Neighborhoods' Food Environments Revisited: Food Deserts or Food Swamps?

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Abstract

This study uses service area-based coverage method and Poisson regression models to assess neighborhood healthy and unhealthy food environments in the City of Edmonton, Canada. We correlate food availability with different neighborhood socio-economic status (SES). Based on different food environments, we further identify three types of vulnerable neighborhoods that can be considered food deserts, food swamps and food tundras. Results from this study can provide policy makers with tailored strategies to effectively improve food environments with limited resources. Key findings include: (1) Neighborhoods with higher rates of deprived population such as unemployed, minority and low income groups have better access to healthy foods in general; (2) Children populations are negatively associated with both healthy and unhealthy food availability; and (3) Good access to public transportation is associated with good coverage of all types of food stores.

Keywords: neighborhood food environment; food desert; food swamp; food tundra; service area; Poisson regression model

1. Introduction

Healthy food intake is essential to overall health status, and is reported to reduce the risk of nutrition-related chronic diseases such as obesity and type II diabetes (Camhi et al., 2015; Swan et al., 2015). There is growing evidence that geographic access to different types of food outlets substantially influences dietary patterns and weight status at the population level (Moore et al., 2009; Morland and Evenson, 2009; Morland et al., 2006). A report that systematically reviews 19 Canadian community food assessments found a positive association between geographic access to non-nutritious food sources and obesity rate, especially among children and youth (Health Canada, 2013). Typically, neighborhood food environments are studied through the lens of the accessibility to different types of food resources, and there are mainly two streams of food outlets in literature. One refers to food retailers that can supply healthy and nutritious foods at relatively affordable prices, such as supermarkets and local grocery stores (see Walker et al., 2010, for a review). The other type is unhealthy food sources such as fast food restaurants and convenience stores that mainly sell fast food and non-perishable items (e.g., Fleischhacker et al., 2011; Black et al., 2014).

Vivid descriptions of different food environments come from various ecological terms (Taylor and Ard, 2015). For example, originating in the United Kingdom in the 1990s, the term “food desert” is now commonly used to describe poor urban communities that lack access to fresh, healthy and affordable food in North America (USDA, 2009). While there is a myriad of food desert studies, a few studies also came up with the concept of a “food oasis” to describe neighborhoods that have superior access to healthy food outlets (Krizan et al., 2015; Short et al., 2007; Walker et al., 2010). Opposite to food oasis, the term “food swamp,” to describe low-income urban communities that have a plethora of fast food restaurants and convenience stores that sell less healthy or unhealthy food, is also gaining popularity (Rose et al., 2009). “Food swamp” is considered an especially valuable concept to describe neighborhood food environments, as the excess of unhealthy food would “inundate” or “swamp out” the healthy food choices residents have (Rose et al., 2009). Identification of different types of food environments is valuable for policy purposes because different types of food environments require specific, tailored strategies to mitigate the problem.

Another strand of research on food environments is to investigate the associations

between neighborhoods' food availability and socio-economic status (SES) (Duan et al., 2013; Lamichhane et al., 2013; Sharkey et al., 2009). In general, the availability of food retailers has been shown to vary with neighborhood SES, depending on study areas. For example, fewer retail sources of healthy food (e.g., supermarkets) and more sources of unhealthy food (e.g., fast food restaurants and conveniences stores) are found to be located in neighborhoods with higher proportions of low-income and ethnic-minority residents relative to more affluent neighborhoods or those with fewer minorities in the U.S. (see Black et al., 2014, for a review). Comparatively, in Canada, more deprived neighborhoods have greater access to both healthy and unhealthy food outlets, with some variations across study areas (Black et al., 2011; Polsky et al., 2014; Smoyer-Tomic et al., 2008).

The objective of this article is to comprehensively assess neighborhood food environments and to investigate associations between neighborhood SES and different food availability. Combining both healthy and unhealthy food outlets, we identify three different types of food environments used in current literature. In addition to the widely assessed "food desert" and "food swamp" issues, we contribute to the literature by introducing a new concept, "food tundra," to describe neighborhoods that have easy access to unhealthy food but deficient healthy food availability. The identification of food tundra neighborhoods can help detect communities that have been "forced" to consume less healthy food because of the abundant availability of fast food and no easy access to healthy food. These targeted areas are in extreme need of an improved physical food environment, especially for deprived groups in these communities. From a policy perspective, we might label them as the most vulnerable group. Furthermore, in contrast to most previous studies that adopted a distance-based method to measure the food accessibility, we also make a contribution to the literature by using the "service area" approach. The service area method addresses the "edge effect" that is often ignored by the distance-based measurement, and can more accurately describe the neighborhood food environment. Finally, we use service area-based Poisson regression models to investigate the unequal associations between neighborhoods' SES and availability of various food sources. Results drawn from this study therefore offer a more nuanced (less biased) understanding of the physical food environment in the study area, and can provide better empirical support for future policy designs.

2. Study Area, Data and Methods

2.1 Study area

As a median-sized North American city in the peri-urban area, the City of Edmonton provides an interesting case study because of its increasing policy focus on community food environment. The City has made substantial efforts to create a favorable food environment for its citizens. Established in 2012, the Edmonton Food Council launched the City's Food and Agriculture Strategy *Fresh*. One of the five goals outlined in the strategy is to develop neighborhoods into healthier and more food secure communities. Developed in consultation with citizens, interest groups, businesses and organizations, the ultimate goal of *Fresh* is to help guide Edmonton toward a resilient food and urban agriculture system (City of Edmonton, 2012). Meanwhile, the City (and the Province alike) has paid particular attention to children and adolescent groups partially because of the increasing childhood obesity epidemic (Health Canada, 2013). School-based health promotion programs that hope to improve healthy living habits of students and to sustain capacity for healthy environments in school communities have been established and kept expanding across the city. For example, the Alberta Project Promoting active Living and healthy Eating in Schools (APPLE Schools) is a school-wide intervention that was launched in 2008. Fung et al. (2012) and Vander Ploeg et al. (2014) reported that APPLE Schools have increased students' vegetable and fruit intake by 10% and students are 40% less likely to be obese.

Several prior studies on the assessment of food access were conducted in Edmonton. Two of them focused on fresh food accessibility and the identification of food deserts. Specifically, Smoyer-Tomic et al. (2006) focused on the supermarkets, and identified nine food desert neighborhoods across the city based on low accessibility and high-need criteria. Wang et al. (2014) further introduced community gardens and farmers' markets into the healthy food analysis. Their results indicated that community gardens and farmers' markets can help alleviate the food desert problem to some extent. Smoyer-Tomic et al. (2008) explored the association between neighborhood SES and exposure to both supermarkets and fast food outlets. Results from this study showed that the odds of exposure to fast food outlets were higher in areas with deprived populations. However, all existing literature ignored the local grocery stores, which are especially important fresh food outlets in

Edmonton, a city that has been invested substantially on local food industry and urban agriculture. Previous studies in Edmonton also did not include convenience stores as a common source of unhealthy food retailers in literature. Furthermore, all these prior studies were based on nearest distance calculation to describe the neighborhood food accessibility. This distance-based approach relies on the centroid to represent the whole neighborhood food environment and ignores the "edge effect" (Sadler et al., 2011).

2.2 *Data*

There are four sets of food stores in this article that can be divided into two streams, healthy and unhealthy food outlets. Healthy food outlets include supermarkets and local grocery stores, and unhealthy food outlets include convenience stores and fast food restaurants. All of these food stores are from DMTI Spatial Inc., which is a commercial company offering location-based data in Canada. Supermarkets are assumed to provide a full range of food products (e.g., fruit, vegetables, meat and dairy products). These full-service supermarkets are mainly the outlets of chain stores such as Sobeys, Safeway, Superstore and Walmart. Local grocery stores or specialty shops also sell fresh fruits and vegetable, meat, or fish and other seafood. Store information was further confirmed by verifying stores' official websites. Non-relevant shops, such as drug markets and liquor stores, were excluded from these two categories. Fast food restaurants are defined as quick-serving food outlets that offer relatively limited menus and food preparation options (e.g., burgers, sandwiches and pizzas), where patrons pay before receiving meals. In this study, they are primarily the outlets of franchised stores such as A&W, KFC, McDonald's, Subway and Wendy's. Stores that do not provide food services on a regular basis or non-food restaurants, such as bars and inns, were excluded from the analysis. Convenience stores are considered outlets that sell a limited selection of daily living items and offer less healthy, sugar and energy-intense food commodities. Based on the classification in the DMTI database, these stores are mainly some chain stores such as 7-Eleven and Mac's and gas station food stores. As a result, we have 82 supermarkets, 40 local grocery stores, 783 fast food restaurants and 199 convenience stores in the City of Edmonton (Figure 1).

[Figure 1 is about here]

We extracted the neighborhood SES from Statistics Canada, National Household Survey

(2011). There are 392 defined neighborhoods in the City of Edmonton. However, 145 are non-residential neighborhoods (mainly industrial areas) that have no residents and census data. We thus excluded these non-residential neighborhoods, and only used 247 residential neighborhoods for following analyses. Road network data and the neighborhood shapefile for Edmonton were obtained from CanMap RouteLogistics (v2012.3), which is managed by the University of British Columbia.

2.3 *Measuring accessibility/availability using GIS approach*

Distance-based measurement is the most commonly used method in food access research. With the help of road network, distances between study areas and food outlets were calculated (McKenzie, 2014; Wang et al., 2014). However, using the centroid of a neighborhood to calculate the distance as the entire neighborhood's food accessibility fails to capture the heterogeneity within a neighborhood (i.e., the different accesses in different sub-areas). In other words, the calculated distance cannot accurately depict residents' actual food availability as they may live randomly within the neighborhood, which could be farther away from the physical centroid of a neighborhood. An additional methodological drawback of the distance-based measurement in most prior studies is the constraint of distance to the closest food outlet. This underestimates the food availability when there are clustering stores in certain areas, which is particularly true in the case of food swamps. A large number of fast food restaurants and convenience stores often exist in a single neighborhood.

As a result, researchers have proposed other methods to alternatively capture neighborhood food availability. For example, Lu and Qiu (2015) and Wang et al. (2014) adopted the coverage method to measure neighborhoods' food availability by drawing buffers based on the center of study areas and thus counting the number of total food stores within a threshold distance (e.g., 1-km). However, these studies also chose the centroid or population-weighted centroid of a neighborhood to represent the whole neighborhood or community. Additionally, food stores outside the neighborhood boundary can be easily neglected when evaluating store availability for a specific neighborhood, which leads to the "edge effect" (Sadler et al., 2011; Van Meter et al., 2010). Sadler et al. (2011) reported that including the edge effect can account for approximately 37% higher in accuracy of food access estimation.

A service area, as the name suggests, defines an area around a food outlet that could be served by the store given certain access criteria (e.g., within 30 minutes walking distance or within a certain threshold road distance like 1-km). This concept has been widely used in literature of the assessment of public services such as health agencies, transit stations and sewerage services (Hochmair, 2015; Lampe et al., 2015; Lieske et al., 2015). However, there exists limited research in the field of food access. Quantitative analysis of service areas study is even scarcer. For instance, Larsen and Gilliland (2008) created a "service area" of 1-km based on each supermarket to assess the level of supermarket access in the case of London, Ontario, but their results were primarily at the descriptive level using mapping techniques. In this study, we first calculated the "service area" for each store, based on a threshold road network distance. Following Larsen and Gilliland (2008), we chose 1-km as the threshold to conduct the service area analysis. Figure 2 shows the distribution of service areas in four different cases when different food outlets are selected.

[Figure 2 is about here]

2.4 *Poisson regression model*

The classic linear regression model using the ordinary least squares (OLS) technique is a common practice in literature that examines the relationship between food accessibility and neighborhood SES (Engler-Stringer et al., 2014; McKenzie, 2014; Wang et al., 2016). Others have used Poisson regression models to investigate the number of stores in association with neighborhood characteristics (Galvez et al., 2007; Lamichhane et al., 2015; Mundorf et al., 2015). This technique can mitigate the problem of clustering food stores in the study area, as a better representation of food availability than the distance-based method. However, most prior studies directly used the store counts within a neighborhood, which ignores the case when residents commute to neighboring communities to purchase food (the so-called "edge effect" issue). To address this problem, we adopted the "service area" method and include those stores in nearby neighborhoods as long as their service areas cover, at least partially, for each neighborhood. The specification of Poisson regression model is as follows,

$$Y(N_i)|\lambda(N_i) \sim Poisson\{\lambda(N_i)\}$$

$$ln\{\lambda(N_i)\} = \boldsymbol{X_i\beta} + \varepsilon(N_i)$$

where $Y(N_i)$ is the count of service areas in neighborhood N_i, and $\lambda(N_i)$ is the expected

count of service areas at the same location. As a common assumption, the logarithm of the expected count is a linear function of covariates and an error term that represents the unobserved elements (Lamichhane et al., 2015; Mundorf et al., 2015). $\boldsymbol{X_i}$ is a vector of neighborhood-level covariates (including an intercept term) of neighborhood N_i, and $\boldsymbol{\beta}$ is a vector of coefficients to be estimated. $\varepsilon(S_i)$ is an *i.i.d.* unobserved error term.

The neighborhood-level independent variables include: the percentage of the adolescent population aged under 19 (*Children*); the percentage of the senior population aged 65 and over (*Senior*); the percentage of residents who have a higher education such as postsecondary certificate, diploma or degree (*High Education*); the percentage of unemployed residents (*Unemployment*); the percentage of minority group (*Minority*), which refers to immigrants who are mainly South Asian, Chinese, Black, Filipino, Latin America etc.; the median income at the neighborhood level (*Median Income*); the percentage of private car access (*Private Car*), which refers to individuals who have access to a car, truck, or van as primary commuting transportation, including both passengers and drivers; and the percentage of residents using public transport who take buses and trains as the primary travel option (*Public Transport*). Note that both *Private Car* and *Public Transit* are based on residents who are over 15 and employed. Table 1 summarizes the neighborhood socio-demographics in Edmonton.

[Table 1 is about here]

3. Results

3.1 Descriptive analysis

Statistics from Table 1 indicate that residential neighborhoods in Edmonton have an average of 2.31 service areas based on healthy food outlets. The supermarket availability is almost double that of local grocery stores. However, there are neighborhoods with clustering local grocery stores that make the maximum number of service areas even higher than that of supermarkets. With respect to unhealthy food sources, the average number of service areas is about 15, with 80% coming from fast food restaurants. In addition, heterogeneity is evident among neighborhoods regarding the spatial pattern of service areas based on different food sources. Figure 2 demonstrates that neighborhoods in the downtown area (located in the center part of the city) are almost covered by any type of

food providers. However, neighborhoods in the southwestern part of the city, named "Riverbend" that were specifically identified by Wang et al. (2014), have quite limited access to both healthy food outlets, but there are several unhealthy food sources in that region. Another interesting finding is that the neighborhoods in the northeastern area of the city have very limited healthy food stores but a rich clustering of convenience stores and a few fast food restaurants. Several supermarkets but almost no local grocery stores exist in the southeastern region of the city. At the same time, quite a few fast food restaurants and convenience stores gather in that region, which may crowd out the healthy food options.

When it comes to the neighborhood SES, Table 1 further shows that slightly more than 40% of residents in the city rely on private cars as primary daily commute, and fewer than 8% of them choose public transit as their main transportation option. Almost half of residents earned higher education and the maximum rate is as high as 75%. The average median household income at the neighborhood level is around $CAD 38,000. However, the gap between the rich and poor is rather huge with the maximum being more than 20 times than the minimum. The rate of unemployed residents is relatively low with an average of 2.24% across the city, with residents in some neighborhoods fully employed. There are neighborhoods with dominantly white residents, and some neighborhoods have more than half minority groups. In some neighborhoods, the percentage of children and seniors can be as high as 35% and 43%, respectively, and the minimum rate is less than 5%.

3.2 Identification of different food environments

Following the common practice, we chose the combination of low healthy food availability, low income and high population density to define "food deserts" (USDA, 2009). Neighborhoods with the number of service areas fewer than two (below the city median), which constitute about 45% of all residential neighborhoods in the city, were defined to have low availability. We then selected the bottom quartile (25%) of median income and top quartile (25%) of population density as the other two criteria. As a result, this leads to seven neighborhoods that might be considered food deserts. A "food swamp" usually refers to as a low-income urban community that has a plethora of unhealthy food outlets such as fast food restaurants and convenience stores (Rose et al., 2009). We thus chose the number of service areas more than 20 (approximately 25% of all residential neighborhoods) as the high

availability of unhealthy food. Combined with other two criteria namely bottom quartile (25%) of median income and top quartile (25%) of population density, we identified 13 food swamp neighborhoods for the city. As policy makers and other interest groups are particularly interested in identifying the most vulnerable neighborhoods, we introduce the concept of "food tundra" by overlapping the "food desert" with "food swamp" neighborhoods to characterize neighborhoods with poor access to healthy food but have excessive coverage of unhealthy food outlets. As a result, we found three food tundra neighborhoods across the city. Figure 3 shows the three types of neighborhood with different food environments, and Table 2 summarizes these neighborhood characteristics.

[Table 2 is about here]

Similar to the results in previous studies in Edmonton (Smoyer-Tomic et al., 2006; Wang et al., 2014), the food desert neighborhoods are scattered across the city. Besides the relatively low availability of healthy food outlets in terms of service areas, they have lower private car access and higher percentage of children and unemployed residents in comparison to the city mean. As for the policy implications, the establishment of community gardens and farmers' markets may potentially help increase the fresh food availability and thus improve the food environment in these food desert neighborhoods (Sadler et al., 2013; Wang et al., 2014). For the food swamp neighborhoods, there is a clear pattern of three clusters in the city, including the city core, university area and the western part of the city (Figure 3). In comparison to the city average, these neighborhoods have higher rates of unemployment and minority groups, have much lower private car access, and rely more on the public transportation systems. Additionally, the percentages of children and senior residents are lower in these regions. Given that these neighborhoods already have abundant food sources (both healthy and unhealthy food outlets), advocating healthy diet habits and promoting educational campaigns may be more feasible strategies.

[Figure 3 is about here]

For the three "food tundras," on average, there is only one supermarket service area for each neighborhood, however, each neighborhood has 27 unhealthy food retailers that can serve the residents. All three neighborhoods (i.e., Aldergove, Belmead and Thorncliff) are located in the western part of the city (see Figure 3). These three neighborhoods have

relatively high populations with disadvantaged SES (i.e., higher unemployment rate, less high educated populations, lower median income and less access to private cars). Meanwhile, the three neighborhoods have higher percentages of children and minority populations.

Results from this section can help the City identify the key neighborhoods with high potential for local business and the main neighborhoods that need particular support. In terms of strategy, it requires careful consideration and tailored plans for different food environments. For those food swamps with adequate access to healthy foods, policy and public efforts may focus on educational campaigns and community-supported programs to promote healthy diet habits. For those food deserts, not including the food tundras, because these neighborhoods are spread across the city, one big supermarket will not solve the problem for all simultaneously. Policy interventions that encourage new supermarket businesses through tax credits and other forms of benefits may not work effectively as these big businesses usually require large amounts of input (e.g., infrastructure, labor, parking space), and the purchasing power and populations are relatively low in these areas. A more realistic plan is to support other small businesses (e.g., local grocery stores and specialty stores) and alternative fresh food suppliers (e.g., food-producing community gardens and yard gardens), which is consistent with the *Fresh* strategy. For the three food tundra neighborhoods, they are the most vulnerable communities which have no easy approximation to fresh food but are heavily surrounded by abundant unhealthy food outlets. Alternatively, the cost of accessing to fast food is lower meanwhile the cost to healthy food is higher than any other neighborhoods in the city. This makes the deprived subpopulations such as children, low-income families, households without access to private cars within the area most vulnerable groups that deserve more public attention and policy efforts. Strategies such as supporting for local grocery stores and alternative fresh food suppliers will also help relieve the issue. At the same time, because all three neighborhoods are located at the same area, a new large supermarket offering a wide variety of healthy food such as meat, fresh produce, dairy and baked goods might substantially improve the food environment for the whole area and is thus worth municipal and community interventions.

3.3 Poisson regression results

With regard to SES inequity, many U.S. studies found that deprived populations, such as

seniors, immigrants and unemployed residents, have comparatively limited access to fresh foods (see Larson et al., 2009; Walker et al., 2010). However, these disadvantaged groups are found to have relatively better fresh food availability in the case of Edmonton, based on results shown in Table 3. Specifically, unemployment rate is significantly positively correlated with an increase in the log of expected counts of service areas, and minority groups are also found to be living in neighborhoods that are well served by healthy food outlets in general. Such evidence can also be found in other Canadian studies. For example, a study in Montreal, Quebec showed a positive relationship between social deprivation index (which includes unemployment rate and recent immigrants) and the number of supermarkets within 1-km (Appariocio et al., 2007). Similar results were also found in another city of the same province, Gatineau, that deprivation is overall positively correlated with better accessibility to fresh fruits and vegetables (Gould et al., 2012). Black et al. (2011) also indicated a positive association between visible minority residents rate and the number of large supermarkets and fresh food stores within 1-km of residential addresses in British Columbia. However, one noteworthy outcome is the significantly negative association between neighborhood's children percentage and the number of service areas given both types of fresh food sources. Similar results in Saskatoon showed that neighborhoods with higher rate of children aged 5-14 have longer distances to the nearest healthy food stores (Engler-Stringer et al., 2014). Considering the increasing obesity rate among children and youth in the province (Health Canada, 2013), this finding should raise local authorities' awareness of the food environment. The unfavorable access to healthy food could potentially attribute to children's unhealthy food intake.

Although we find that overall, disadvantaged groups have relatively better access to healthy stores, we also revealed that for these swamp, desert and tundra neighborhoods, the percentages of deprived populations are higher than the city average. However, the inversed situations in those 20 neighborhoods are not significant enough to influence the regression results, which represent the average situation (of the 247 neighborhoods). Our seemingly contradictory results from the food environment assessment for specific vulnerable neighborhoods and a general association analysis are both important and essential to better understand the food access issue and therefore to design appropriate

policies and programs to improve the situation. Meanwhile, overly exaggerating the food environment issue and the unfavorable inequality between different socio-economic groups should be avoided.

When it comes to the unhealthy food availability, many studies in United States tend to find that unemployed and immigrant groups are more vulnerable and have easier access to less favorable food outlets such as fast food restaurants and convenience stores (see Laxy et al., 2015; Pearce et al., 2007; Powell et al., 2007). Our results from Table 4 are generally consistent with their outcomes. For instance, neighborhoods with higher rates of unemployment and minority groups have more service areas of unhealthy food sources. For the adolescent and senior groups, however, they are less likely to get access to these unhealthy foods compared to other age groups. Similar results can be found in another Canadian prairie city (Saskatoon) in which neighborhoods with a higher rate of children aged 5-14 have longer distances to the nearest unhealthy food stores (Engler-Stringer et al., 2014). Wealthy residents tend to live where there are fewer services of unhealthy food outlets, although the effect is relatively small. But such results do not exist when it comes to healthy food availability. Residents with high education tend to have more healthy food services, but the association turns out to be statistically insignificant for the unhealthy food availability.

In combination of results from both healthy and unhealthy food outlets (Table 3 and Table 4), we can see that public transit displays a significantly positive association with both healthy and unhealthy food availability. This positive relationship can be explained through the supply and demand theory. Residents largely relying on public transit tend to live near public transit centers in the city, where a fairly large number of food outlets, both healthy and unhealthy ones, are located. Despite quite a few available healthy food outlets, there are pervasive unhealthy food sources, which could inundate residents' healthy food options. As a result, it is not surprising that a group of food swamp neighborhoods cluster in the downtown area where there is the most convenient public transit system across the city, as shown in Figure 3. While establishing a more complete public transit network can improve healthy food access by attracting more fresh food businesses, our results further imply that advocating educational campaigns for a healthy diet, may be of higher need to ameliorate the overall food environment in these neighborhoods. Another note from the comparison is

the negative relationship between the adolescent group and the number of service areas in both healthy and unhealthy food sources. As it has been indicated that adolescents are beginning to make their own food choices and the dietary habits formed during these years can have a long-lasting impact on their food intake throughout the lifespan (Kelder et al., 1994), policy makers and other interest groups in the city may want to pay special attention to the food environment of this group. Our findings can thus provide some clues for future policy designs. Although the children group tends to have fewer service areas of unhealthy food, the healthy food availability is quite limited as well in a general sense. Specific programs, such as the involvement in community gardens and participation in APPLE Schools, can be effectively implemented in neighborhoods with higher adolescent rates.

[Tables 3 and 4 are about here]

4. Discussion and Conclusion

This study uses service area methods to assess neighborhood food environments and investigates food availability in association with neighborhood socio-economic status. The key results include: (1) Deprived communities in general have better access to fresh foods. However, for the three types of vulnerable neighborhoods (food swamps, food deserts and food tundras), we find they have relatively high percentage of disadvantaged groups; (2) Children face poor coverage of both healthy and unhealthy food stores in nearby areas; and (3) Public transportation is positively associated with the availability of all types of food retailers. Implications for improving vulnerable neighborhoods food environments using different strategies and promoting local grocery stores and urban agriculture were discussed to provide useful information for future policy designs.

From an empirical perspective, the identification of food swamps, food deserts and food tundras provide policymakers and the public with an in-depth understanding of neighborhood food environments and contribute to the design of more effective strategies. Results also assist in identifying the most vulnerable communities that require immediate and substantial supports, and thus contribute to a better allocation of the limited municipal resources (e.g., financial and staff supports).

Finally, the service area-based method considers spatial heterogeneity within a

neighborhood/community and solves the edge effects at the same time. Therefore, it might be a useful expansion of the traditional distance-, coverage-, and density-based assessments for OLS/Poisson regression methods. Future studies might also find it useful when investigating other related food environment issues.

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Table 1. Summary of Service Area and Neighborhood Characteristics (N=247)

Variables[a]	Median	Mean	Minimum	Maximum
Service Area (No.)				
Healthy Food Outlets	2	2.31	0	13
Supermarkets	1	1.52	0	6
Local Grocery Stores	0	0.79	0	8
Unhealthy Food Outlets	12	14.97	0	109
Fast Food Restaurants	9	12.08	0	99
Convenience Stores	3	2.89	0	10
Population Density (1,000 per km^2)	2.80	3.27	0.01	99.70
Children (%)	23.43	22.80	4.88	35.05
Senior (%)	10.91	12.36	1.10	43.27
High Education (%)	44.98	46.27	13.82	75.86
Unemployment (%)	2.13	2.24	0.00	7.37
Minority (%)	23.52	23.88	0.00	56.60
Median Income (1,000 CAD$)	35.91	37.60	3.23	65.22
Private Car (%)	42.00	41.71	9.32	68.86
Public Transport (%)	6.82	7.25	0.00	19.04

[a]: We investigated the potential multicollinearity problem and found coefficients of correlation matrix are all relatively small.

Table 2. Summary of Neighborhoods with Different Food Environments

Variables	Mean Value			
	Food Desert (N=7)	Food Swamp (N=13)	Food Tundra (N=3)	City (N=247)
Service Area (No.)				
Healthy Food Outlets	1	4.85	1	2.31
Unhealthy Food Outlets	14.57	40	27	14.97
Population Density (1,000 per km^2)	4.15	4.72	3.73	3.27
Children (%)	24.10	19.77	25.42	22.80
Senior (%)	8.76	10.34	9.30	12.36
High Education (%)	44.27	44.68	43.99	46.27
Unemployment (%)	3.79	3.47	2.79	2.24
Minority (%)	24.06	26.67	28.89	23.88
Median Income (1,000 CAD$)	29.96	27.52	30.09	37.60
Private Car (%)	39.69	34.92	40.98	41.71
Public Transport (%)	10.54	10.64	10.02	7.25

Table 3. Poisson Regression Results for Healthy Food Outlets (N=247)

Variables	Service Area (No.)		
	Supermarkets	Local Grocery Stores	Healthy Food Outlets
Constant	1.979***	2.007***	2.680***
	(0.597)	(0.761)	(0.469)
Children	-3.884***	-7.399***	-5.292***
	(1.341)	(1.660)	(1.035)
Senior	0.691	0.482	0.410
	(0.863)	(1.113)	(0.680)
High Education	-1.099	-2.672***	-1.663***
	(0.742)	(0.973)	(0.588)
Unemployment	-2.518	21.662***	6.989*
	(5.233)	(6.432)	(4.048)
Minority	1.701***	0.127	1.350***
	(0.631)	(0.900)	(0.515)
Median Income	-0.015	0.014	-0.003
	(0.010)	(0.014)	(0.008)
Private Car	-1.198	-3.060**	-1.925***
	(0.913)	(1.256)	(0.735)
Public Transport	4.902**	6.629**	5.054***
	(1.988)	(2.711)	(1.599)
Log-likelihood	-362.90	-272.15	-449.80
Pseudo R^2	0.103	0.218	0.183

***, **, and * indicate the coefficient is significant at 1%, 5%, and 10% level, respectively.

Standard errors are in parentheses.

Table 4. Poisson Regression Results for Unhealthy Food Outlets (N=247)

Variables	Service Area (No.)		
	Fast Food Restaurants	Convenience Stores	Unhealthy Food Outlets
Constant	5.236***	1.902***	5.212***
	(0.183)	(0.488)	(0.169)
Children	-9.141***	-3.030***	-8.209***
	(0.452)	(1.039)	(0.412)
Senior	-1.336***	0.474	-1.161***
	(0.291)	(0.688)	(0.266)
High Education	0.026	-0.692	-0.120
	(0.252)	(0.557)	(0.229)
Unemployment	4.756***	-1.460	3.429**
	(1.751)	(3.912)	(1.589)
Minority	2.015***	1.059**	1.876***
	(0.223)	(0.457)	(0.199)
Median Income	-0.016***	-0.027***	-0.018***
	(0.003)	(0.008)	(0.003)
Private Car	-1.995***	1.243*	-1.474***
	(0.309)	(0.675)	(0.279)
Public Transport	1.397**	4.202***	1.775***
	(0.673)	(1.455)	(0.609)
Log-likelihood	-1249.30	-464.29	-1300.33
Pseudo R^2	0.386	0.096	0.375

***, **, and * indicate the coefficient is significant at 1%, 5%, and 10% level, respectively.

Standard errors are in parentheses.

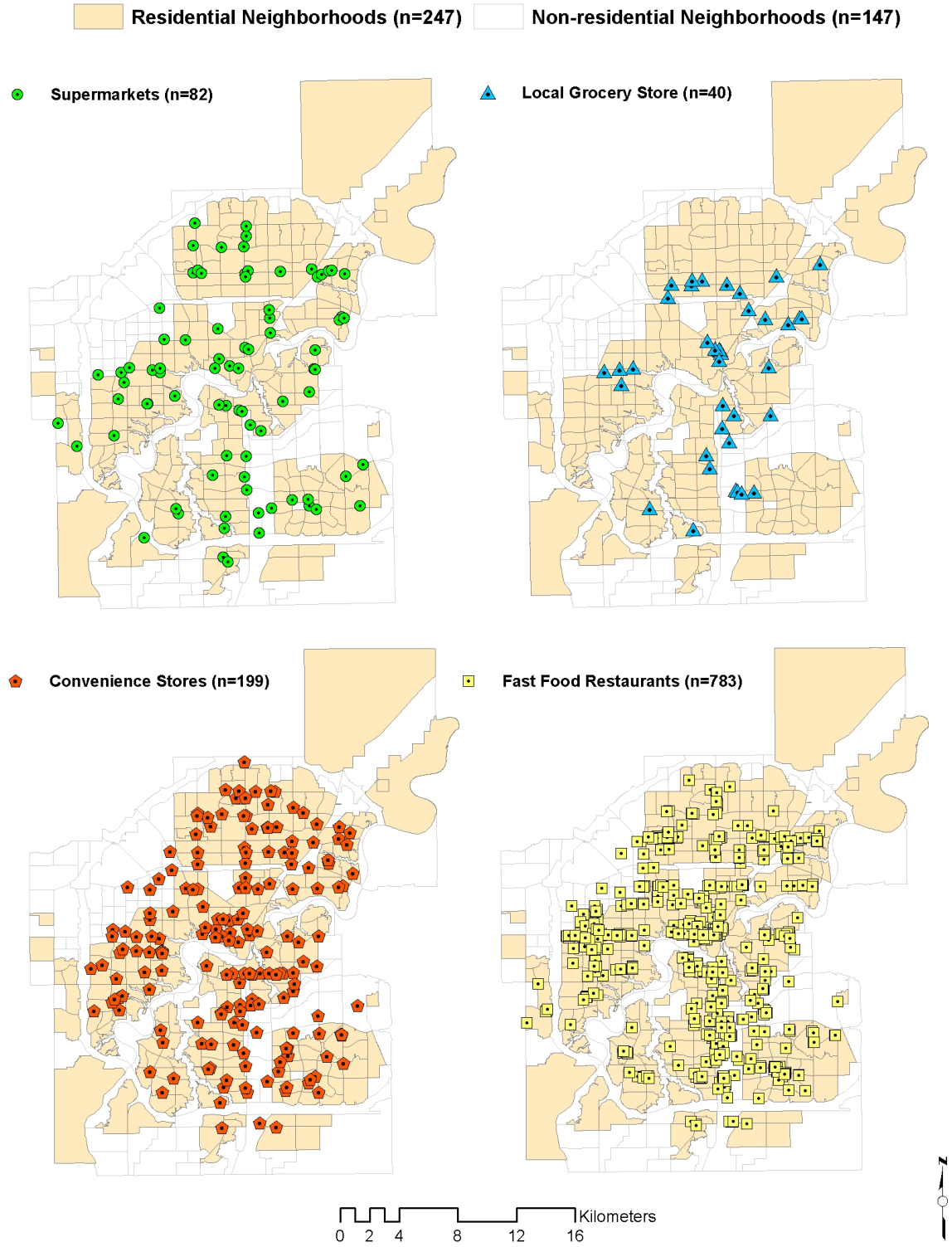

Figure 1. Distribution of Food Outlets in Edmonton

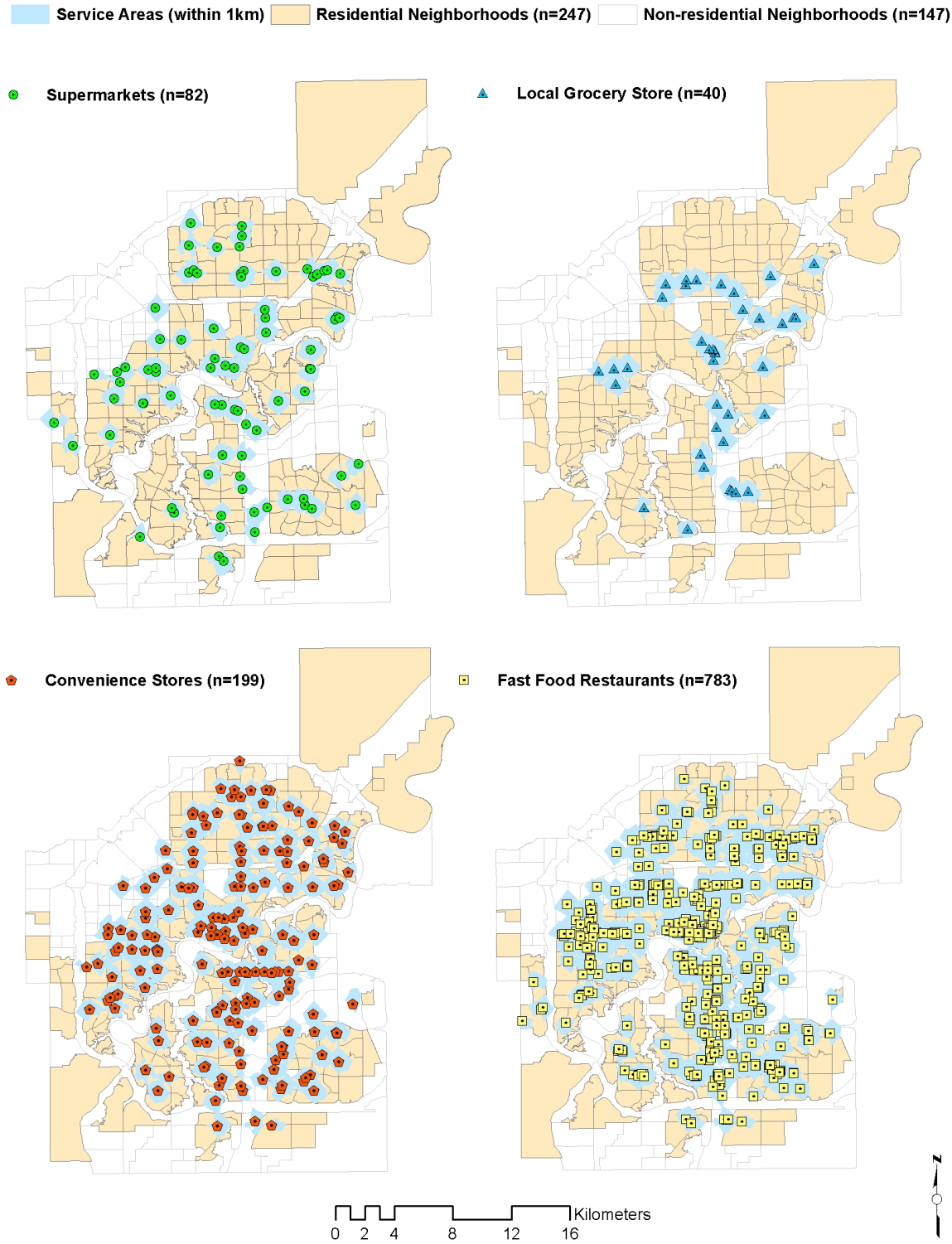

Figure 2. Service Areas of Food Outlets in Edmonton

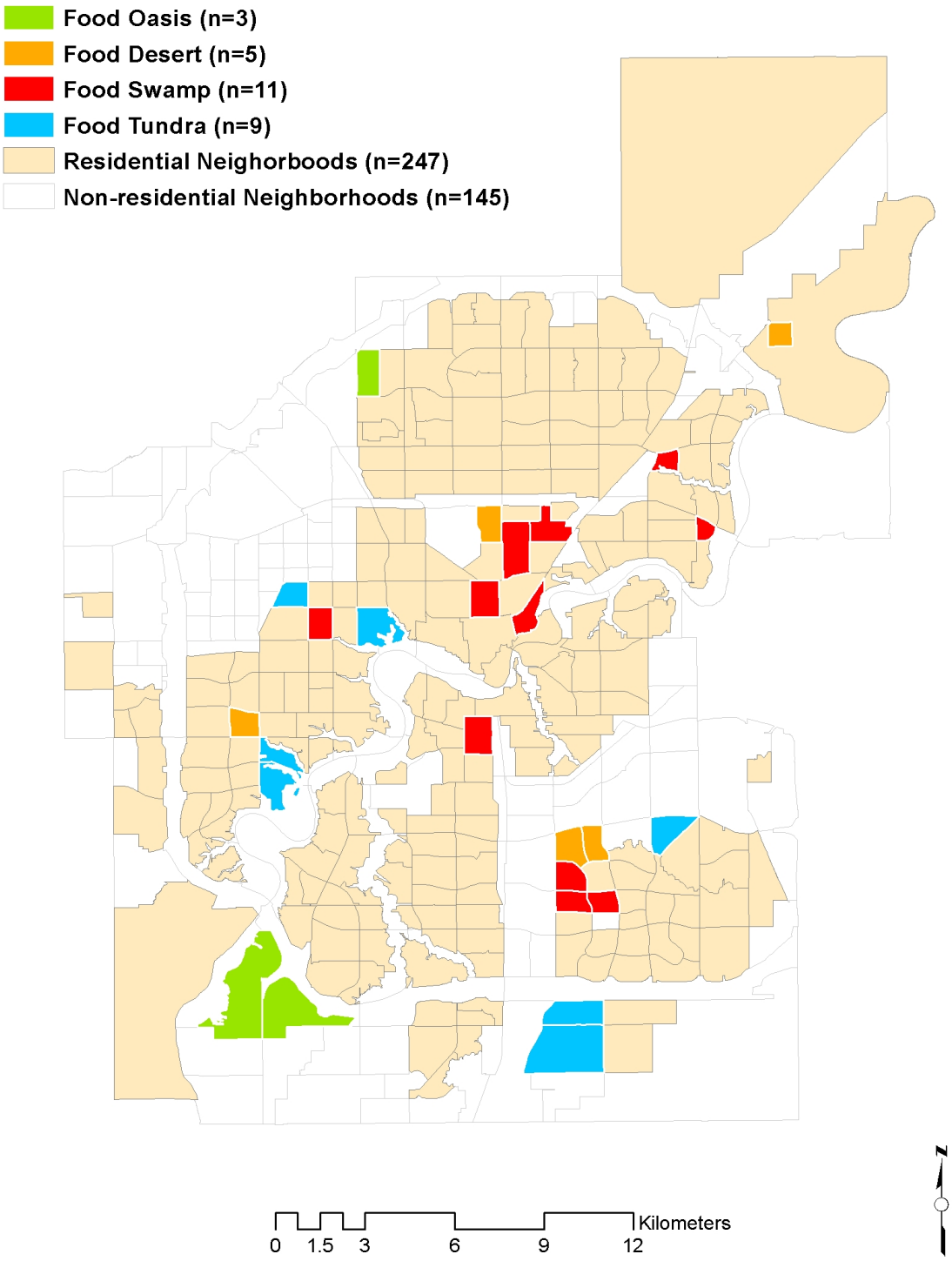

Figure 3. Identification of Neighborhoods with Different Food Environments