisig & Hobbiss, 2000). Since then, the term has been used differently by various researchers. For example, in a study by

Cummins and Macintyre (2002a), food deserts were defined as “poor urban areas, where residents cannot buy affordable, healthy food” (Cummins & Macintyre, 2002a; Walker et al., 2010). More recently, the United States Department of Agriculture described 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” (Ver Ploeg et al., 2009).

To date, there is no general agreement on the definition of food deserts, and what measures are required for identifying food deserts, thus contributing to the debate about their actual existence (Walker et al., 2010). Research from the United States has found strong support for the existence of food deserts - areas with higher proportions of low-income or African American residents had poor access to supermarkets and healthy foods (for an extensive review of food deserts research in the U.S. see Walker et al., 2010). However, studies conducted in developed countries outside the U.S. have yielded mixed and sometimes contrary findings. For example, research from the United Kingdom has questioned the extent of food deserts, which found socioeconomically deprived areas housed more food stores of all types overall, and more large, independent food stores compared to wealthier areas (Black et al., 2011; Cummins & Macintyre, 2002b; White et al., 2004). Similar results have been found in New Zealand, where the travel time to large supermarkets was substantially less in the most versus least deprived areas (Black et al., 2011; Pearce et al., 2007). In addition, research on Brisbane, Australia, found little difference in accessibility to retailers selling healthy foods among socioeconomically varied urban areas (Black et al., 2011; Winkler et al., 2006).

In Canada, the issue of food deserts has only recently drawn attention and a limited number of studies have been published in the peer-reviewed literature. There is no public evidence of widespread food deserts in Canada, although a few studies have been identified in the literature (e.g., Larsen & Gilliland, 2008; Cushon et al., 2013). For example, In London, Ontario, Larsen and Gilliland (2008) found that distinct food deserts exist in the east neighbourhoods, yet supermarket accessibility varied little in relation to levels of socioeconomic distress. The most distressed city neighbourhoods had the lowest access to supermarkets by foot, but they had relatively higher public transit access (Larsen & Gilliland, 2008). Findings were similar in Saskatoon, where although food deserts have been identified in some of the most deprived areas of the city, there is no clear pattern between food access and area-level socioeconomic status (Cushon et al., 2013). Besides the academic literature, several community food assessments also identified food deserts in other Canadian cities, including Toronto (Martin Prosperity Institute, 2010), Winnipeg (Food Matters Manitoba, 2013) and some northern and remote communities (Health Canada, 2013).

However, other studies (e.g., Apparicio et al., 2007; Black et al., 2011; Smoyer-Tomic et al., 2006) have reported either no consistent patterning of grocery stores based on socioeconomic status, or that socioeconomically disadvantaged areas had better food access than advantaged areas. For example, several Montreal-based studies found that there are very few problematic food deserts in the city, and neighbourhood socioeconomic status is not a consistent predictor of access to supermarkets or fruit and vegetable vendors (Apparicio et al., 2007; Bertrand et al., 2008). Furthermore, Smoyer-Tomic et al. (2006) reported that in Edmonton, inner-city and high-need neighbourhoods (i.e., those characterized by high proportions of the low-income, elderly and low vehicle ownership rates) had better access to supermarkets than did the remainder of the city (Smoyer-Tomic et al., 2006).

Overall, the literature on food deserts to date indicates inconsistent findings within and between developed countries, including Canada, where several conceptual and methodological gaps remain in the knowledge base regarding the distribution of food retailers and underlying mechanisms for geographic variations (Beaulac et al., 2009). Such limitations are described in depth in previous review studies (e.g., Beaulac et al., 2009; Leete et al., 2012; Walker et al., 2010) but there are specific gaps which this study aims to fill.

First, although many food desert studies have examined differences in accessibility to healthy foods and retailer stores between socio-economically diverse neighbourhoods, few studies have explicitly explained why geographic disparities might exist in food access.

The majority of studies have exclusively focused on the variables or indices that reflect neighbourhood socioeconomic status, while ignoring the potential impacts of other area-level variables. For example, it has been shown that urban planning practices like zoning have an important role in shaping the distribution of commercial and other venues across urban spaces (Black et al., 2011). However, little has been done to explicitly describe or test if zoning and commercial siting has contributed to spatial disparities in food access (Black et al., 2011). Smoyer-Tomic et al. (2008) and Black et al. (2011) are the two exceptions that have empirically tested the role of urban planning and zoning factors in influencing food store access, specifically in Edmonton, Alberta and the province of British Columbia. Their results suggest that, at least in their study areas, housing and transportation considerations have a great impact on the distribution of food stores and may mediate associations between neighbourhood socio-demographic factors and store availability. To date, few of these urban planning factors have been examined in other Canadian cities.

Secondly, most studies of food deserts in Canada have mainly focused on accessibility to supermarkets, and some have examined alternative sources of healthy foods (e.g., fruit and vegetable stores, farmers' markets), but few have explored accessibility to obesogenic foods, such as fast food outlets. There is evidence that in areas without a supermarket nearby, fast food outlets (if readily available) often serve as a substitute for food access (Regan et al., 2006; Spence et al., 2009). There is preliminary evidence that limited access to supermarkets (a source of affordable, heathy foods) and relatively easier access to fast food outlets (a source of affordable, unhealthy foods) may contribute to poor diets and, ultimately, to obesity and diet-related diseases. Therefore, a small and growing body of research has begun to assess the relative accessibility to healthy and unhealthy foods (e.g. supermarkets and fast-food outlets) by means of various relative access measures such as the ratio of the number of unhealthy food outlets to the number of healthy food outlets (Spence et al., 2009), the ratio of the distance to the nearest healthy food outlets to the distance to the nearest unhealthy food outlets (Cushon et al., 2013), and the percentage of healthy food outlets (Luan et al., 2015). By measuring the balance between healthy and unhealthy food outlets within a geographic area, these relative access measures allow for a more comprehensive analysis of the food environment. Recent research has demonstrated that relative access measure seems to better represent food purchasing and consumption behaviors and is more relevant than absolute measure of one type of food source to understanding health outcomes (Luan et al., 2015). In fact, recent reviews of Canadian food environments have shown that despite the lack of evidence for the widespread existence of food deserts, there is consistent evidence of "food swamps" - socioeconomically deprived areas that have easier access to less healthy foods compared with access to healthy foods (Health Canada, 2013). However, limited published research has simultaneously examined food deserts and food swamps in a geographic area.

This study attempts to address these gaps by exploring the potential existence of food deserts and food swamps in the city of Windsor in 2018. Specifically, this paper aims to address the following research questions: 1) Does access to supermarkets and fast food outlets vary across neighbourhoods of different levels of socioeconomic deprivation? 2) How is access to supermarkets and fast food outlets related to neighbourhood socioeconomic characteristics after controlling for planning and zoning factors? 3) Where are the food deserts and food swamps within

the city?

In order to answer the above questions, geographic accessibility to supermarkets and fast food outlets was measured and mapped using geographic information systems (GIS). A food balance score was calculated to quantify the relative accessibility to supermarkets and fast food outlets. Then, multivariate regression models were applied to examine whether the differences in geographic food access and food balance vary by neighbourhood-level socioeconomic status after taking urban planning and zoning factors into account. Finally, food access and food balance measures were compared with neighbourhood-level socioeconomic deprivation to identify food deserts and food swamps in Windsor.

METHODOLOGY

Study Setting

The study was conducted in the city of Windsor, Ontario, which is the southernmost city in Canada. As of 2016, Windsor had a population of 217,188, spreading across 146.38 square kilometers of land area (Statistics Canada, 2017a). Windsor is an ethnically diverse city with 28% of the population being foreign-born (immigrants) and 27% of the population being visible minorities (Statistics Canada, 2017a). As of 2016, the low-income rate for Windsor remains among the highest in Canada and the level of post-secondary education remains below the national average (Statistics Canada, 2017a).

Furthermore, according to the most recent Windsor-Essex County Health Report, fewer people in this region reported that they eat five or more fruits and vegetables per day compared to the provincial average. The number of unique visits to food banks has steadily increased from 9,188 in 2012 to 9,722 in 2014 (United Way Centraide Windsor-Essex County, 2015). As a whole, these statistics indicate that access to healthy and nutritious food is an important concern in Windsor.

Defining and Measuring the Geographic Unit of Interest

This study uses Census Dissemination Area (DA) as a proxy for neighbourhood which, according to Statistics Canada, is “a small, relatively stable geographic unit composed of one or more adjacent dissemination blocks with an average population of 400 to 700 persons” (Statistics Canada, 2016). DAs are the smallest standard geographic area for which all census data are released, making them the appropriate geographic scale at which associated socioeconomic and zoning characteristics can be examined. In total, 376 Windsor DAs with a population of 217,188 were analyzed in this study.

Food Store Data

This study focuses on two types of food retailers: supermarkets and fast food outlets. The presence of a supermarket has been a common proxy for the availability of a variety of healthy, nutritious foods at competitive prices and has generally been the focus of food desert studies (Leete et al., 2012). It has been acknowledged that in some urban environments, other types of food retailers such as smaller grocery stores, and farmers’ markets may also be found to provide a range of

healthy, affordable foods. However, the problem with including these stores in the analysis is that the range of foods sold in these stores is highly varied (Ver Ploeg et al., 2009) and it is difficult to do a complete assessment of the contents of these stores due to the time and budgetary constraints of this study. For example, fruit and vegetable markets, as well as meat and seafood markets can serve as sources for affordable and nutritious foods, whereas they typically do not provide the full range of food options as supermarkets do (Ver Ploeg et al., 2009). Furthermore, the monetary costs of an equal quantity of food purchased in smaller grocery stores or convenience stores are higher than the costs at supermarkets. Studies in several Canadian cities have found that residents will have to pay an average of 1.6 times more for identical food items purchased at area convenience stores versus supermarkets (Larsen & Gilliland, 2008).

Therefore, this study measures access to supermarkets as the proxy for access to healthy foods. Supermarkets were defined as those stores offering a full range of food products (e.g., fresh meat and poultry, produce, dairy, dry and packaged foods and frozen foods) with a minimum of ten employees and had no required store membership (Smoyer-Tomic et al., 2006). Based on this criteria, 22 stores in Windsor were included in this study, including both major chain and independent supermarkets. Information on their locations was gathered in 2018 from local business directories and company websites, and verified by several additional sources: yellow pages, phone calls to retailers, inspection of air photos, and site visits.

Fast food outlets tend to sell nutritionally deficient, processed foods that are high in calories, fat, and sodium and have served as a central measure of potential exposure to obesity-promoting food environments (Black, 2014; Cushon et al., 2013). Thus, this study uses proximity to fast foods as a proxy for accessibility to unhealthy foods. Fast food addresses were collected via Mergent Intellect (Mergent Intellect, 2018), an online database of business information for both private and public companies in the US and Canada. Searches within the database were conducted using the Standard Industrial Classification (SIC) code for fast food restaurants and stands (581203) in Windsor, ON, resulting in a database of 150 fast food outlets.

The locations for supermarkets and fast food outlets included in this study were first determined by geocoding their addresses to street files by using QGIS 2.18.13 (QGIS Development Team, 2017), then manual checks and corrections were performed as needed.

Food Access and Food Balance

Based on the methodology used by Apparicio et al. (2007), this study examines spatial accessibility to supermarkets using three different measures: proximity, diversity and variety. Each of the three measures serves as an indicator of different dimensions of food access in an attempt to adequately describe the complexity of a person's accessibility to a service (Apparicio et al., 2007). In particular, proximity measures the distance from the centre of each census block to the nearest supermarket. Diversity was defined as the number of supermarkets located within 1 kilometer of the centre of each census block. One kilometer was chosen as it is widely considered a reasonable walking distance for an adult in an urban setting (Leete et al., 2012). This measure allows us to determine how many supermarkets residents would have access to by foot. Variety was defined as the average distance from the centre of each census block to the nearest three supermarkets belonging to different chains. Different supermarket companies are assumed to carry a range of brands and prices, thus increasing the variety of choices for customers (Apparicio et al., 2007).

To minimize aggregation error, the three accessibility measures were calculated from the centroid of blocks. Blocks are the smallest geographic units for which population and dwelling counts are obtainable from Statistics Canada1 and are precise units for accounting for micro-level variations in population density (Larsen & Gilliland, 2008). Then, to obtain accessibility measures at the DA level (the unit of analysis), the population-weighted average measure of blocks within each DA's boundaries was calculated:

$$M_{Ni} = \frac{\sum_{j \in i} P_j X_{Nj}}{\sum_{j \in i} P_j}$$

Where N =1, 2, 3 indicates the measures of proximity, diversity and variety respectively, and X_{Nj} represents the block-level accessibility input specific to that measure. In each case, p_j is the total population of block j entirely included in DA i. For proximity (M_{1i}), $X_{1j} = \min(D_j)$, where D_j is a vector of the distances between the centroid of block j and each of the supermarkets in the sample. For diversity (M_{2i}), $X_{2j}$is the number of supermarkets located within 1 kilometer of the centroid of census block j. For variety (M_{3i}), X_{3j} is the mean distance between the centroid of census block j and the three nearest supermarkets belonging to different chains (Leete et al., 2012).

All three accessibility measures were based on the shortest network distance, that is, the shortest path along a street in order to better represent actual travel distance for going to a supermarket on foot (Apparicio et al., 2007). Network distances were computed using road network files from the 2016 DMTI CanMap Content Suite (DMTI Spatial Inc., 2016) and the Network Analyst extension within ArcGIS 10.5.1 (Esri Inc., 2017).

A similar procedure was performed to calculate the distance to the nearest fast food outlet to determine proximity. Then a food balance score – the minimum distance to the nearest supermarket divided by the minimum distance to the nearest fast food outlet – was calculated for each DA. A food balance score of 1 indicates that a supermarket is the same distance from a neighbourhood as a fast food outlet. Such an area was considered to be in balance in terms of food access – it's just as easy or difficult to reach healthy or unhealthy food stores. Areas with a food balance score of greater than 1, which means the nearest fast food outlet was closer than the nearest supermarket, were considered less "balanced" (Cushon et al., 2013).

Neighbourhood Socioeconomic Characteristics and Deprivation Index

The neighbourhood socioeconomic characteristics used in this study were obtained from the 2016 Canadian Census (Statistics Canada, 2017b). As mentioned earlier, previous Canadian studies of food deserts have established a list of variables that reflect the characteristics of subpopulations that are particularly vulnerable to food access barriers (Apparicio et al., 2007; Cushon et al., 2013; Larsen & Gilliland, 2008). In this study, the variables were chosen based on their plausible connection to food accessibility as well as the availability of relevant data at the DA level. First, socio-economic status has been recognized as an important determinant of inequalities in food accessibility. Therefore, the following variables for income, education, employment and family characteristics were used to represent different aspects of socioeconomic disadvantage at the

[1] Unfortunately, all other census data is suppressed at the scale due to confidentiality purposes.

neighbourhood level: 1) median after-tax income of households in 2015; 2) percentage of people aged 25 to 64 years old without high school diploma; 3) unemployment rate; 4) percentage of lone-parent families. Furthermore, Windsor is one of the most ethnically diverse cities in Ontario, partly due to the large number of immigrants. To characterize neighbourhood racial/ethnic composition, the percentage of visible minorities and the percentage of recent immigrants (immigrated between 2011 and 2016) were included in this study. In addition, people with limited physical mobility (e.g., elderly and disabled individuals) and lack of access to a vehicle or reliable public transit have been shown to have difficulty accessing food stores outside their immediate neighbourhoods. We used the percentage of the population aged 65 years and over as an indicator of elderly status. It is difficult to measure vehicle ownership and public transit access directly, as currently no relevant variable is readily available at such small geographic levels (i.e., DA). As a result, the percentage of the employed labour force who commuted to work by private vehicles (as driver) was used as a rough proxy for private vehicle ownership, and the percentage of the employed labour force who commuted to work by public transit as a proxy for the use of public transit.

While each of the variables above contributes to certain dimensions of socioeconomic characteristics that are related to food access, it is often a combination of variables that shows a more complete picture of socioeconomic status across a region. Therefore, the socioeconomic deprivation index was constructed in this study by combing the individual variables mentioned above into a single summary measure. This index was further compared with the food access and balance measures, in an attempt to identify food deserts and food swamps in Windsor. More specifically, the socioeconomic deprivation index was calculated using principal component analysis (PCA), the preferred approach for developing composite socioeconomic indexes in the literature (Pampalon et al., 2009). For each component identified, the PCA produces a factor score which represents the value of the component in each DA. In this study, only the first component score, which explains the largest possible proportion of variance in the original variables was used to create the composite index. The composite index produced in this way is a weighted summary measure that specifies the different contribution (weight) of each original variable and thus provides a better summary of the distribution of socioeconomic status across Windsor's neighbourhoods (Dall et al., 2006). The deprivation index was calculated for each DA and was standardized on a 0 to 1 scale with greater scores corresponding to higher levels of socioeconomic deprivation.

Urban Planning and Zoning Factors

In this study, the selection of neighbourhood planning and zoning factors was informed by prior health literature on the relationship between zoning and commercial siting and food store availability (Black et al., 2011; Smoyer-Tomic et al., 2008). Specifically, the following two variables were drawn from the 2016 Canadian Census to capture aspects of zoning. Percentage of single detached houses was used as a proxy measure of the exclusiveness of residential zoning, because the restriction of zoning to single family use of housing can prevent food stores from being developed in certain areas (Black et al., 2011; Shlay & Rossi, 1981). Since retail businesses, such as food stores, require a certain customer base (i.e., population density threshold) to be profitable (Larsen & Gilliland, 2008), and neighbourhoods (i.e., DAs) differ in population size and area, population density (the number of residents per square kilometre) was employed as a control for the size of the potential customer base corresponding to a certain area (Smoyer-Tomic et al., 2008).

Data Analysis

The analyses in this study generally proceeded in four steps. First, descriptive analyses and thematic mapping were used to assess the distributions of supermarkets, fast food outlets, and neighbourhood socioeconomic and zoning characteristics. Second, the associations between food access, food balance and neighbourhood socioeconomic deprivation were examined by using one-way analysis of variance (ANOVA). Third, multivariate regression models were then applied to assess the degree to which neighbourhood-level socioeconomic and zoning variables each predicted food access and food balance net of the other independent variables being studied. The regression models were estimated for each of the five primary outcome variables: 1) the distance to the nearest supermarket; 2) number of supermarkets within 1 km; 3) the distance to the nearest three supermarkets belonging to different chains; 4) the distance to the nearest fast food outlet; 5) the food balance score. Two types of regression methods were used. For the three distance measures and the food balance score, ordinary least squares (OLS) regression was used which requires a continuous outcome variable that has a normal distribution. All these measures have a skew distribution which, however, was not a serious issue in the analysis as the residuals from these models had a near-normal distribution. For models predicting the number of supermarkets within 1 km, negative binomial regression was applied, since it is appropriate for modeling over-dispersed count variables. Finally, this study attempts to identify potential food deserts and food swamps in Windsor. Food deserts were defined as the most deprived areas (i.e. neighbourhoods that fell into the highest quartile of the socioeconomic deprivation index score) with the lowest accessibility to supermarkets (i.e. neighbourhoods that fell into the worst tertile for each of the access measures), and food swamps were identified as the most deprived areas that were the most out-of-balance in terms of food access (i.e. neighbourhoods that fell into the highest quartile of the food balance score). All statistical analyses were executed using SPSS version 25 (IBM Corp., 2017).

RESULT

Supermarket Accessibility

Table 1 details the descriptive statistics for food access and food balance measures and all neighbourhood socioeconomic and zoning variables. In Windsor, the average neighbourhood resident needed to travel about 1.7 kilometres to reach a supermarket. Only 13% of Windsor residents lived within 1 kilometre of a supermarket. The mean distance to the three nearest supermarkets belonging to different chains was 2.5 kilometres.

The spatial distribution of supermarkets along with the three accessibility measures are displayed in Figure 1-Figure 4. In Windsor, supermarkets were mainly distributed along major roads and intersections (Figure 1). Overall, the three accessibility measures revealed a similar pattern that more densely populated neighbourhoods (Figure 8) and neighbourhoods along major roads have better accessibility to supermarkets than elsewhere (Figure 2-4). Unlike other Canadian cities where supermarket accessibility follows a core-periphery pattern (e.g. London, Edmonton, and Montreal), central, inner-city neighbourhoods with good accessibility in Windsor coexisted with suburban neighbourhoods with good accessibility, and vice versa. Specifically, neighbourhoods with good supermarket accessibility were mostly concentrated in two parts of the

city: One is located in the city centre, its surrounding areas along Ouellette Avenue, and the areas southwest of the university along Huron Church. They are older, inner-city neighbourhoods with high levels of socioeconomic deprivation (Figure 7). Another one is on the east side of the city, including several inner-suburban neighbourhoods along Tecumseh Road East, as well as affluent, suburban neighbourhoods close to the east end of the city (known locally as "Riverside"). By contrast, there are large suburban areas in the southwest, south and east end of the city that had substantially low accessibility to supermarkets. On the other hand, exceptional clusters of low accessibility also appeared in some inner-city neighbourhoods, particularly in the university area and the Sandwich District west of the bridge, as well as the east part of the Walkerville District2. These neighbourhoods contained some of the city's most socioeconomically deprived populations (Figure 7). Despite these similarities, a degree of divergence still exists between different accessibility measures. As can be seen from the maps, the areas with low supermarket accessibility identified by the diversity measure (Figure 3) were more extensive than the other two measures (Figure 1 and Figure 2), mainly due to the large number of neighbourhoods lacking a supermarket within ready walking distance. Furthermore, neighbourhoods near the southern end of Dougall Avenue or the southern end of Walker Road showed good proximity to a single supermarket, but they had limited accessibility in terms of diversity and variety. Suburban neighbourhoods along Tecumseh Road East and Wyandotte Street East tended to have the best access to supermarkets, in that they not only had at least one supermarket within walking distance but also had several different supermarkets nearby.

The spatial variance of supermarket accessibility can be further demonstrated by the Moran's I statistics shown in Table 2. For each of the three measures, the Moran's I statistic was highly statistically significant, indicating that neighbourhoods with good accessibility to supermarkets were spatially clustered, as were neighbourhoods with bad accessibility. In addition, the Moran's I values were higher for the proximity and variety measures (0.8 and 0.84) as opposed to the diversity measure (0.54). This implies that, for the measure of number of supermarkets within 1 kilometer, areas with similar values were less clustered in space.

Fast Food Accessibility and Food Balance

There were almost 7 times more fast food outlets than supermarkets in Windsor. The mean distance to the nearest fast food outlet was 844 metres, 886 metres closer than the mean distance to the nearest supermarket of 1730 metres (Table 1). Almost 58% of the city's population lived within 1 kilometer of a fast food outlet. Compared to supermarkets, the distribution of fast food outlets showed a more dispersed pattern (Figure 1). Generally, inner-city neighbourhoods (e.g. downtown, the university area, Walkerville) had the greatest accessibility to fast food outlets compared to other areas of the city (Figure 5). A significant Moran's I statistic indicates that neighbourhoods with good or bad fast food accessibility also clustered in space (Table 2).

The mean food balance score in Windsor was 3, indicating that the average resident needed to travel three times as far to reach the closest supermarket as they did to reach the closest fast food outlet. Neighbourhoods with the highest food balance scores (that are the most out-of-balance in terms of food access) clustered in the Sandwich District, the university area, the Walkerville

[2] For details about the planning districts, please refer to the City of Windsor Open Data Catalogue: https://opendata.citywindsor.ca/opendata/details/209

District and the suburban areas in the south (Figure 6).

Table 1. Descriptive Statistics for Food Access, Food Balance, Neighbourhood Socioeconomic and Zoning Variables

Food store variables	Mean	S.D.	Min	Max	Percentiles 25	50	75
Distance to the nearest supermarket (meters)	1730.0	901.6	167.8	4739.1	1054.5	1565.0	2207.2
Number of supermarkets within 1 kilometer (count)	0.2	0.4	0.0	2.0	0.0	0.0	0.4
Average distance to the three closest supermarkets from different chains (meters)	2472.9	834.2	842.6	5718.3	1861.9	2295.3	2859.2
Distance to the nearest fast food outlet (meters)	844.5	498.8	52.4	2865.9	433.5	735.9	1194.0
Food balance score	2.6	2.0	0.3	16.9	1.4	2.0	3.3
Socio-economic and zoning variables							
Median household income ($)	52535	20232	11616	109312	37120	49237	67840
Unemployment rate	10.1	6.7	0.0	43.6	5.7	9.1	12.5
Percentage of population aged 65 and over	17.3	8.9	0.0	64.1	11.8	15.5	20.8
Percentage of recent immigrants	4.2	5.5	0.0	30.1	0.0	2.4	6.0
Percentage of visible minorities	24.5	18.1	0.0	86.4	10.4	20.0	34.8
Percentage of lone-parent families	25.2	10.8	5.9	60.5	16.3	25.0	32.1

Food store variables	Mean	S.D.	Min	Max	Percentiles 25	50	75
Percentage of people aged 25 to 64 years old without high school diploma	12.3	8.3	0.0	41.4	6.4	10.9	17.7
Percentage of the employed labour force who commuted to work by private vehicles	78.4	13.9	28.0	100.0	71.3	81.3	88.9
Percentage of employed labour force who commuted to work by public transit	6.4	7.4	0.0	52.0	0.0	5.0	10.0
Population density (per square km)	3511	4888	28	84314	2049	2873	4192
Percentage of single detached houses	64.2	32.4	0.0	100.0	37.6	71.4	95.9
Socioeconomic deprivation index	0.4	0.2	0.0	1.0	0.3	0.4	0.5

Table 1. Spatial Autocorrelation Statistics for Food Access Measures

	Moran's I	z-score	p-value
Distance to the nearest supermarket (meters)	0.80	25.96	<.001
Number of supermarkets within 1 kilometer (count)	0.54	17.56	<.001
Average distance to the three closest supermarkets from different chains (meters)	0.84	27.02	<.001
Distance to the nearest fast food outlet (meters)	0.61	19.70	<.001

Note. Moran’s I statistics were calculated with a rook binary connectivity matrix (1 where dissemination area I and j share a border only; 0 otherwise).

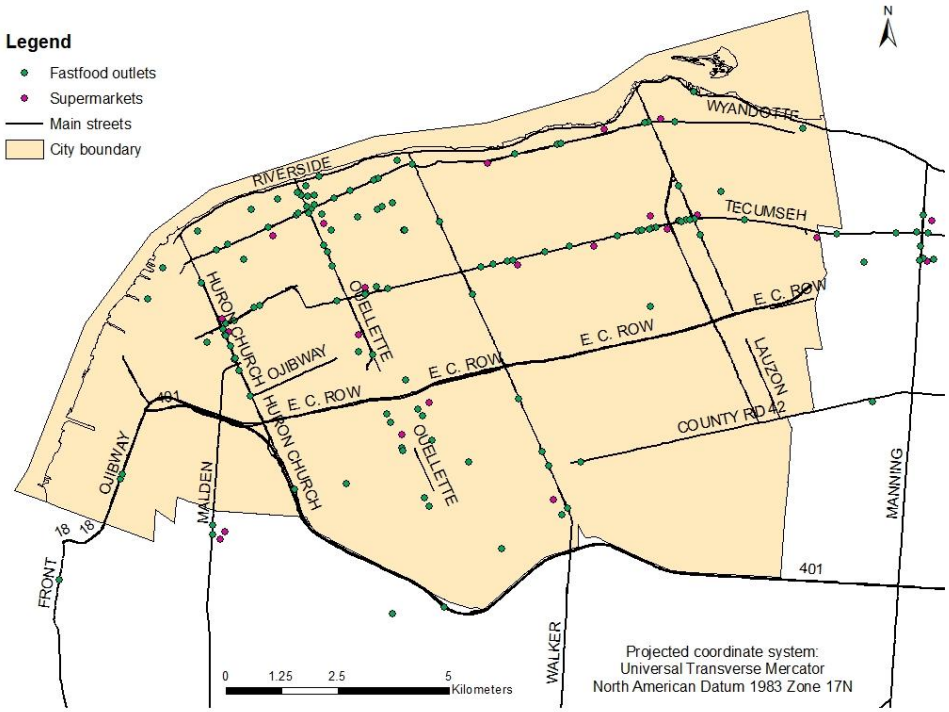

Figure 1. Locations of Supermarkets and Fast Food Outlets in Windsor, ON, 2018

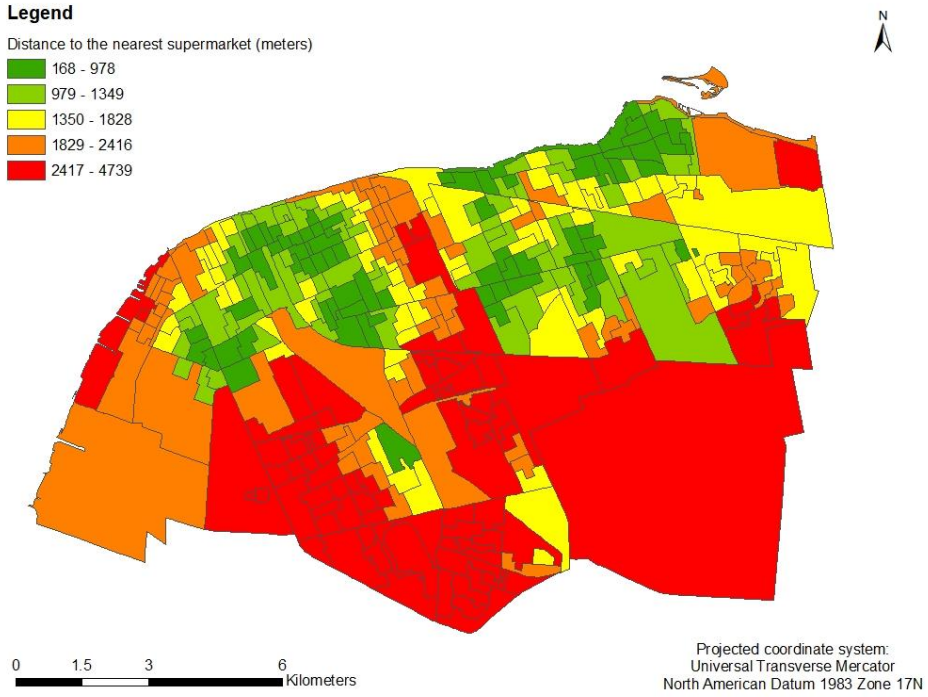

Figure 2. Supermarket Proximity, Windsor, ON, 2018

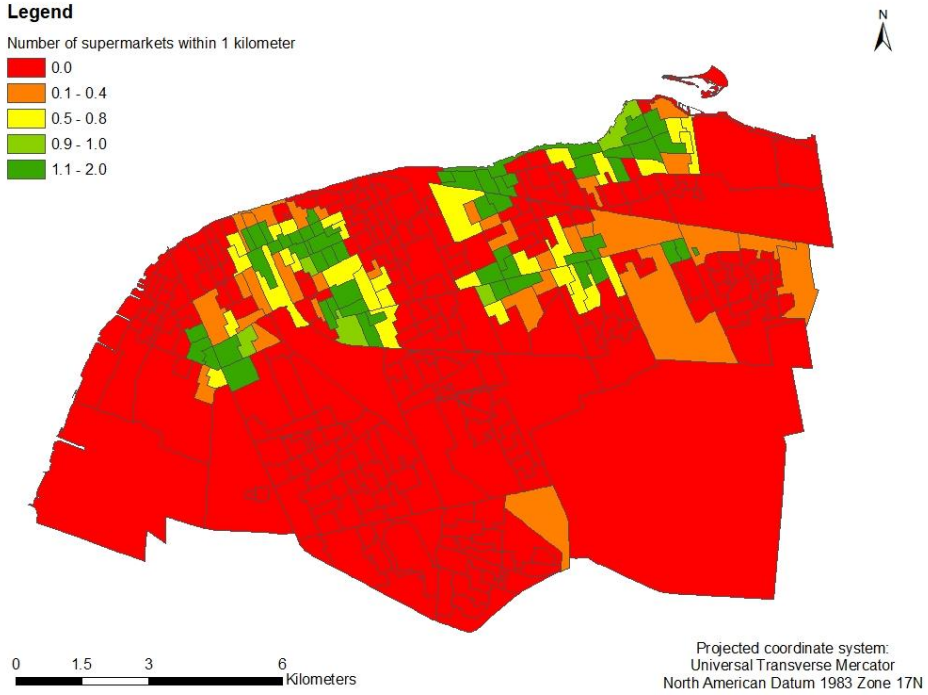

Figure 3. Supermarket Diversity, Windsor, ON, 2018

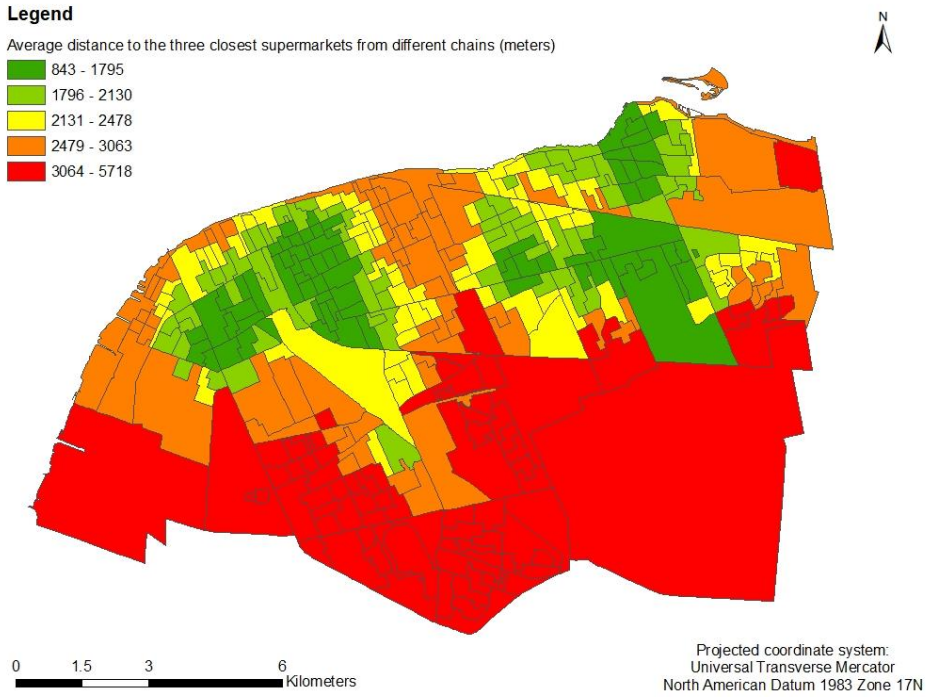

Figure 4. Supermarket Variety, Windsor, ON, 2018

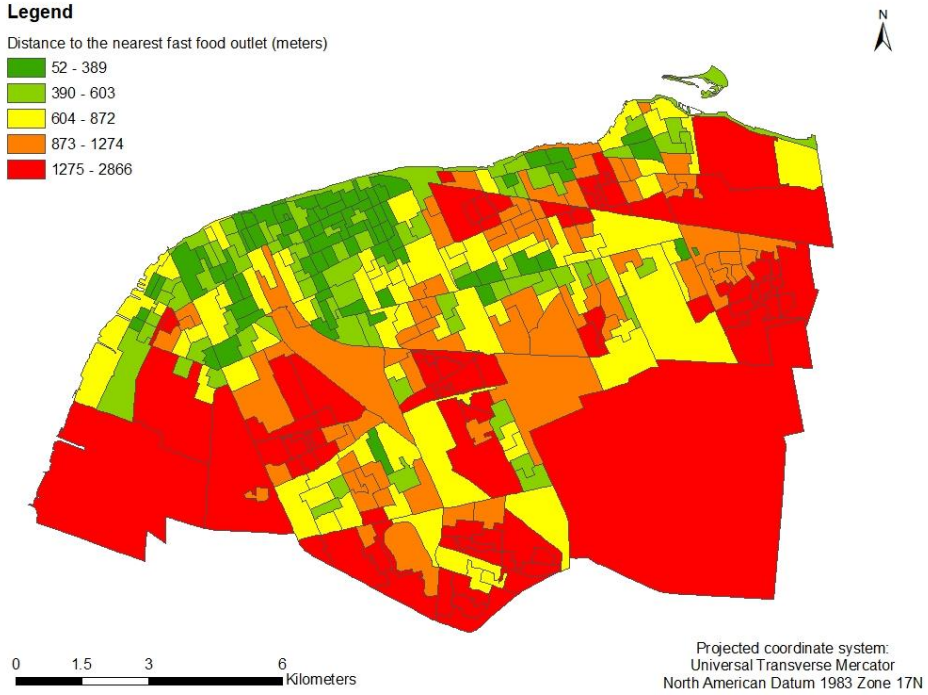

Figure 5. Fast Food Proximity, Windsor, ON, 2018

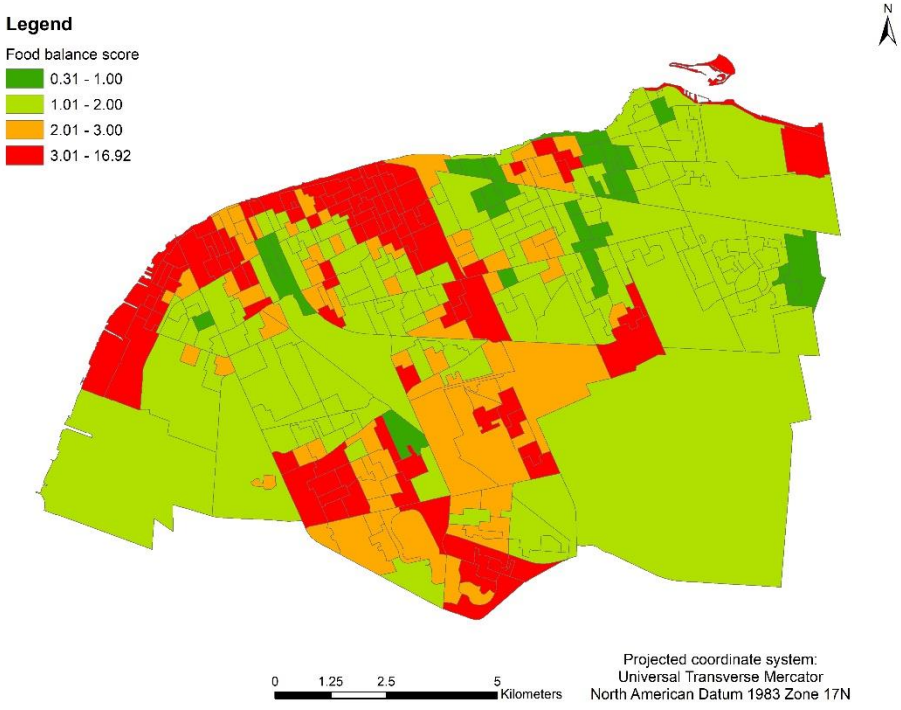

Figure 6. Food Balance Score, Windsor, ON, 2018

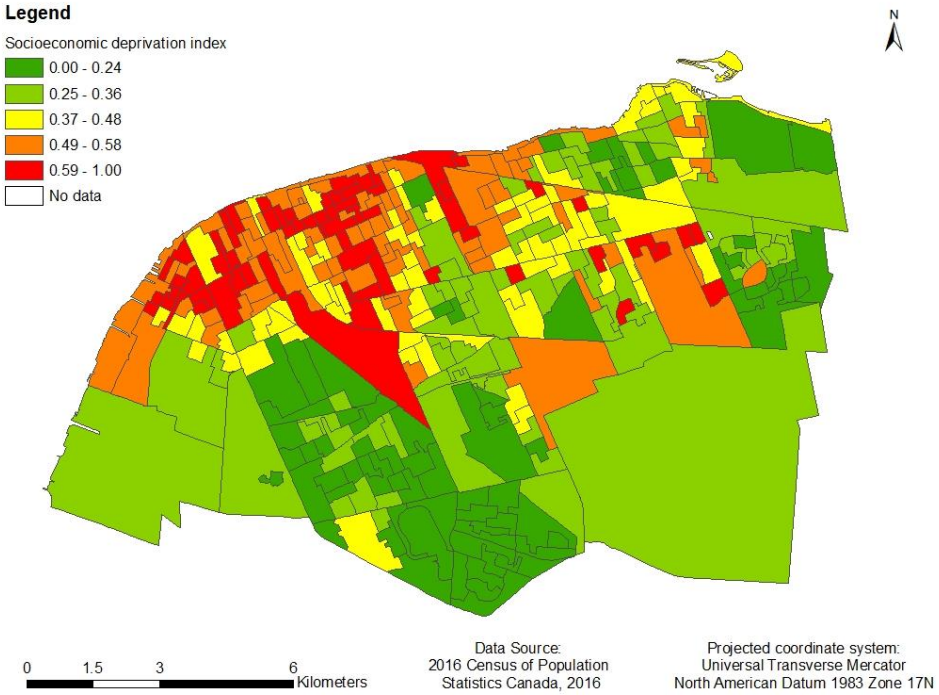

Figure 7. Socioeconomic Deprivation Index, Windsor, ON, 2018

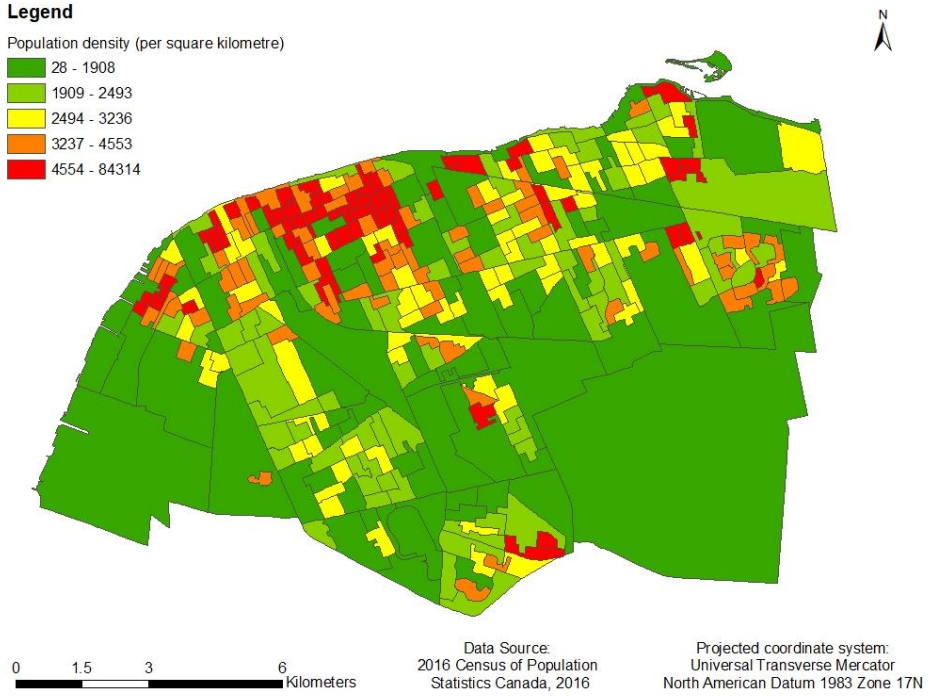

Figure 8. Population Density, Windsor, ON, 2018

Relationship Between Food Access and Balance Measures and Neighbourhood Characteristics

To explore socioeconomic inequalities in relation to food access and food balance, all of Windsor's 376 DAs were first categorized into quartiles (25%, 50%, 75%, 100%) according to their socioeconomic deprivation index scores. Quartile 1 represents the least deprived neighbourhoods, while quartile 4 represents the most deprived. Differences in supermarket accessibility, fast food accessibility and food balance scores between deprivation quartiles were then examined and tested for statistical significance by using one-way ANOVA . The results are shown in Table 3. Overall, there was a statistically significant difference in food access and food balance among neighbourhoods with different levels of socioeconomic deprivation. Specifically, post hoc tests indicate that supermarket proximity, supermarket variety, and fast food proximity tended to decrease as socioeconomic deprivation increased, despite that the difference between the two most deprived quartiles (quartiles 3 and 4) was not statistically significant. For supermarket diversity, the least deprived DAs (quartile 1) were significantly worse than all other quartiles. A clear pattern did not exist for food balance score and socioeconomic deprivation, although the most deprived DAs (quartile 4) were significantly more imbalanced than those in quantile 1 and 2.

In sum, the above analyses have shown that food access and food balance varied across Windsor's neighbourhoods. The following multivariate regression models were used to further investigate how individual neighbourhood socioeconomic and zoning characteristics influenced the variation in food access and food balance net of the other characteristics. The results can be seen in Table 4. After controlling for the other variables in the models, neighbourhoods with lower median household income and a lower proportion of visible minorities were more likely to have shorter distances to the nearest supermarket as well as the nearest three supermarkets belonging to different chains. An increased percentage of single-parent families was also significantly associated with shorter distance to the three nearest different chain-name supermarkets. Among all the variables included in the model, median household income was the only significant predictor of the number of supermarkets within 1 kilometre. Keeping other factors constant, neighbourhoods with lower median household income, less concentration of visible minorities, and lower private vehicle ownership were more likely to have a proximate fast food outlet. Neighbourhoods with higher percentages of senior populations, single-parent families and people who drive to work were more likely to have balanced food options – the nearest supermarket was closer than the nearest fast food outlet.

By contrast, neither of the zoning variables – population density and the percentage of single-detached houses - showed significant effect on any of the food access and food balance measures, after adjusting for other socioeconomic factors in the models.

Table 2. Means, Standard Deviations, and One-Way ANOVA for Food Access and Food Balance Measures by Socioeconomic Deprivation Quartile

Deprivation Quartile		Supermarket proximity[a]	Supermarket diversity[b]	Supermarket variety[c]	Fast food proximity[d]	Food balance score
1	M	2565.9	0.1	3293.9	1281.0	2.3
	SD	991.3	0.2	963.0	504.1	1.3
2	M	1684.4	0.2	2438.0	874.7	2.2
	SD	792.5	0.4	684.8	423.4	1.2
3	M	1386.1	0.3	2127.6	662.9	2.8
	SD	584.0	0.5	453.0	384.2	2.2
4	M	1305.6	0.3	2055.2	569.7	3.2
	SD	562.2	0.4	470.3	345.8	2.6
	F (3, 371)	54.87	9.91	66.29	53.25	5.32
	p	<.001	<.001	<.001	<.001	.001
	η^2	.31	.07	.35	.30	.04
	Post Hoc[e]	1>2>3,4	1<2,3,4	1>2>3,4	1>2>3,4	1,2<4

Note. a. Supermarket proximity is defined as the distance to the nearest supermarket.

b. Supermarket diversity is defined as the number of supermarkets within 1 km.

c. Supermarket variety is defined as the average distance to the nearest three supermarkets belonging to different chains.

d. Fast food proximity is defined as the distance to the nearest fast food outlet.

e. Post hoc tests indicate which group (quartile) means were significantly different from each other.

Table 3A. Ordinary Least Squares Regression Models for Supermarket Proximity and Variety

	Distance to the nearest supermarket				Average distance to the three closest supermarkets from different chains			
	B	SE	β	t	B	SE	β	t
Median household income (in 1,000$)	25.86**	4.24	0.58	6.10	23.68**	3.80	0.58	6.23
Unemployment rate	-0.56	7.37	0.00	-0.08	-0.25	6.61	0.00	-0.04
Percentage of population aged 65 and over	-4.85	5.56	-0.05	-0.87	-1.58	4.99	-0.02	-0.32
Percentage of recent immigrants	2.64	10.10	0.02	0.26	-2.26	9.06	-0.02	-0.25
Percentage of visible minorities	8.91**	3.08	0.18	2.89	7.83**	2.77	0.17	2.83
Percentage of lone-parent families	-2.83	5.87	-0.03	-0.48	-11.40*	5.26	-0.15	-2.17
Percentage of people aged 25 to 64 years old without high school diploma	-12.23	6.32	-0.11	-1.93	-2.25	5.67	-0.02	-0.40
Percentage of the employed labour force who commuted to work by private vehicles	2.61	4.88	0.04	0.53	4.42	4.38	0.07	1.01
Percentage of employed labour force who commuted to work by public transit	3.94	8.01	0.03	0.49	6.84	7.18	0.06	0.95
Population density (1000 per square km)	-10.02	8.40	-0.05	-1.19	-8.13	7.54	-0.05	-1.08
Percentage of single detached houses	-3.69	2.04	-0.13	-1.81	-3.42	1.83	-0.13	-1.87
R^2				.34				.38

Note. *p<.05, **p<.01.

Table 4B. Ordinary Least Squares Regression Models for Fast Food Proximity and Food Balance Score

	Distance to the nearest fast food outlet				Food balance score			
	B	SE	β	t	B	SE	β	t
Median household income (in 1,000$)	11.13**	2.33	0.45	4.79	-0.01	0.01	-0.05	-0.49
Unemployment rate	-0.35	4.04	-0.01	-0.09	0.01	0.02	0.02	0.28
Percentage of population aged 65 and over	1.87	3.05	0.03	0.62	-0.03*	0.01	-0.13	-2.12
Percentage of recent immigrants	-3.51	5.54	-0.04	-0.63	0.00	0.03	0.00	-0.01
Percentage of visible minorities	4.68**	1.69	0.17	2.77	0.00	0.01	-0.03	-0.45
Percentage of lone-parent families	5.02	3.22	0.11	1.56	-0.04**	0.02	-0.24	-2.95
Percentage of people aged 25 to 64 years old without high school diploma	2.53	3.47	0.04	0.73	-0.02	0.02	-0.08	-1.17
Percentage of the employed labour force who commuted to work by private vehicles	14.19**	2.68	0.40	5.30	-0.05**	0.01	-0.35	-4.03
Percentage of employed labour force who commuted to work by public transit	6.85	4.39	0.10	1.56	0.00	0.02	0.00	-0.03
Population density (1000 per square km)	-1.94	4.61	-0.02	-0.42	-0.01	0.02	-0.03	-0.55
Percentage of single detached houses	-0.21	1.12	-0.01	-0.19	-0.01	0.01	-0.16	-1.88
R^2				0.36				0.15

Note. *p<.05, **p<.01

Table 4C. Negative Binomial Regression Model for Supermarket Diversity

	Number of supermarkets within 1 kilometer			
	B	SE	exp (B)	95% CI for exp (B)
Median household income (in 1,000$)	-0.04**	0.02	0.96	[0.93,0.99]
Unemployment rate	-0.02	0.02	0.98	[0.94,1.03]
Percentage of population aged 65 and over	0.01	0.02	1.01	[0.98,1.05]
Percentage of recent immigrants	0.04	0.03	1.04	[0.98,1.10]
Percentage of visible minorities	-0.02	0.01	0.98	[0.96,1.00]
Percentage of lone-parent families	-0.01	0.02	0.99	[0.96,1.03]
Percentage of people aged 25 to 64 years old without high school diploma	0.02	0.02	1.02	[0.99,1.06]
Percentage of the employed labour force who commuted to work by private vehicles	-0.01	0.02	0.99	[0.96,1.02]
Percentage of employed labour force who commuted to work by public transit	-0.01	0.02	0.99	[0.94,1.03]
Population density (1000 per square km)	-0.03	0.05	0.97	[0.88,1.07]
Percentage of single detached houses	0.01	0.01	1.01	[1.00,1.02]

Note. Log likelihood = -208 (df = 363), AIC = 439, BIC = 486.

**p<.01.

Identification of Food Deserts and Food Swamps

Finally, food access and food balance measures were combined with neighbourhood socioeconomic deprivation index scores to identify food deserts and food swamps in Windsor. As shown in Figure 9, there were in total 7 neighbourhoods (DAs) identified as “food deserts” in Windsor and they were scattered throughout different parts of the city. Four of them were located in the Sandwich District near the industrial plants; one neighbourhood was located in the north end of the Walkerville District by the river; one neighbourhood was located just west of the former Ford Motor Company’s engine plant; and the last one was located in the southeast of the Fontainebleau District. On average, residents living in these “food deserts” areas were 2,248 metres away from the nearest supermarket, and within 2,858 metres of the three closest different chain-name supermarkets. Both distances are far beyond reasonable walking distance. This low

accessibility can be potentially problematic, as these neighbourhoods also exhibited a high level of socioeconomic deprivation. In fact, all of the neighbourhoods identified above had median household income in the lowest quartile (25% city-wide) and had a percentage of single-parent families and a percentage of people without high school degrees in the top quartile. These areas also had below average vehicle ownership rates. Low-income and single-parent families, especially those without a vehicle, may find it challenging to access supermarkets outside their immediate neighbourhood due to their limited financial resources and time. As a consequence, they are more likely to rely on independent, smaller grocers or convenience stores, which sell a smaller variety of foods, and at higher prices.

On the other hand, there were more neighbourhoods (DAs) identified as food swamps than food deserts in Windsor (Figure 10) – those 34 DAs were mostly located in the northern part of the city, including the Sandwich District, the areas just east of the University of Windsor, the downtown core, and the areas in the north of the Walkerville District. Residents of these neighbourhoods on average needed to travel about 1,590 metres to reach the nearest supermarket, while only 321 metres to reach the nearest fast food outlet, so they had an average food balance score as high as 5.6. Similar to the "food deserts" identified above, these "food swamps" areas were also characterized by disadvantaged socioeconomic status in terms of low income, low vehicle ownership, low education attainment and high unemployment rates. In addition, most of them (85%) were ethnically diverse neighbourhoods with the proportion of visible minorities above the city's mean. Compared to supermarkets, fast food outlets tend to have fewer healthy food options but more energy-dense, less nutritious, processed foods. Previous research has indicated that not only higher exposure to fast food outlets but also lower prices per energy value for processed foods than healthier foods can encourage disadvantaged groups such as those with low income to purchase and consume more unhealthy foods. This may contribute to higher overweight and obesity rates found among low-income households (Drewnowski & Specter, 2004; Smoyer-Tomic et al., 2008).

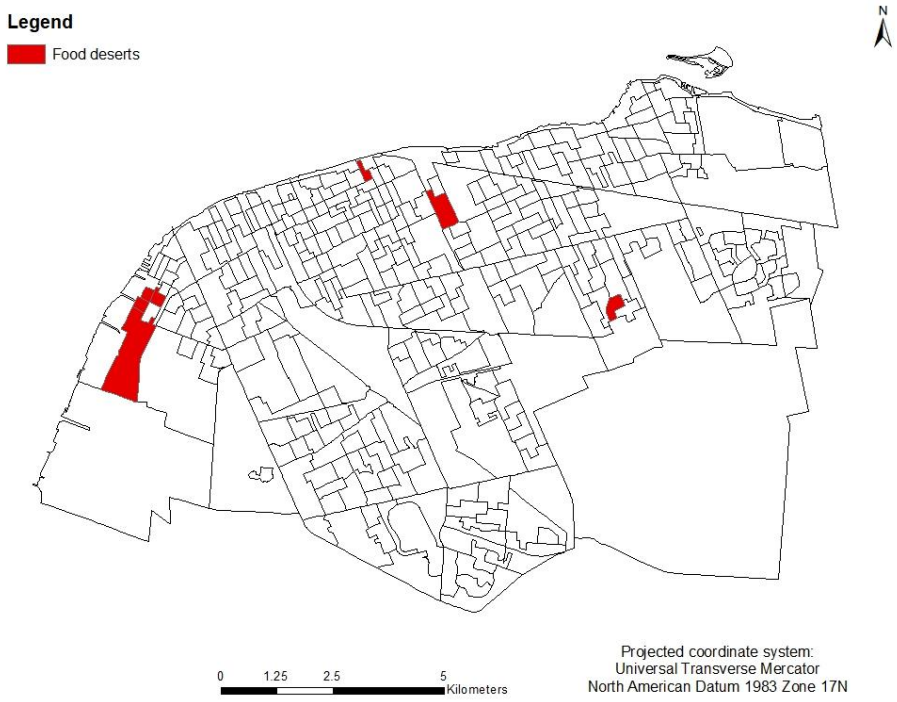

Figure 9. Food Deserts, Windsor, ON, 2018

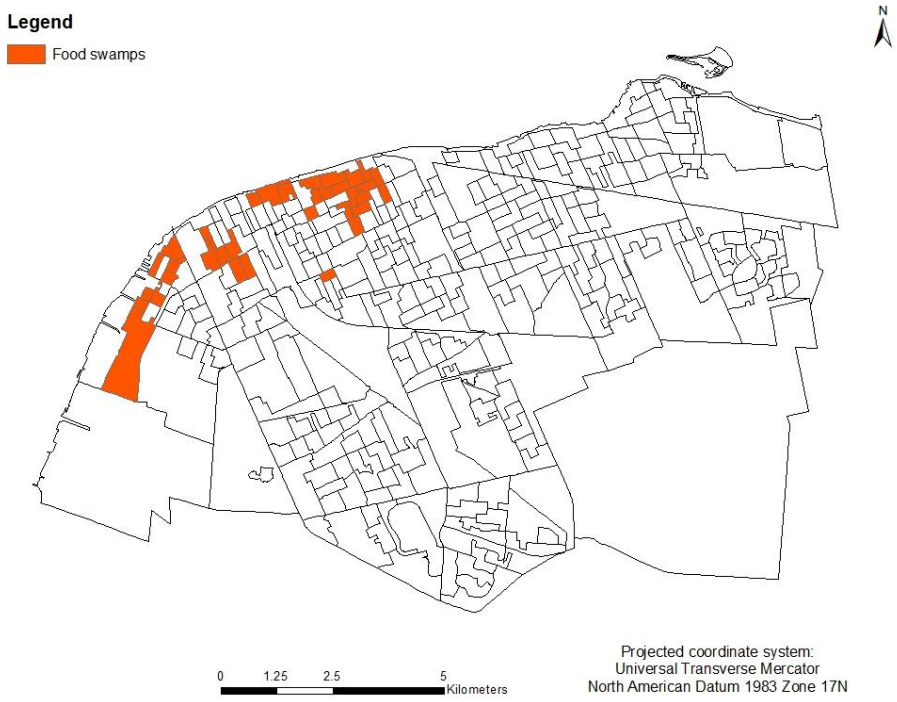

Figure 10. Food Swamps, Windsor, ON, 2018

DISCUSSION

The Spatial Patterns of Food Access and Food Balance

The results of this study indicate that in general, fast food outlets were more accessible than supermarkets in Windsor as more than half (58%) of the city's populations lived within walking distance (1 kilometre or less) of a fast food outlet, while only 13% of residents lived within walking distance of a supermarket. In fact, about 44% of the city residents lived more than twice as far from a supermarket as from a fast food outlet. Especially in some areas of the Sandwich District, food balance score was as high as 16.9, which means that residents of these areas lived about 17 times closer to a fast food outlet than a supermarket. This may be in part due to the big difference between the number of supermarkets and the number of fast food outlets that were examined in this study. It also reflects the general trend in the retail food landscape of most Canadian cities today - while the total number of fast food outlets has risen, the number of grocery stores and supermarkets has declined in recent decades due to the increased centralization of the retail food industry in Canada. Canadian food retailing has transformed from a system characterized primarily by independent, small-scale and neighbourhood-embedded grocers to a centralized, consolidated, scaled up system dominated by a few large food retailers (Bedore, 2013).

On the other hand, the spatial distribution of supermarkets and fast food outlets generally showed a similar pattern despite their different levels of accessibility - they both appeared to cluster in densely populated areas along the major roads and intersections. Previous studies conducted in other Canadian cities (e.g., London, Edmonton, Montreal) mostly found that supermarket accessibility follows a core-periphery pattern, with inner-city neighbourhoods having relatively better access to supermarkets compared to more peripheral areas. However, the empirical results for Windsor indicate a notably different picture - central, inner-city neighbourhoods with good accessibility coexisted with suburban neighbourhoods with good accessibility, and vice versa. The possible explanations could be that first, retail business such as supermarkets and fast food outlets require a certain customer base to be profitable. Therefore, it is not surprising that accessibility to supermarkets and fast food outlets in Windsor somewhat followed the spatial pattern of population density which generally decreased from central areas of the city to outlying areas. Higher population densities in those central areas are more supportive of profitable market areas for food retailers, compared to the lower densities in the suburbs (Smoyer-Tomic et al., 2006). It is worth noting that, however, low accessibility to supermarkets in some old, inner-city neighbourhoods (e.g. the Sandwich District, the Ford City) could be a result of several central-city stores closures that have occurred in recent years, which is partially attributed to emerging population loss in those areas. Local market research has indicated that Windsor's population has been increasingly moving outward from the central neighbourhoods to the new subdivisions outside the city core in recent years (N. Barry Lyon Consultants Limited, 2006). Such population shifts, plus the nationwide consolidation of the food retail industry, has made many older and smaller supermarkets in some mature, inner-city neighbourhoods unprofitable, resulting in their closure. Furthermore, most North American urban planning operates through zoning by setting aside various parcels of land for separate and distinct uses (e.g., residential, commercial, industrial and agricultural uses) (Black et al., 2011). It is important to recognize that such processes can also influence how food stores are distributed across urban spaces. Previous research has indicated that zoning tends to serve the exclusionary interests of entrenched elites and place a model of stable residential neighbourhoods

above other possible uses (Black et al., 2011; Sewell, 1994; Shlay & Rossi, 1981). As a result, this sort of planning is more likely to keep out food stores and other uses from residentially zoned wealthier neighbourhoods, attempting to preserve home values in these areas (Black et al., 2011; Shlay & Rossi, 1981). However, this can also potentially cause limited access to local food stores in those communities, which may in part explain why several large residential areas in the southwest, south and east end of Windsor had low accessibility to supermarkets and fast food outlets. In addition, the increased centralization among Canada's food retailers has resulted in a food landscape dominated increasingly by large corporate chain supermarkets, which require larger land parcels and are often more reliant upon people with private vehicles. Not surprisingly, locations with more readily available land (e.g., locations with commercial and residential mixed use) and that are closer to major transportation routes are also more likely to have more food options (Black et al., 2011). For example, some of Windsor's suburban neighbourhoods along Tecumseh Road East and Wyandotte Street East had very good access to supermarkets.

The Role of Neighbourhood Characteristics on Food Access and Food Balance

The above empirical results for Windsor provide an interesting comparison with findings from previous studies where the relationship between food access and socioeconomic status was examined. For supermarket accessibility, our results generally provide support for those studies from New Zealand (Pearce et al., 2007) and some UK studies (e.g., Cummins & Macintyre, 2002b; White et al., 2004), which found better supermarket provision in socioeconomically deprived areas. Our findings also reveal some similarities to those from other Canadian cities, including Edmonton (Smoyer-Tomic et al., 2006) and the metropolitan regions of British Columbia (Black et al., 2011) where more affluent urban neighbourhoods housed fewer supermarkets than lower income areas. In contrast, many U.S. studies (e.g., Morland et al., 2002; Walker et al., 2010; Zenk et al., 2005) have shown that lower-SES neighbourhoods, particularly those with higher proportions of low-income or African American residents, had lower supermarket accessibility. In terms of ethnic composition, our Windsor findings appear to show some support for those from the U.S., insofar as neighbourhoods with higher proportions of visible minorities were associated with decreased supermarket accessibility even after adjusting for income and other socio-economic variables. Consistent with previous research in the U.S. and U.K. (Cummins et al., 2005; Morland et al., 2002), our results suggest that neighbourhoods of greater socioeconomic deprivation had higher exposure to fast food outlets. In particular, neighbourhoods with lower median household income and lower private vehicle ownership were more likely to have access to a nearby fast food outlet. Nevertheless, unlike several U.S. studies (e.g., Block et al., 2004; Lewis et al., 2005) where predominantly African American neighbourhoods had greater exposure to fast food outlets than predominantly white areas, increased minority composition in Windsor was associated with lower accessibility to fast food outlets. This may imply that, other things being equal, food retailers like supermarkets and fast food outlets in Windsor are less likely to consider minority communities as a valuable customer base in their siting decisions. Visible minorities in Windsor on average face higher levels of poverty. According to the 2016 Canadian census, the prevalence of low income among visible minorities in Windsor was 17.5%, compared to 12.9% for non-visible minorities (Statistics Canada, 2017c). It has also been shown that minority populations often rely on small, independent food stores that sell foods used commonly in the cuisines of specific ethnic groups, such as Chinese, Indian, Korean, and African specialties. (Black et. al, 2011). Consequently, ethnically diverse neighbourhoods may seem less attractive and profitable for supermarkets and fast food outlets.

There are few studies in the food desert literature with which to compare our findings regarding the association between food balance and neighbourhood deprivation. A recent study in Saskatoon, Saskatchewan, found that food balance generally worsened as material deprivation and social deprivation increased (Cushon et al., 2013). However, this does not appear to be the case in Windsor, where food balance was not significantly different by neighbourhood-level deprivation. Our results still indicate that neighbourhoods with higher concentrations of single-parent families, senior populations, and people who drive to work were more likely to have a more balanced food environment.

Strengths, Limitation and Suggestions for Future Research

This study has several notable strengths. First, there has been a limited amount of research into the comparative accessibility to supermarkets and fast food outlets in Canada. This study simultaneously examined supermarkets and fast food outlets accessibility, and explicitly compared them by using a food balance score. Secondly, this study also explores the association of both food access and food balance with neighbourhood characteristics based on a variety of census variables for income, ethnicity, education, employment, family status, transportation and zoning. By using multivariate regression models, this study has identified several neighbourhood characteristics that had the most significant effect on food access and food balance in Windsor after taking other variables into account. Thirdly, this study not only focuses on socioeconomically deprived areas with limited access to supermarkets as the majority of food desert studies do, but also explored the potential existence of food swamps - socioeconomically deprived areas that have easier access to less healthy foods (fast food outlets) compared with access to healthy foods (supermarkets). This is a unique contribution to the food desert literature as it allows for a more comprehensive analysis of the food environment.

There are some limitations to this study. First, due to time and budgetary constraints, this study only focuses on supermarkets as the main source of healthy foods. However, other types of small food retailers like fruit and vegetable markets, specialty stores (butcher, fishmonger) and ethnic grocery shops may also offer a range of healthy food products (Apparicio et al., 2007). The presence of these kinds of smaller food stores may thus improve residents' access to healthy foods, especially in areas where large supermarkets are not easily accessible. However, it should be noted that the availability, quality, and price of foods sold in these stores could vary quite highly (Apparicio et al., 2007). Therefore, future studies could include a broader set of stores where fresh foods are sold and attention could be paid to the potential differences in food quality and food prices in those different types of food retailers. Secondly, this study is cross-sectional, which does not account for trends over time. As discussed above, the landscape of food retailers in Canada has changed dramatically in the last decades as has its potential impact on individual food consumption patterns, and diet-related health. Longitudinal studies should be considered for further studies in the future, such as tracking how supermarkets, fast food outlets and neighbourhood characteristics changed over time as well as the temporality of associations between them. Thirdly, the ecological nature of this study does not allow us to draw conclusions about individual food shopping patterns and behaviors. In other words, people within the same neighbourhood can still have different levels of access to healthy/unhealthy foods due to their various economic statuses, social and cultural norms, as well as physical and psychological characteristics. Future studies using individual-level data on food shopping and consumption behaviors would shed light on where individuals do their food shopping, and how these decisions are influenced by geographic distance to food stores,

convenience of transportation, as well as other personal factors.

CONCLUSION

This study shows that access to supermarkets and fast food outlets varied according to neighbourhood-level socioeconomic deprivation in Windsor, with socioeconomically disadvantaged areas having better food access than advantaged areas. However, food balance did not follow a clear socioeconomic gradient. The results also identify a couple of socioeconomic characteristics that had significant effects on food access and food balance after taking urban planning and zoning factors into account. Consistent with previous findings in other Canadian cities, this study finds that "food swamps" were more prevalent than "food deserts" in Windsor.

Taken together, the results from this study provide new insights into the geographic variation in access to healthy/unhealthy food stores as well as the role of neighbourhood characteristics on such spatial disparities in Windsor. These findings have important implications for local policy and practice that aim to improve the food environments. In particular, food policy and program interventions should not only focus on increasing access to affordable and nutritious foods, but also on reducing exposure to unhealthy food options. The focus of those interventions should differ depending on whether the community is a "food desert" or a "food swamp." For example, to address "food deserts," the municipal government could create incentives (e.g. tax breaks, development charges reductions) to attract full-service grocery stores to marginalized, underserved areas. The city could also develop policies and programs to draw other sources of healthy foods like famers' markets, community gardens, and healthy mobile food vendors in underserved areas to increase access to healthy and fresh foods. On the other hand, a feasible solution for "food swamps" would be to use zoning regulations to limit the prevalence of fast food outlets in specific communities, or to implement healthy corner store programs that increase the availability and affordability of healthy foods in existing convenience stores (Mah et. al, 2014). In conclusion, reshaping food environments to enhance public health is challenging and calls for multidisciplinary collaborations between public health, provincial governments, municipalities, and private industry. The results from this study can be used by key stakeholders to identify spatial disparities in food access and allocate resources to the areas most in need, in order to create healthier and more equitable food environments.

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