Geo-Spatial Methods to Better Understand Urban Food Deserts

Brian Ceh, Alison Jackson-Holland

Abstract—Food deserts are a reality in some cities. These deserts can be described as a shortage of healthy food options within close proximity of consumers. The shortage in this case is typically facilitated by a lack of stores in an urban area that provide adequate fruit and vegetable choices. This study explores new avenues to better understand food deserts by examining modes of transportation that are available to shoppers or consumers, e.g. walking, automobile, or public transit. Further, this study is unique in that it not only explores the location of large grocery stores, but small grocery and convenience stores too. In this study, the relationship between some socio-economic indicators, such as personal income, are also explored to determine any possible association with food deserts. In addition, to help facilitate our understanding of food deserts, complex network spatial models that are built on adequate algorithms are used to investigate the possibility of food deserts in the city of Hamilton, Canada. It is found that Hamilton, Canada is adequate serviced by retailers who provide healthy food choices and that the food desert phenomena is almost absent.

Keywords—Canada, desert, food, Hamilton, stores.

I. INTRODUCTION

FOOD deserts are defined as areas of low food retail access and economic deprivation characterized by poor accessibility to healthy, affordable food [2]-[4], [10], [12], [21], [35], [55], [56]. Since the mid-1990's, the term has become more widely used. In the policy debate, food deserts have been associated with a complexity of inter-linkages between increasing health inequalities, social marginalization, disparities in food retail accessibility, compromised nutrition and poor health outcomes [41], [43], [45], [54].

The lack of access to affordable healthy food has been suggested to be a contributing factor to poor diet [25], [33]. Consequently, the concept of food deserts has been gaining attention, particularly in North America and Britain, where there has been the mass suburbanization of food retailers and residents [3], [4], [27], [54]. Large grocery stores and supermarkets have moved away from the city centres in preference for suburban and exurban locations leaving some residents of older inner-city neighbourhoods with few grocery shopping options.

Food deserts are localized phenomena that are found throughout many cities, yet their existence and classification remains contested. Some researchers, government agencies and social agencies claim that food deserts are the result of misguided social policy and local government. In actuality, food deserts can be linked to the historical shift of economic activity from centralized to more dispersed locations. Also, increasing automobile ownership facilitated the rapid expansion of urban areas and has allowed more distant grocery stores to be accessible. Automobile mobility became the primary determinant in network planning over public transportation or walking. Municipal planning focused on the automobile as the predominant mode of transportation and it has enabled growth of urban areas to develop at a much faster pace and larger scale. And it is this car-centric urban development that supports the theory that a lack of grocery store access for the socio-economically disadvantaged is the consequence of the government's failure to consider the mobility constraints of disadvantaged individuals. In reality, the prevailing economic pressures of retailers and a growing suburban population necessitates supermarkets and grocery stores to locate in areas accessible by car to reach a large customer base and facilitate the distribution of goods. The oversight of these market pressures has led some to suggest that retailers and government are purposefully marginalizing segments of consumers. The distribution of stores may result in some neighbourhoods having lower accessibility to healthy foods than others. However, retailers and governments do not actively seek to marginalize any area.

The exact cause of food deserts is difficult to identify. Several studies have concluded that the issue is multifaceted. The existence of food deserts can be attributed to market pressures and mass suburbanization that, in combination, effectively worsens the situation for the disadvantaged. A lack of supermarkets and grocery stores impacts food availability and overall health outcomes, particularly for economically-deprived individuals, as good health is dependent on adequate nutrition [13], [14], [51]. Yet other less measurable factors may also be at play [11], [33], [40]. The failure of many people in the developed world to consume a healthy diet has, in part, been linked to the contested existence of food deserts [40]. Furthermore, the fact that the definition of what constitutes a food desert remains largely dependent on the focus of the research makes them difficult to understand.

Much of the retail-related research has been focused on the demand-side. This study incorporates a supply-side approach by examining the spatial distribution of food stores and accessibility for local residents of the Hamilton CMA. Few food study papers explore the difference in distance between large chain grocery stores and smaller food stores. The Hamilton CMA was chosen as the area of study for this research as it is a mid-sized city with socioeconomically

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contrasting areas, and as suggested by [44].

II. RESEARCH STATEMENT

The research conducted in this paper will focus on examining if disparities in access to food stores exist for individuals residing in different neighbourhoods (dissemination blocks) across the Hamilton CMA. This study uses the dimension of proximity (distance) to assess accessibility. First, by following the research by [24] to assess the distance that individuals living within different neighbourhoods of the Hamilton CMA must travel to access their closest grocery store. And second, by following the research by [7] to determine the level of accessibility for three modes of transportation: private automobile, walking and public transit (bus). Four tiers of food stores will be examined:

1) Tier One – high end supermarket chains (e.g. Loblaws);
2) Tier Two – discount supermarket chains (e.g. No Frills);
3) Tier Three –small local independent food stores;
4) Tier Four – neighbourhood convenience stores.

The purpose of this major research paper is to detect spatial variation in food retail accessibility, establish the statistical relationship between locations of potential food deserts and low-income areas, and determine if potential food deserts exist at any of the four tiers of food stores. The focus of this paper is to explore the concept of food deserts and food store accessibility. For this reason, several accessibility measures will be used to identify areas of concern where potential food retail gaps may exist. The objectives of this study are:

1) Calculate the distance to the closest grocery store by tier for each neighbourhood (Dissemination Block) in the Hamilton CMA.
2) Assess change in grocery store accessibility between 2006 and 2011.
3) Define the relationship between the locations of potential food deserts and the locations of low-income areas.
4) Calculate the service areas of food stores for each Tier for different modes of transportation and identify any potential food deserts.

The service areas will be examined for three modes of transportation. To delineate service areas for **private automobile** a 5 km service area that represents an average travel time of 10-12 minutes will be created, and for **walking** a 1 km service area will be used that reflects a 15 minute walk. To analyze accessibility to food stores using **public transportation** an economic analysis of the population living within a 500 m walking distance of Hamilton Street Railway (HSR) bus routes will be performed. This method was chosen because most of the supermarkets and local food stores are located in the areas accessible by this mode of transportation. This will help determine the characteristics of the population that are within the accessible distance and beyond the accessible distance of food stores. As the cost of a good includes the effort it takes to get to a store, consumers weigh the perceived costs versus benefits. They are only willing to travel so far to purchase a particular product. This concept of distance decay refers to the consumers' willingness to purchase a given product whereby fewer customers purchase a

good as the cost (in time and distance) increases

III. DEFINING FOOD DESERTS

Food deserts, grocery gaps, and food poverty are terms all used to refer to the notion of food inaccessibility or unavailability related to the underservice of grocery retailing within certain places [15], [30], [36], [40], [55]. In the most literal sense, food deserts can refer to a lack of food retailers in a defined area - typically a neighbourhood or greater. More commonly, the concept links to the importance of quality, varied and affordable food offered by food stores. In neighbourhoods where food deserts have been found, for many residents, particularly those with low-income or limited mobility, the lack of nearby stores creates a significant barrier to proper nutrition and a healthy diet [49]. Food deserts are commonly identified in neighbourhoods of relative social deprivation, particularly low income. Consequently, access to food retail is examined in relation to local socioeconomic characteristics [3], [4], [27], [36], [55].

The definition of food deserts has remained fluid and largely conceptual. The lack of consensus amongst researchers as to which measures are relevant to identifying geographical areas of food deserts has contributed to the debate over their actual existence (particularly in the UK) [3], [11], [40]. Part of the difficulty is attributed to the numerous ways in which people access food; access to food is largely understood to be more than a function of geography or individual lifestyle factors alone [3], [36].

Studies have been found to be based largely on measures to nearby supermarkets without the inclusion of small independent grocers and convenience stores [27], [31], [56]. Chain supermarkets are commonly understood to offer better quality foods, availability and selection in number and type of goods available at lower prices [6], [8], [26], [27], [56].

Chain supermarkets have the advantage of economies of scale, greater bargaining power with distributors and can negotiate lower rent that allow them to sell food products for cheaper prices on average than in small grocery and convenience stores [8], [22], [31], [36]. Discount chain grocery stores rely heavily on economies of scale and run larger stores to operate profitably; the physical need for more space makes them unsuitable for inner-city neighbourhoods [8]. In socially distressed areas, the absence of supermarkets in socially distressed areas means that residents without access to a car have few shopping choices; fresh fruits and vegetables have been found to be less available and more difficult to acquire [26], [27], [54].

Though much of the research on food deserts focuses on accessibility to supermarkets, partly because data can be easily attained on large food retailers, the role and location of the independent or small chain food provider often goes unseen. A study on food availability in Francisco [41] found that in areas without large chain supermarkets smaller retail chains and independent grocers offer residents healthy foods at affordable prices. Yet others have found that while small food and convenience stores offer opportunities for support of local economies, residents living in food deserts must pay more for

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groceries [26], [27] and that healthy foods are more expensive in low-income areas compared to more affluent ones [37].

IV. HEALTH RISKS ASSOCIATED WITH FOOD DESERTS/FOOD INSECURITY

It is well recognized that a healthy diet leads to better health and reduced healthcare costs, whereas an unhealthy diet leads to poor health [18], [28], [56]. In particular, a diet that includes fresh fruits and vegetables is linked to the reduced risk of obesity, diabetes, and cardiovascular disease [19], [56]. It has been found that individuals living in low-income areas do not consume the recommended amount of fruits and vegetables. Furthermore, the absence of these foods may be associated with a higher prevalence of morbidity and mortality rates observed in low-income populations [23]. Residents of some low-income areas must rely on convenience stores and gas stations that offer foods of lower quality, but are more filling [27], [29], [42].

Residents of food deserts who experience food insecurity are at risk of important physical, psychological, physiological and socio-familial consequences. Household food insecurity has been linked to high cholesterol, heart disease, diabetes and developmental deficiencies in children [17], [19], [48]. A study of elementary school children in US metropolitan areas showed a strong correlation between the cost of fruits and vegetables and gains in body mass index (BMI), and observed greater impact on those children living in poverty [46].

Among socioeconomic determinants of health, low-income and relative deprivation is consistently linked to poor health outcomes [14], [19], [52]. In the examination of food deserts, a range of socioeconomic factors are used to measure neighbourhood deprivation including: income, home value, population density, level of education, family status, mobility (car ownership), age, social assistance and low-income cut-off [27], [31], [56]. Consequently, how neighbourhood status is defined is subjective, and to a certain degree, determined by the focus of research [7]. Nevertheless, where potential food deserts have been identified, low-income prevalence has been a common characteristic. In the UK, poor food retail provision has been found in areas with low-income and poor mobility [16], [36]. Whereas in the U.S., food deserts are more commonly related to poverty and race (African Americans and Hispanics) in inner-city neighbourhoods [38], [56]. Canada's poorest neighbourhoods tend to have large concentrations of recent immigrants and visible minorities experiencing declining incomes [29], [49].

Not everyone living in a food desert experience physical constraints, as those with access to a vehicle can drive to the closest grocery store. Yet for individuals who must leave their neighbourhood or travel further to shop for groceries, the lack of vehicle access further compounds the problem and thereby makes routine tasks task much more difficult; it is often inconvenient and time-consuming [9], [14]. Households with limited transportation, of which low-income individuals and the elderly are the most likely, must plan ahead and be flexible in their transportation options. Mobility strategies include lengthy bus commutes, expensive cab fares, the dependence on a family member, partner or friend for transportation, and walking [9], [34], [44].

V. WHERE FOOD DESERTS HAVE BEEN FOUND

Food deserts are a phenomenon of the industrialized world found in both rural and urban areas. A current review of the research by [4] summarizes the findings of studies that have identified food deserts in the US, UK, Canada, Australia and New Zealand. This review suggests that the degree of food desertification is worse in the US, where localized deprivation exacerbates individual disadvantage.

In the US, studies regarding geographic accessibility have found that areas of low-income and a high proportion of African Americans had fewer supermarkets and chain grocery retailers per capita than socioeconomically advantaged areas [31], [39], [56]. In terms of distance, residents of low-income neighbourhoods [53], [56] and a high proportion of African Americans [20] and [56] had to travel greater distances to shop for groceries at supermarkets. And in rural America, [32] found that of all US counties, 418 were food deserts, nearly 98% of which were located in counties with less than 10,000 people. Counties where food deserts are commonplace are concentrated in North Dakota and Montana, and stretch along a band to the western portion of Texas.

Spatial variations in urban and suburban neighbourhood (by census tracts) access to supermarkets in London, Ontario, as well as the changing levels of supermarket accessibility over time (1961-2005) were analyzed [27]. Similar to the methods used by [3], this study examined distance to the closest supermarket and number of supermarkets within 1 km, but unlike the Montreal study, measured accessibility in relation to walking and public transit. Furthermore, areas with the poorest access by walking were located in neighbourhoods with the greatest socioeconomic distress. Those supermarkets that had the best access by means of walking were typically located in less distressed neighbourhoods. And over time, access to supermarkets was found to have diminished with the average proportion of census tract population with easy access dropping from 45% in 1961 to 18% in 2005.

VI. POLICY IMPLICATIONS

Early accessibility research conducted in the 1990's that identified some areas of Britain as food deserts. Consequently, the results influenced policy recommendations to promote adequate retail provision [1]. It has been argued that a lack of empirical evidence that food deserts exist and that policy responses aimed at retailers are misguided [11]. Studies suggest that it is the interplay of factors including income, access, transportation, availability, price, cooking skills and confidence that contribute to the formation of food and shopping behaviour [25]. A study conducted by [33] in an economically-deprived urban area in South Yorkshire, England found that neither the lack of supermarket access or food price influenced fruit and vegetable consumption, but that socio-cultural values towards diet held by individuals discouraged healthy food consumption. It has been found that

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in Montreal, Canada, some of the most affluent residents had the poorest availability of fruits and vegetables [5]. These studies indicate that poor nutritional intake is not always a consequence of measurable factors such distance to food stores, healthy food availability, affordability or mode of transportation. They suggest that an individual's socio-cultural values and attitudinal beliefs strongly influence dietary lifestyles.

VII. DATA AND METHODS

This study examines the differences in accessibility that residents of different areas have to purchase groceries in the Hamilton CMA. The metropolitan area, located approximately 70 km west of the City of Toronto, includes the Cities of Hamilton, Burlington and Grimsby. The City of Hamilton was amalgamated in 2001 from previously separate administrative areas of the City of Hamilton, towns of Dundas, Ancaster, Flamborough, township of Glanbrook and Stoney Creek (Fig. 1). The CMA's total population in 2011 is $721,053, a 4% increase from 2006, and had a Median Total Income (all

economic families) of $71,600 in 2006 [47].

To determine if potential food deserts exist in the Hamilton CMA at any of the four tiers of food stores, four analyses were conducted. The first was a minimum distance analysis utilizing ArcGIS Network Analyst to examine the spatial variation in grocery store accessibility based on distance to closest store, the results of which were used in a correlation analysis. These findings allowed for the identification of areas of relative economic disadvantage that may need to be monitored. The second was a service area analysis using Network Analyst that allowed the demarcation of the estimated extent of travel in distance to a grocery store by driving and walking for each tier of food stores and for the tiers combined. The third was a service area analysis of all food stores using the Hamilton Street Railway bus routes. The fourth was a hot-spot analysis of large chain supermarkets (tiers one and two combined) and smaller independent and convenience stores (tiers three and four combined). These findings identified areas where store clusters may be present.
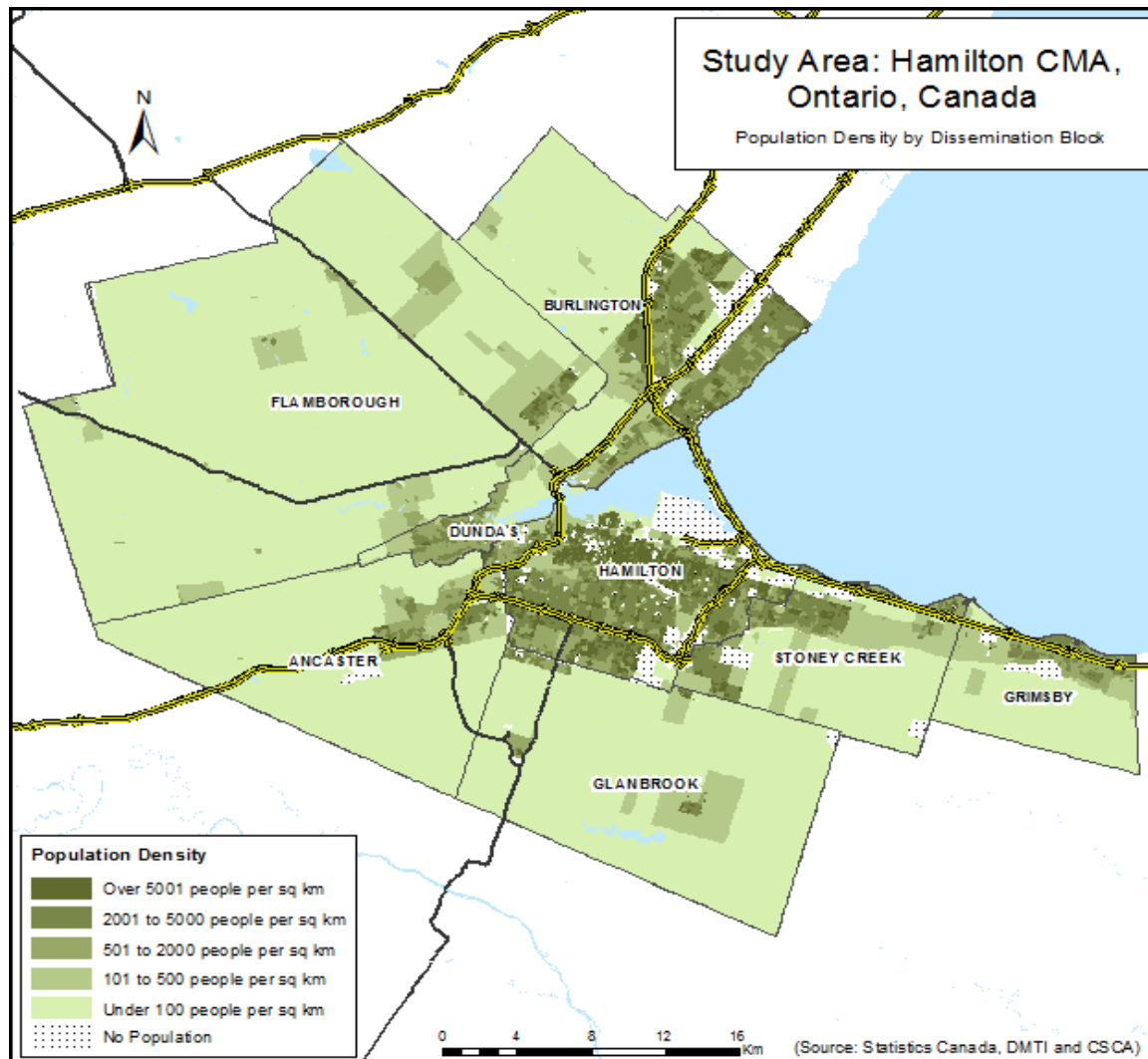

Fig. 1 The study Area: The Hamilton CMA [47], [56]

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Although this study uses the finest geographic level at which census data are available (dissemination blocks), some units span a larger distance than others. Depending on the spatial distribution of the population within a given dissemination block, the distance measured from the block's centroid to the closest grocery store are estimates of the true distance residents must to travel for groceries, and the extent of the population serviced by the food providers are only estimates of the true service coverage for the different modes of transportation.

The dataset containing all of the food stores that were open in the Hamilton CMA in 2007 and 2011 was provided by the CSCA at Ryerson University [57]. The stores have been selected based on the NAICS classification code, first three digits 445, relating to the category of food and beverage stores. This includes food stores (supermarkets, other grocery stores, and convenience stores), specialty food stores (meat markets, fish and seafood markets, fruit and vegetable markets, other specialty food stores, baked goods stores, confectionery and nut stores, and other specialty food stores), as well as beer, wine, and liquor stores [50]. Store data from 2007 was used rather than 2006 because it was a more complete dataset (data collection of strip malls and power centres began in 2007). A minor difference (gap) exists between the time of collection of store data and census data. For the sake of simplicity, all discussion based on store data and results based on 2007 stores will be referred to as 2006 to correspond with the matching year of the census.

TABLE I
HAMILTON CMA TIER ONE AND TIER TWO CLASSIFICATIONS

Tier	Food Store Name
	A&P
	Ultra Mart & Drugs
Tier One	Ultra Mart & Drugs
	Sobeys
	Fortinos
Tier Two	Food Basics
	Price Chopper
	No Frills
	Foodland
	The Barn Fruit Markets
	Longo's Fruit Markets
Tier Three	Ernie's Meat Market
	Vallentino's Bakery
	Fenworth Food Market
Tier Four	Hasty Market/Farah's Foods
	Fresh Variety Convenience
	M&M Meat Shops

VIII. DIVISION OF TIERS

The food stores that were open in 2007 and 2011 have been separated into four tiers based on the average cost of goods they sell. It is also important to distinguish full-line supermarkets from smaller food stores as the former have been found to carry more healthy food items at lower prices. Supermarkets are defined as large corporate 'chain' grocers and are further classified based on pricing strategy. This classification was chosen to simulate consumer choice in store selection through product pricing. Tier One consists of high-end large chain grocery stores whose target market includes customers of higher income households or individuals that have no choice but to shop there due to accessibility constraints (Table I). Tier Two consists of large chain discount grocery stores that use everyday low pricing. They offer value-brand products with generic labels and cater to consumers that are more conscious of price and less discriminate about brand and service (Table I). Tier Three includes small independent food stores, specialty food stores such as bakeries, fruit and vegetable markets and other stores that offer healthy food items that do not fit into Tier One or Two divisions. Tier Four consists of convenience and franchise stores.

IX. SPATIAL AND TEMPORAL CONCORDANCE BETWEEN 2006 AND 2011 DISSEMINATION BLOCKS

The lowest level of geography that income data is available from Statistics Canada is at the dissemination area. To help calculate 2011 median household income values of residents living inside and outside of service areas, it was necessary to match the 2006 dissemination block polygons to those present in 2011. This was done by first applying the 2006 median household income information at the dissemination area to the dissemination block level, and then to the corresponding 2011 dissemination blocks. This is possible because dissemination blocks are 'nested' within dissemination areas and boundary files include an attribute field with a unique identifier that describes which dissemination area each block belongs to.

X. NETWORK ANALYSIS: SERVICE AREA DELINEATION

The service areas for each of the tiers of food stores were delineated based on travel distances to estimate accessibility by multiple modes of transportation. These analyses were conducted in ArcGIS Network Analyst using the Service Area function and the same road network dataset as used in the minimum distance analysis. The service area for private transportation was defined based on 5 km travel distance that followed vehicle road restrictions (i.e. one-ways, turn restrictions), whereas the walking service area was based on a 1 km travel distance without any restrictions. These values assume that it will take an individual approximately 10-12 minutes to drive at 50 km/h, whereas a 1 km distance will take approximately 15 minutes to walk at a speed of 4 km/h. Each service area for the four tiers of stores were mapped separately and collapsed to identify potential food retail gaps by store type. The third service area analysis examined accessibility to all food stores for residents living within a 6-8 minute walk or 500 m of bus routes in the City of Hamilton. Public transportation accessibility was not defined by network distance to stores as it was found that the majority of stores were located in close proximity to bus routes. The population residing within the defined service area was considered to have access to all stores.

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XI. FINDINGS

Between 2006 and 2011, the total number of food stores at all tiers increased only very slightly (Table II). Over this five-year period the Hamilton CMA gained seven Tier One high-end chain grocery stores and eight Tier Three independently-owned food stores accounting for a positive change of 33% and 18%, respectively. At the same time, there was a loss of eight Tier Two discount chain grocery stores as well as five Tier Four convenience and franchise stores, representing respectively a negative 23.5% and 2.6% change. While such a loss in the proportion of discount supermarkets may be cause for concern regarding affordability of healthy food for certain individuals living in affected neighbourhoods, the overall change in the number of large chain grocery stores (Tier One and Tier Two) together was insignificant with a loss of only 1 or a 1.8% decrease. With relatively little change in the total number of large chain grocery stores, few food deserts are likely to be found, particularly once the independent grocery and convenience-type food stores are taken into consideration. It is likely that from 2006 to 2011, individuals will have a shorter distance to travel to the nearest grocery store (Figs. 2 and 3). The minimum distance to the nearest grocery store was calculated from the centroids of 4,956 and 5,237 centroids of 2006 and 2011 dissemination blocks, respectively. As Table III shows, between 2006 and 2011, the weighted average distance to the closest Tier One chain grocery store and Tier Three independent grocery store *decreased* respectively by approximately 10% and 4%, and *increased* for Tier Two chain grocery store and Tier Four food store by 23% and 21%, respectively. The most drastic change was the increase in distance to Tier Two discount chain stores, whereas the least change was found in the distance to Tier Three independent food stores. Another interesting observation that can be made is that the greatest average distance to travel to any tier of food retailer is for Tier Four convenience and franchise stores for both years (Figs. 2 and 3).

TABLE II
NUMBER OF STORES BY TIER CATEGORY AND YEAR

Tier	2006	% of TOTAL	2011	% of TOTAL
Tier One (high-end chain)	21	7.1%	28	9.4%
Tier Two (discount chain)	34	11.5%	26	8.7%
Tier Three (independents)	44	14.9%	52	17.4%
Tier Four (convenience)	197	66.5%	192	64.5%
TOTAL STORES	296	100%	298	100%

TABLE III
WEIGHTED AVERAGE DISTANCE TO THE CLOSEST GROCERY STORE BY STORE TIERS (IN METERS)

Tier	2006	2011	% Change
Tier One (high-end chain)	3,166	2,839	-10.3%
Tier Two (discount chain)	2,867	3,533	23.2%
Tier Three (independents)	1,807	1,739	-3.8%
Tier Four (convenience)	3,334	4,038	21%
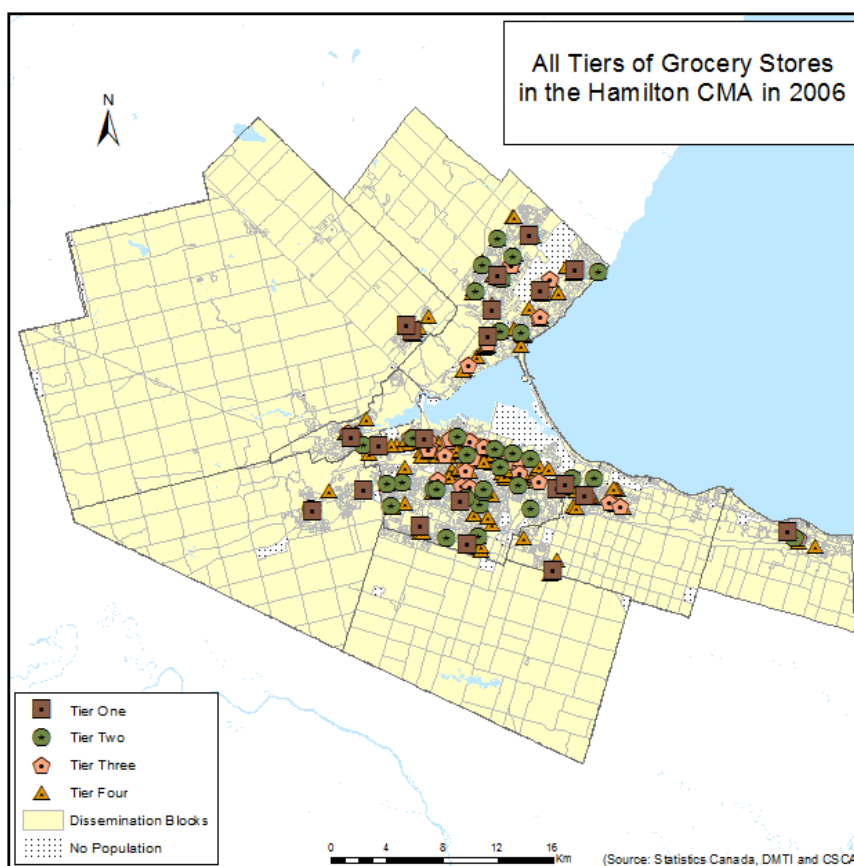
Fig. 2 Food stores by Tier in 2006 [47], [57]

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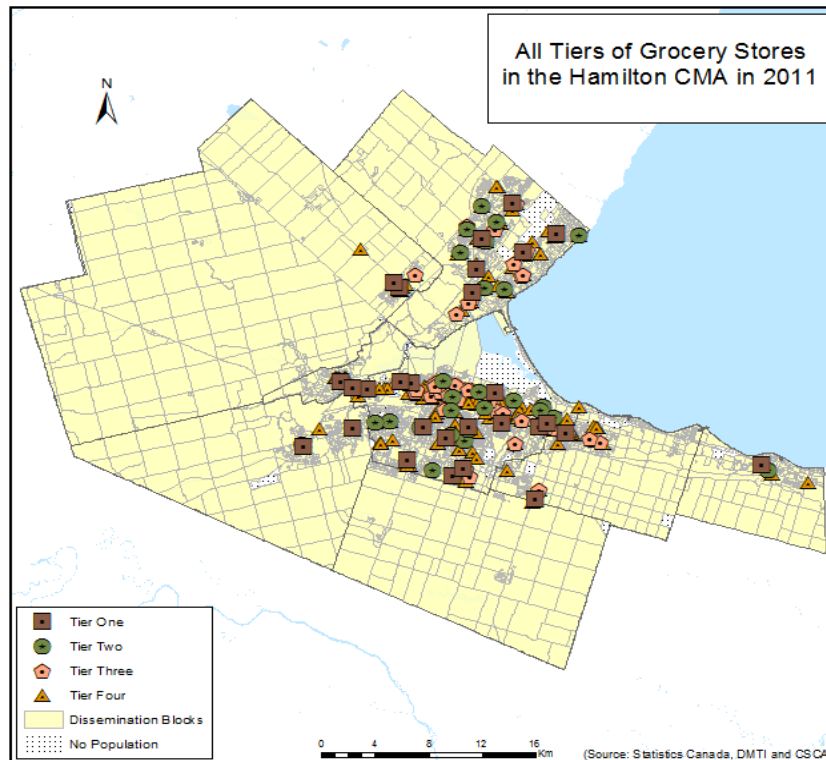
Fig. 3 Food stores by Tier in 2011 [47], [57]

Figs. 4-7 show the changes in distance to the closest grocery store for individuals living in different areas of the Hamilton CMA in 2011. In general, the average distance is greater for individuals residing in the rural areas than for those living in suburban and urban neighbourhoods. The following observations relating to each of the tiers can be made:
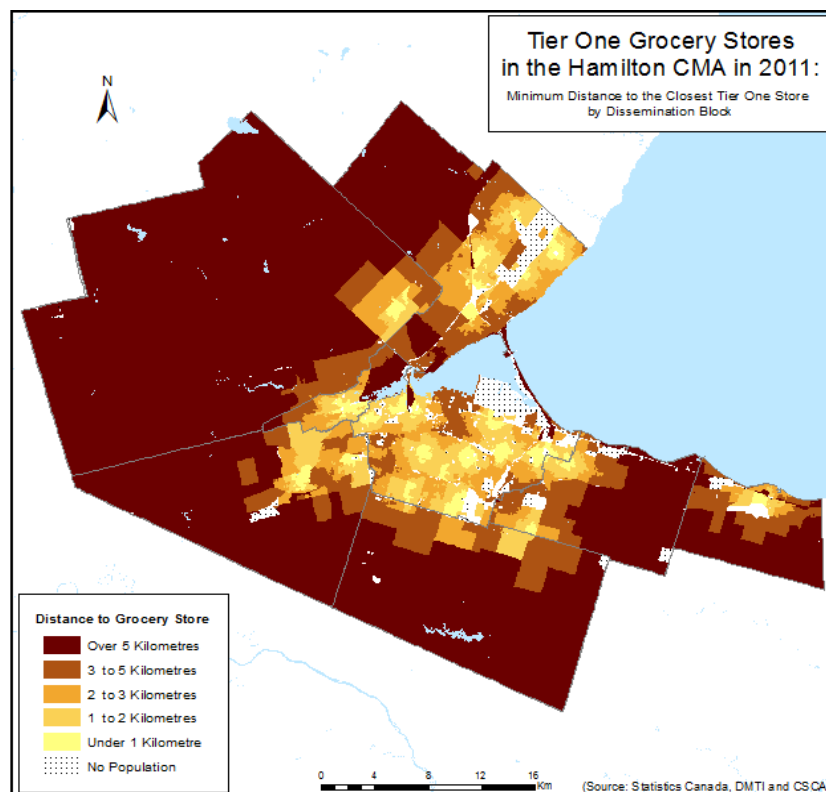
Fig. 4 Minimum Distance to the Closest Tier One Grocery Store in 2011 [47], [57]
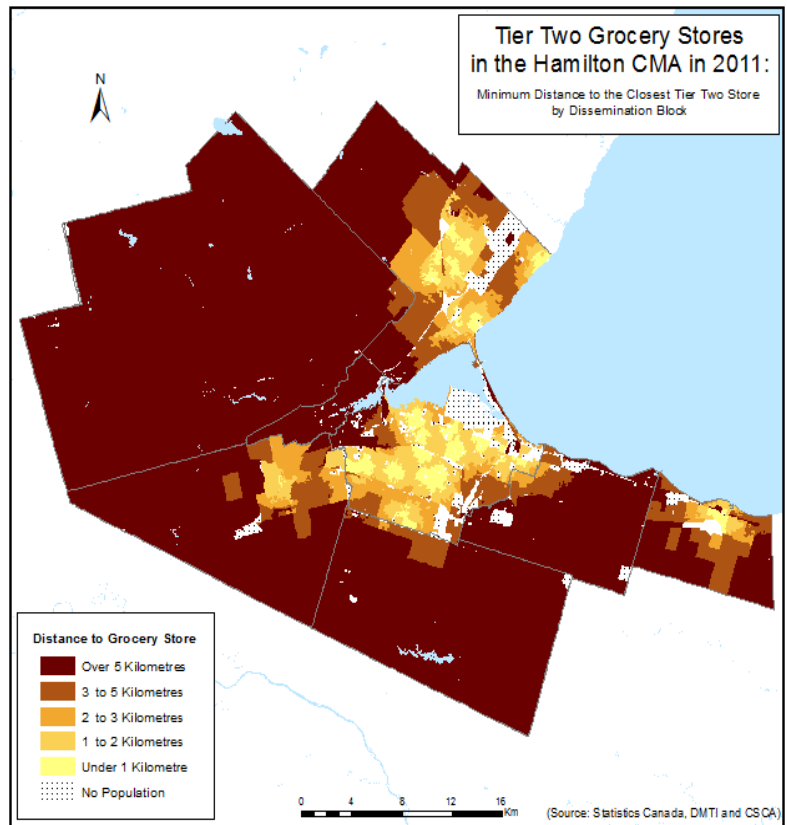
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Fig. 5 Minimum Distance to the Closest Tier Two Grocery Store in 2011 [47], [57]

Fig. 6 Minimum Distance to the Closest Tier Three Store [47], [57]

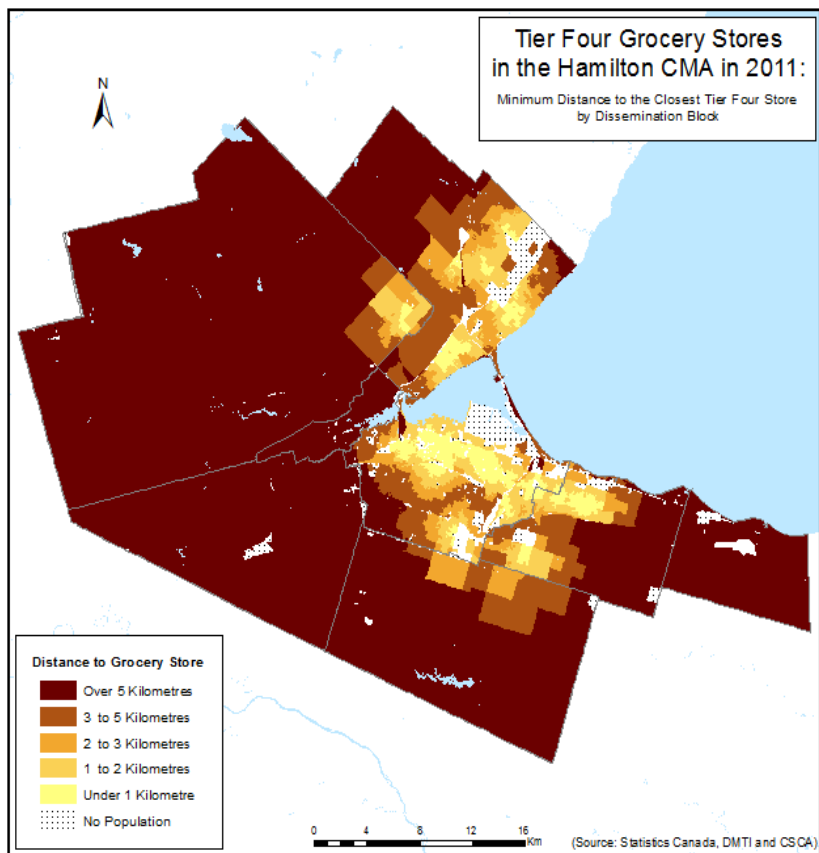World Academy of Science, Engineering and Technology
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Tier One: Some Hamilton residents had shorter distances to travel in 2011, as the City of Hamilton gained 2 Tier One supermarkets downtown and three on the Hamilton Mountain. Similarly, residents of Dundas and nearby Ancaster gained a Tier One grocery store located in Dundas.

Tier Two: Certain individuals living in Hamilton and Dundas had farther distances to shop to access a Tier Two supermarket. In West Hamilton and Downtown Hamilton as well as in Dundas, Tier Two discount chain stores have been replaced by Tier One high-end supermarkets. Overall, East Hamilton lost two Tier Two stores as did Downtown Hamilton and the Hamilton Mountain area which lost four.

Tier Three: Although the overall number of Tier Three stores increased, particularly in the more densely populated areas, certain regions experienced an overall loss. Dundas lost 1 and Grimsby lost both of its only independent food stores. The Hamilton Mountain showed an overall gain of 1 Tier Three store. Several new Tier Three stores located in the areas of Downtown and East Hamilton as well as in Burlington.

Tier Four: In general, the distribution of Tier Four convenience and franchise stores are well dispersed. Little change occurred in the overall number of Tier Four stores in the City of Hamilton and Stoney Creek. The City of Burlington lost five and town of Dundas lost one; the towns of Flamborough and Ancaster both gained one Tier Four store each.

XII. CORRELATION BETWEEN MINIMUM DISTANCE TO A GROCERY STORE AND INCOME

Median family income by dissemination block for the year 2006 has been mapped to determine if the pattern shows any similarities to that of the minimum distance for 2006 across each of the four tiers (Fig. 8). The incidence of low income after tax (all age groups) as defined by Statistics Canada is 12.1% (11% male and 12.1% female) of the Hamilton CMA population. The map clearly illustrates the difference in household earnings between the various regions. No similarities between the spatial pattern of median household income and the minimum distance to the closest grocery store are identifiable for any of the tiers (Fig. 8). Although a positive relationship was expected between minimum distance and income, all correlation values showed a much weaker relationship than anticipated (Table IV). The strongest relationship was found between Tier Four convenience stores and minimum distance with an r-value of 0.188 that is statistically significant at the 0.01 confidence level. The correlation value of a single variable that explains 18% of the variation in a bivariate correlation is moderately notable. However, in an attempt to improve upon these results, correlation was performed using other variables related to household size. These variables have been chosen to represent the city-suburban differences identified in the patterns of minimum distance. Similar to the resulting correlation values between distance and income, the strongest correlation is that between the minimum distance to Tier Four stores and 6+ person households with an r-value of 0.371. All correlation values show a moderate-weak positive relationship between minimum distance and large household size (6+ persons) and are statistically significant at the 0.01 confidence level (Table V).

TABLE IV
CORRELATIONS BETWEEN MINIMUM DISTANCE AND MEDIAN HOUSEHOLD INCOME IN 2006

Tier	Sig. (P-value)	Pearson Coefficient
Tier One (high-end chain)	0.193	0.180
Tier Two (discount chain)	0.000	0.142**
Tier Three (independents)	0.000	0.118**
Tier Four (convenience)	0.000	0.188**
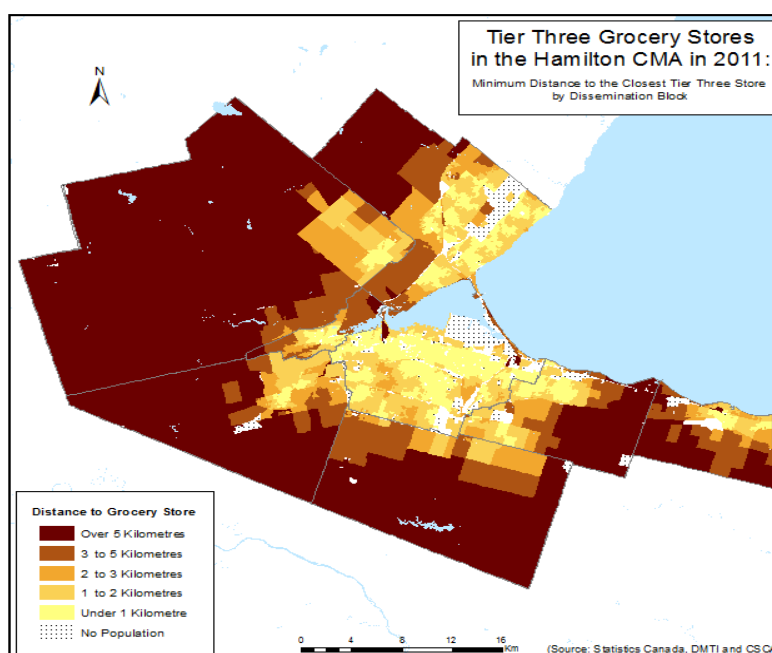
Fig. 7 Minimum Distance to the Closest Tier Four Grocery Store in 2011 [47], [57]

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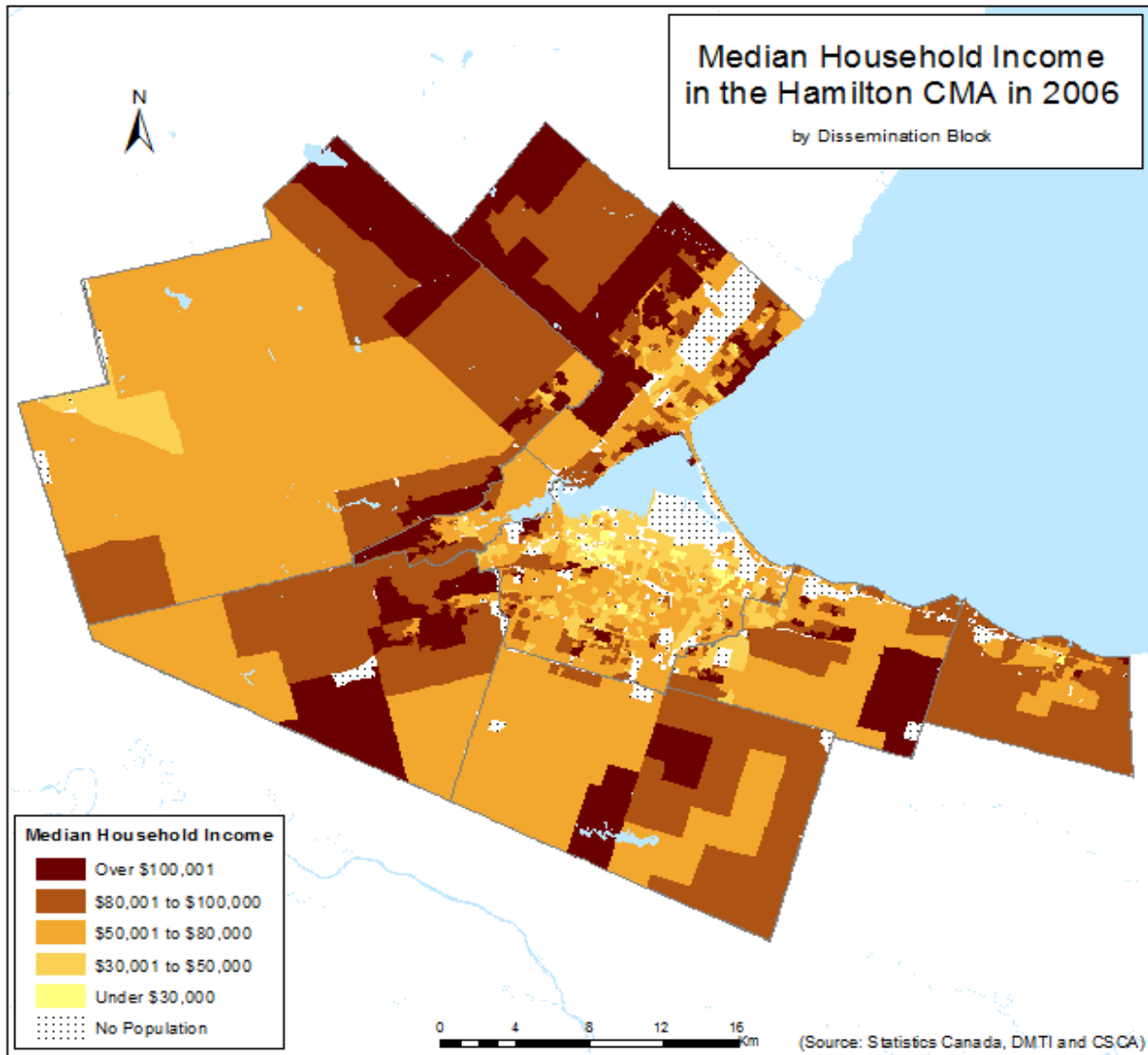Vol:11, No:8, 2017

Fig. 8 Median Household Income in 2006 [47], [57]

TABLE V
CORRELATIONS BETWEEN MINIMUM DISTANCE AND 6+ PERSON HOUSEHOLDS IN 2006

Tier	Sig. (P-value)	Pearson Coefficient
Tier One (high-end chain)	0.000	0.292**
Tier Two (discount chain)	0.000	0.338**
Tier Three (independents)	0.000	0.353**
Tier Four (convenience)	0.000	0.371**

** Denotes values significant at the 0.01 Confidence Level

TABLE VI
DRIVE DISTANCE SERVICE AREA ANALYSIS

Grocery Store Type	Service Area Coverage (%)	Area (km²)
Tier One	22.59%	303
Tier Two	16.85%	226
Tier Three	17.67%	237
Tier Four	28.70%	385
All Tiers	28.93%	388

XIII. PRIVATE TRANSPORTATION SERVICE AREA ANALYSIS

The extent of the service areas for each of the four tiers of food stores using the proxy of private transportation (Figs. 12-16) indicated that approximately 23% of the Hamilton CMA was serviced by Tier One stores, 17% and 18% by Tier Two and Tier Three stores, respectively, and 29% was serviced by Tier Four stores (Table VI). Nearly one third of the study area is serviced by food providers when all of the food retail stores are accounted for.

Across all of the tiers, the greatest proportion (89%) of the population using private transportation is serviced by Tier Four convenience and franchise stores, while Tier Three independent food stores service the smallest proportion (72%). For Tier One, the population characteristics indicate that approximately 89% of the population residing in the Hamilton CMA is adequately serviced by high-end chain grocery stores (Table VII). Despite this, there are two densely populated areas where service area coverage was lacking and are classified as potential food gaps: (1) downtown Hamilton (2)

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the western Hamilton 'mountain' (Fig. 9). The Tier Two findings show that approximately 78% of the population was serviced by discount chain grocery stores. Five smaller gaps in service coverage are classified as potential food deserts: (1) west Stoney Creek (2) west downtown Hamilton (3) Ancaster (near the Hamilton mountain) (4) Dundas (5) central Burlington (Fig. 10). The Tier Three independent grocery service areas cover approximately 72% of the population. Five small areas lack service and have been identified as potential food deserts: (1) Grimsby (2) central Hamilton 'mountain' (3) Ancaster (4) Dundas (5) central Burlington (Fig. 11). One finding of particular significance is that despite the loss of Tier Two stores from the downtown and east Hamilton neighbourhoods identified earlier, these areas did not reveal any potential food deserts and appear to be adequately serviced. For Tier Four, approximately 91% of the Hamilton CMA residents are serviced by convenience and franchise stores. No potential food deserts are identified as the Tier Four stores are well distributed and the only areas lacking coverage are located in sparsely populated areas (Fig. 12).

When all fields/tiers are collapsed the notion of a food desert virtually disappears from analysis (Fig. 13).

One interesting finding is that the level of income was higher for those individuals living outside of the service areas reflecting the typical city-suburban pattern of wealth, whereby the suburban and rural areas tend to have higher proportions of high income households compared to the central city (Tables VII and VIII).

TABLE VII
POPULATION CHARACTERISTICS OF RESIDENTS WITHIN THE PRIVATE TRANSPORTATION SERVICE AREA

Walk Distance	Total Pop.	Pop. (%)	Median Income ($)	Density (persons per km²)
Tier One	88,109	12.21%	69,420	3,879
Tier Two	120,243	16.66%	62,661	4,860
Tier Three	161,144	22.33%	59,588	6,119
Tier Four	355,721	49.29%	68,722	4,881

TABLE VIII
POPULATION CHARACTERISTICS OF RESIDENTS OUTSIDE THE PRIVATE TRANSPORTATION SERVICE AREA

Drive Distance	Total Pop.	Pop. (%)	Median Household Income ($)	Density (persons per km²)
Tier One	643,050	89.11	77,457	4,468
Tier Two	564,788	78.26	76,095	4,647
Tier Three	522,355	72.38	74,712	4,761
Tier Four	659,789	91.43	77,860	4,391

XIV. WALKING SERVICE AREA ANALYSIS

The walking service area analysis for each tier of stores (Figs. 14-19) shows a much more distinct pattern concentrated around each store. Also, compared to private transportation the walking service areas have many more smaller gaps where service is lacking. Consequently, a much greater proportion of the population is underserviced by each of the store tiers. For

example, approximately only 12% of residents of the Hamilton CMA are within a 1 km walking distance of Tier One supermarkets, 17% by Tier Two discount supermarkets, 22% by Tier Three food stores and 49% by Tier Four convenience stores (Table IX). Given the spatial distribution of food stores and extent of underservice at each tier, it is not surprising that several areas are classified as potential food deserts at Tier One, Tier Two and Tier Three and one at Tier Four (Figs. 14-17). Interestingly, the areas that lost several Tier Two stores that correspond with lower income neighbourhoods did not reveal any potential food gaps (Fig. 8).

Tier Three stores had the highest population density of residents whereas Tier One stores had the lowest (Table IX). This reflects locational differences with Tier Three smaller food stores being located closer to city centres, whereas Tier One and Tier Two chain stores are located in more suburban areas (Figs. 14–17).

Examination of the 500 m buffer created around the City of Hamilton's public transportation bus routes indicates that the majority of individuals reside within close proximity to bus service (Table XI).

TABLE IX
POPULATION CHARACTERISTICS OF RESIDENTS WITHIN THE WALKING SERVICE AREA

Drive Distance	Total Pop.	Pop. (%)	Median Household Income	Density (persons per km²)
Tier One	78,620	10.80	90,936	1,481
Tier Two	156,882	21.72	89,045	2,170
Tier Three	199,315	27.62	89,820	2,336
Tier Four	61,881	8.57	90,045	1,175

TABLE X
POPULATION CHARACTERISTICS OF RESIDENTS OUTSIDE THE WALKING SERVICE AREA

Walk Distance	Total Pop.	Pop (%)	Median Income ($)	Density (persons per km²)
Tier One	633,560	87.79%	80,112	4,131
Tier Two	601,427	83.34%	81,811	3,982
Tier Three	560,526	77.67%	84,330	3,446
Tier Four	365,949	50.71%	90,594	3,114

This accounts for approximately 62% of residents within the Hamilton CMA with an average density of 4,723 people per km². These findings are of significance because the majority of food stores within all four tiers are located along major roads and bus routes (Fig. 20).

TABLE XI
CHARACTERISTICS OF RESIDENTS WITHIN AND OUTSIDE PUBLIC TRANSPORTATION SERVICE AREA

Bus Routes	Total Pop	Pop (%)	Median Household Income ($)	Density (persons per km²)
Inside 500m Buffer	446,194	61.83%	67,939	4,723
Outside 500m Buffer	275,476	38.17%	97,562	2,956

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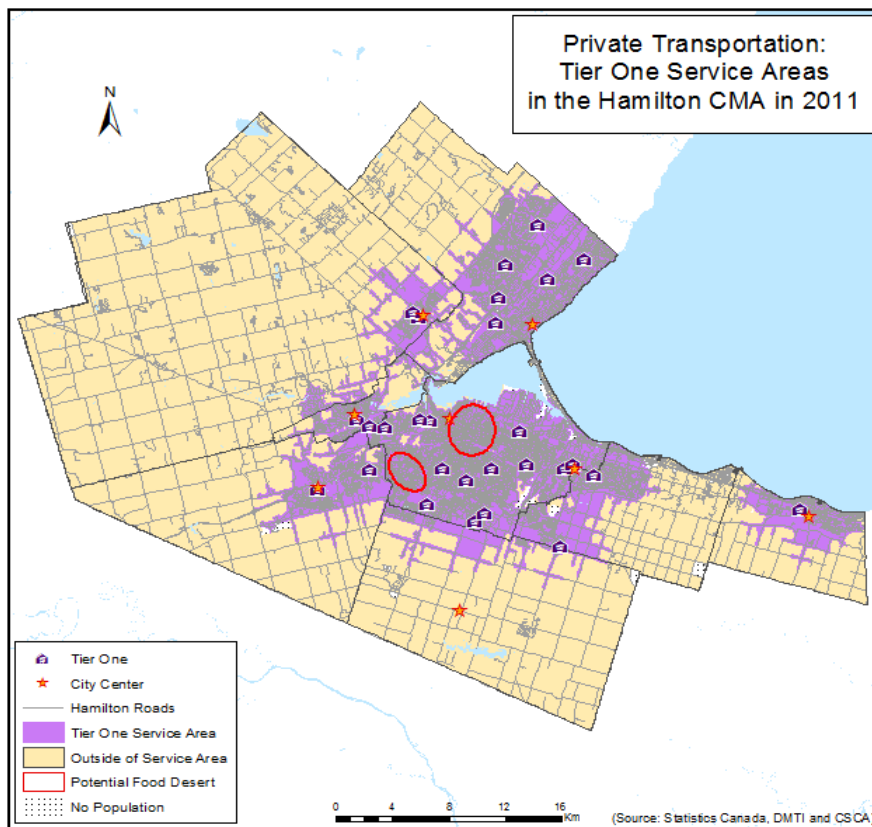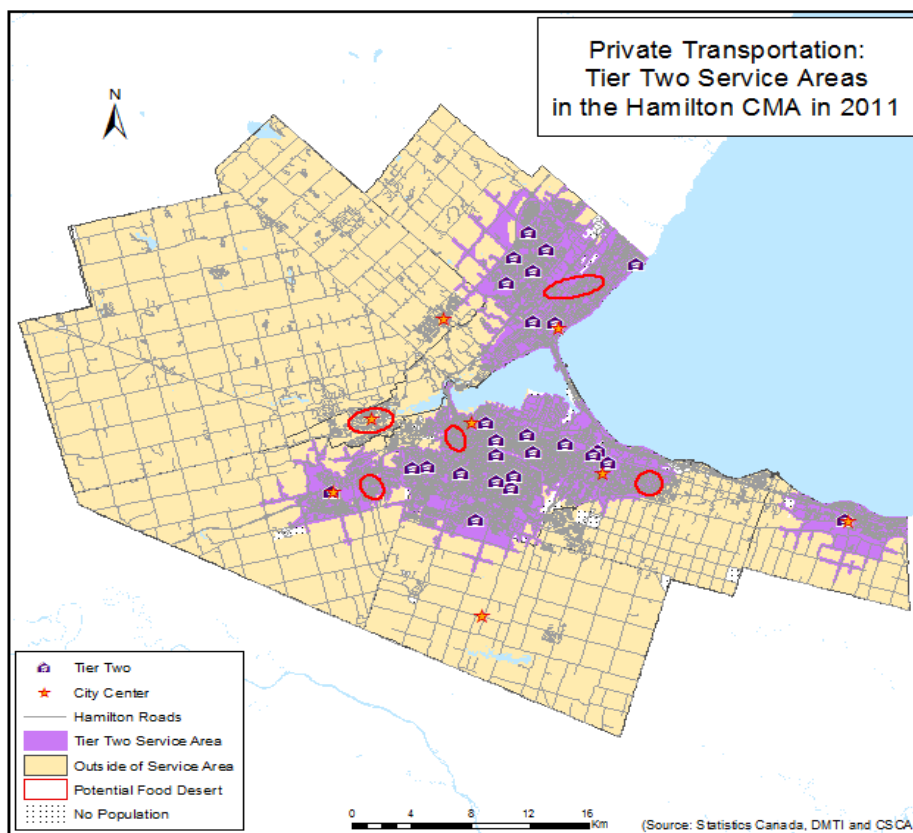Vol:11, No:8, 2017

Fig. 9 Tier One Service Areas with Potential Food Deserts for Private Transportation [47], [57]

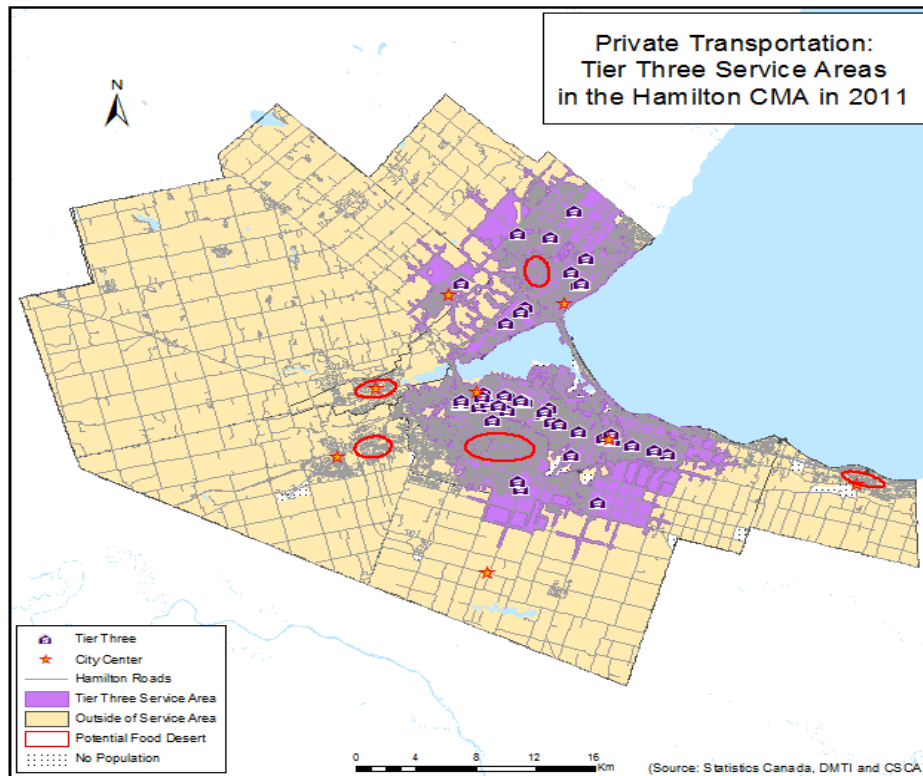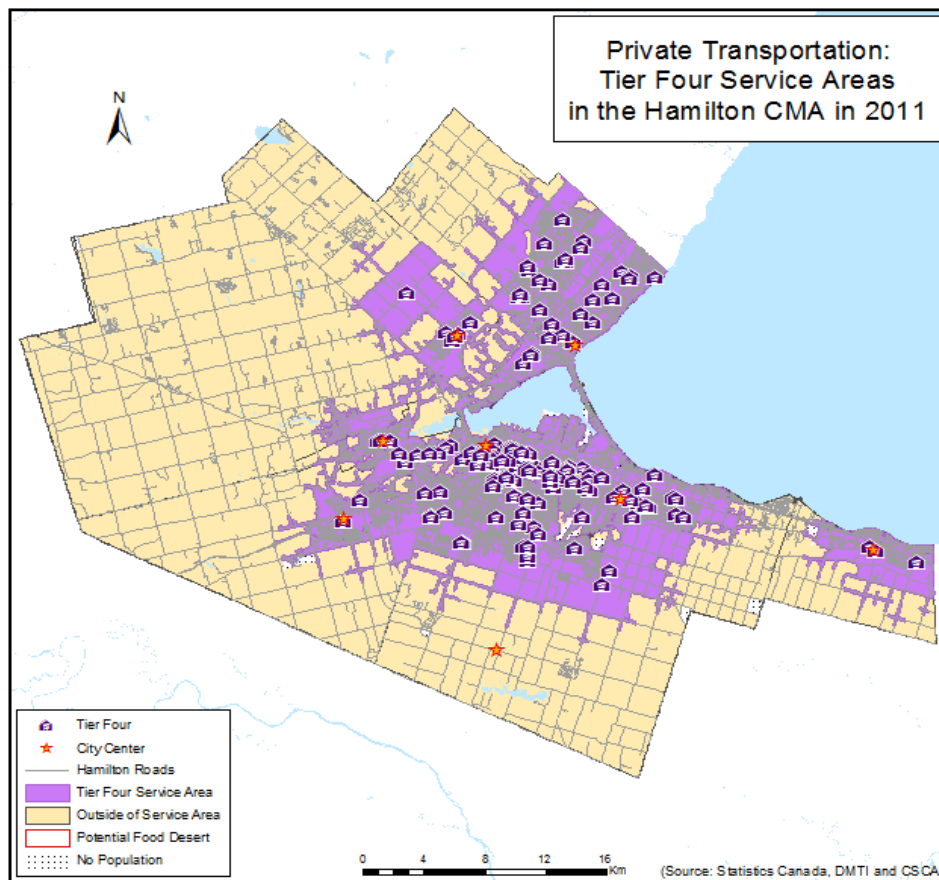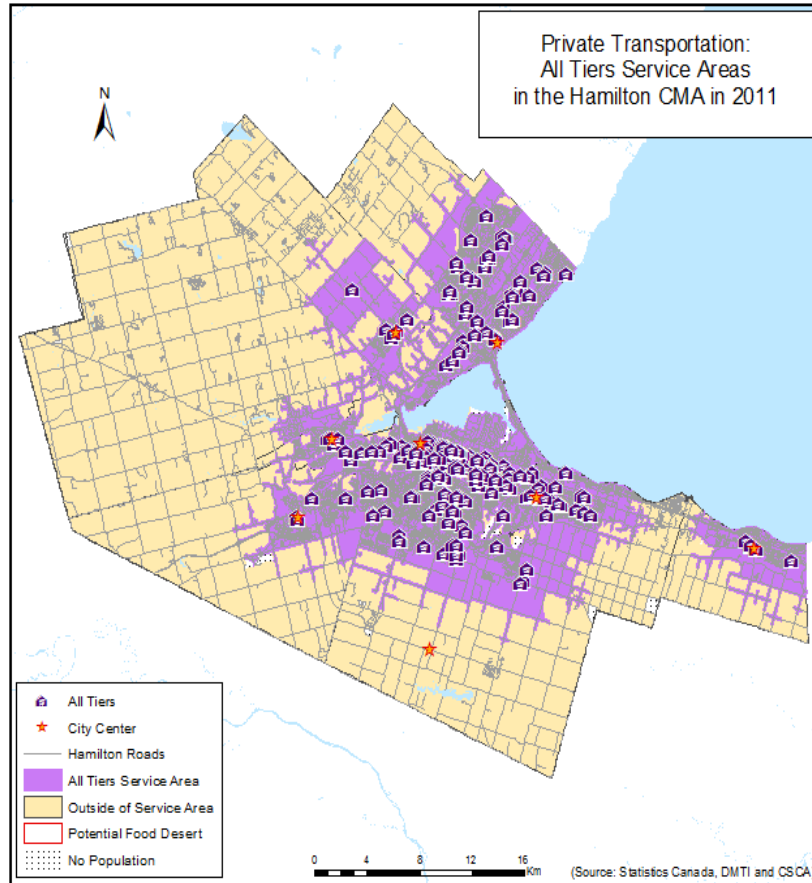Fig. 10 Tier Two Service Areas with Potential Food Deserts for Private Transportation [47], [57]

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Fig. 11 Tier Three Service Areas with Potential Food Deserts for Private Transportation [47], [57]

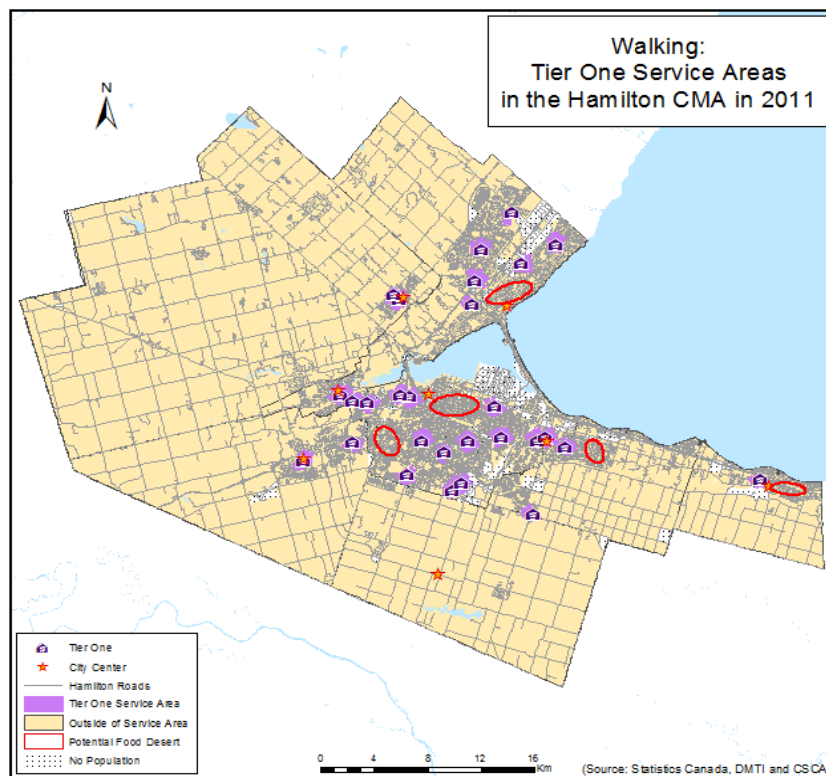Fig. 12 Tier Four Service Areas with Potential Food Deserts for Private Transportation [47], [57]

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Fig. 13 All Tiers Collapsed Service Areas with Potential Food Deserts for Private Transportation [47], [57]

Fig. 14 Tier One Service Areas with Potential Food Deserts for Walking [47], [57]

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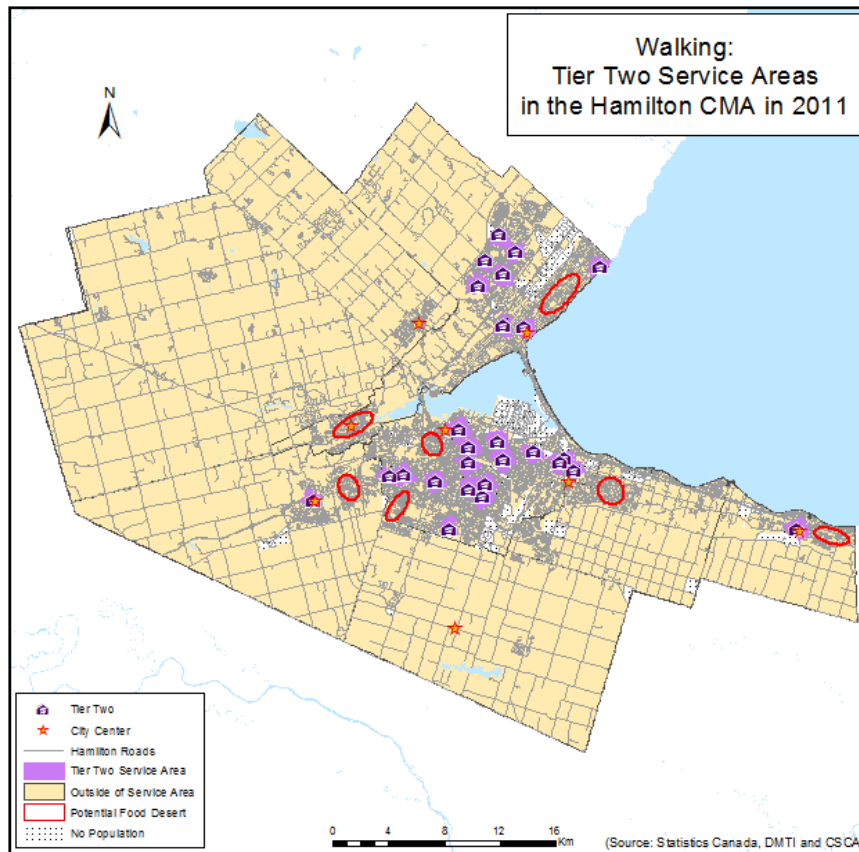International Journal of Civil and Environmental Engineering
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Fig. 15 Tier Two Service Areas with Potential Food Deserts for Walking [47], [57]

Fig. 16 Tier Three Service Areas with Potential Food Deserts for Walking [47], [57]
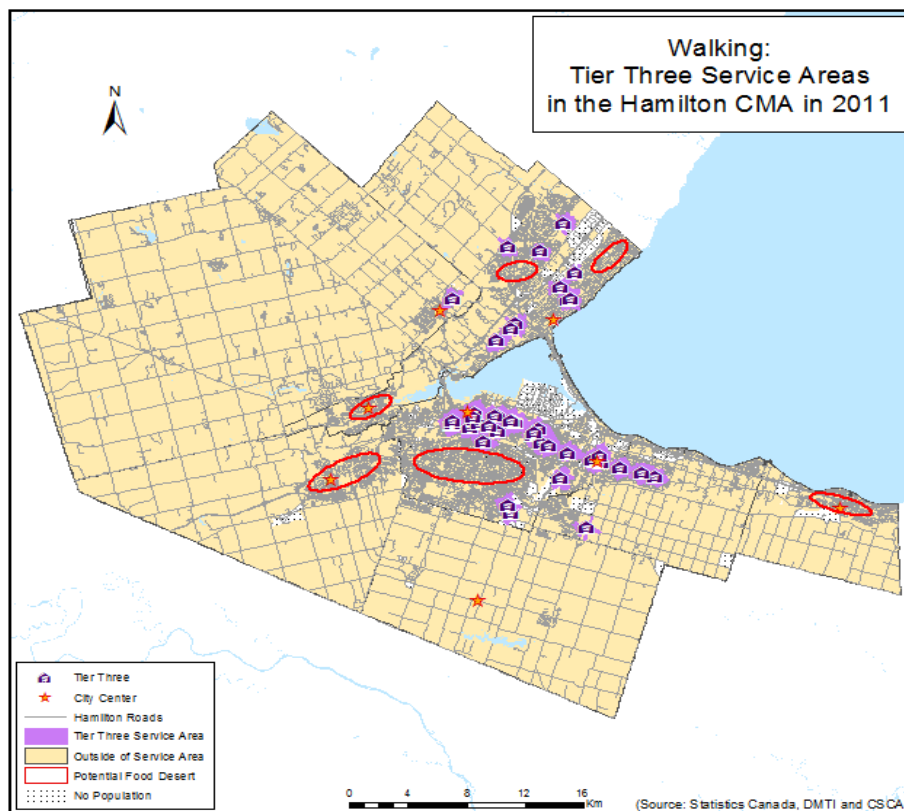
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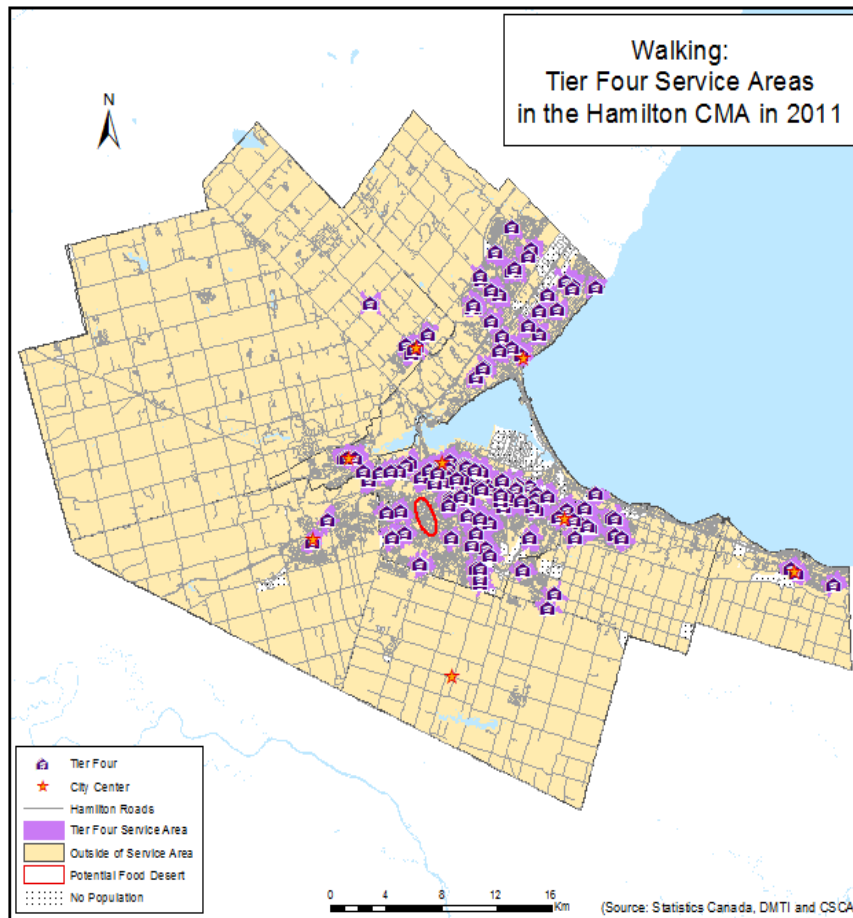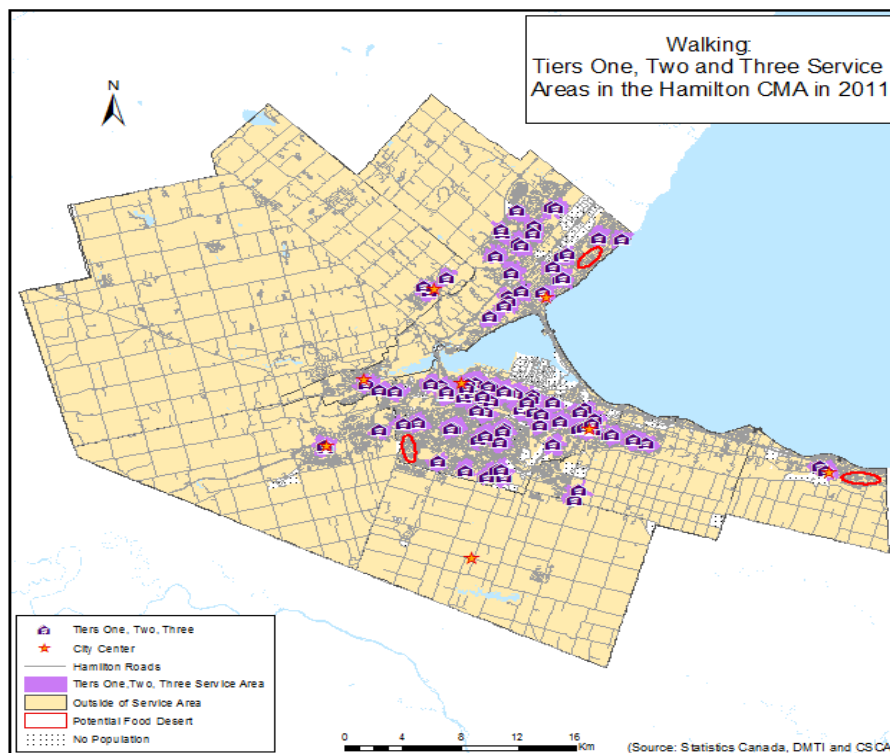Vol:11, No:8, 2017

Fig. 17 Tier Four Service Areas with Potential Food Deserts for Walking [47], [57]

Fig. 18 Tiers One, Two and Three Collapsed Service Areas with Potential Food Deserts for Walking [47], [57]

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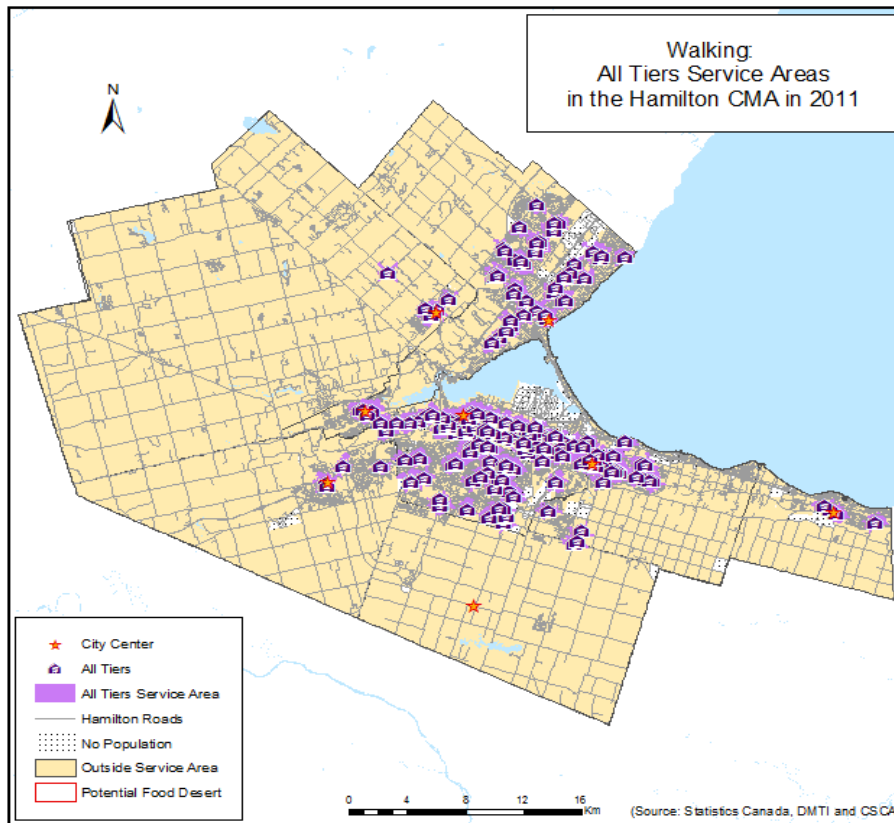International Journal of Civil and Environmental Engineering
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Fig. 19 All Tiers Collapsed Service Areas with Potential Food Deserts for Walking [47], [57]

Fig. 20 All Tiers Service Areas with Potential Food Deserts for Public Transportation [47], [57]
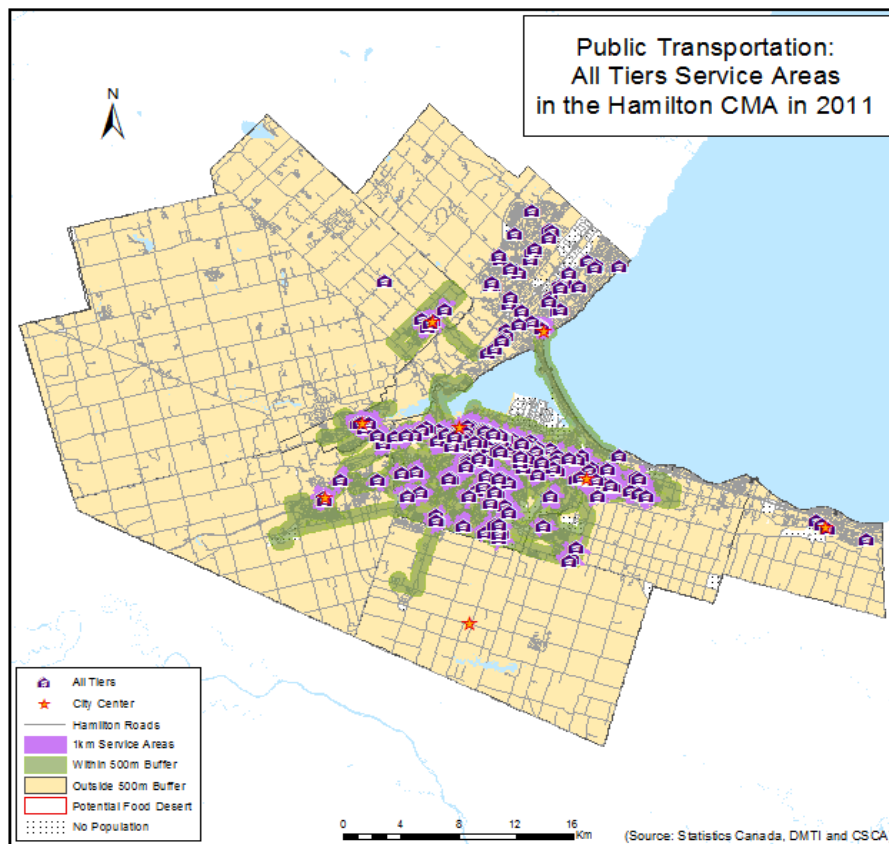
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XV. CONCLUSION

The findings of this study have revealed three important conclusions: 1) that more food stores are found to be present in the Hamilton CMA than expected, 2) that the residents of the Hamilton CMA have adequate access to affordable, healthy food by multiple modes of transportation, and 3) very few potential food gaps are found at each of the tiers with no areas qualifying as food deserts when all four tiers of food stores are included. Other important findings of this paper can be summarized as follows:

The Hamilton CMA experienced a negligible change in the total number of food stores between the years 2006 and 2011 (Table II). Across the categories, the study area gained 33% of Tier One high-end chain grocery stores and 18% of Tier Three independent food stores and lost 2.6% of Tier Four convenience and franchise food stores. The most significant loss was 23.5% of Tier Two discount grocery stores, the majority of which are located in the lower income areas of Downtown and East Hamilton;

The average distance that residents needed to travel to the closest grocery store decreased by 10% for Tier One stores and 4% for Tier Three stores over the five year period, while it increased 23% to reach Tier Two stores and 21% for Tier Four stores (Table III). The distance to the nearest grocery store showed very little correlation with the median household income, however a moderately-low positive relationship was found with large households of 6-plus persons. All of the tiers of food stores are accessible by at least one mode of affordable transportation.

It was expected that the total number of food stores in the Hamilton CMA would be lower than what is present since, as discussed earlier, grocery retailers have become increasingly consolidated and many have a preference towards larger store formats. Moreover, fewer Tier Three independent food stores were expected. Contrary to expectations, it was found that the Hamilton CMA had essentially the same total number of food stores in 2011 as it did five years previous. And in actuality, the number of Tier Three and Tier One stores increased. The reason for this could be that less profitable Tier Two stores were closed and new Tier One stores opened operating under the same conglomerate. As well, the loss of Tier Two stores likely provided greater need and market opportunities for small independent grocery start-ups. For example, several independent grocers, deli's, meat, and ethnic specialty food stores located in the areas of Downtown and East Hamilton where Tier Two stores had closed since 2006. To better understand the overall changes in grocery retail in the Hamilton CMA, future studies should include an analysis of floor space and average food basket cost as proxies for food availability and affordability.

As expected, rural areas had a much greater distance to travel to reach a grocery store than urban and suburban neighbourhoods. This makes sense since stores require a certain population living within close proximity in order to be profitable. In order to better understand differences in accessibility related to distance, future research of the Hamilton CMA should divide the study area. However, the general trends of this study are still valid. The distance to the closest store was expected to be greater for large chain grocery stores (Tiers One and Two) than for independent (Tier Three) and convenience stores (Tier Four). The average distance to reach a Tier One or Tier Two supermarket was further than for Tier Three stores; however, it was shorter than the closest Tier Four store in both 2006 and 2011. This may be contrary to that which would be expected but is attributable to differences in urban form. The majority of Tier Four stores are located in the urban areas making it necessary for individuals living in suburban and rural areas to travel much further.

While a positive relationship between income and distance was expected, no substantial relationship was found. The likely reason is that stores are locating in areas with sufficient population density. The linear distribution of stores that parallels the waterfront shows a clear relationship between store location and urban form. Since the correlation results for the median household income variable were not as strong as hoped, an attempt to rectify this shortcoming was made by using a variable representing household size. The variable of households with six or more people was found to be positively correlated with distance, but was moderately-weak. Once again, dividing the study area between urban/suburban and rural would likely provide a more accurate understanding of the relationship between income and distance that may exist.

The service areas for private transportation indicated that over 91% of individuals residing in the Hamilton CMA have access to all tiers of food stores by automobile. Theoretically, assuming that all individuals have access to a vehicle, over 91% of the population had adequate service when all four tiers of food stores combined. This finding is of significance because it indicates that the networks of transportation and grocery retail have been well-planned and food stores have been made accessible by the most predominant mode of transportation. The income levels of individuals living within the 5 km service areas across all Tiers are relatively similar to those residing outside. The findings also suggest that food stores locate based on population density rather than income. As expected, food stores are accessible to much fewer people for residents walking than for driving to shop for groceries since the distance a person is willing to walk to shop and carry groceries is quite short. More distinct differences in income and density are found in the walking distance service areas.

The findings suggest that certain economic and population criteria may drive grocery store locational choices. As mentioned earlier, Tier One high-end chain grocery stores target individuals that will typically spend more for higher quality foods and service, whereas Tier Two discount chain grocery stores cater to more price conscious consumers. The findings are significant as they indicate that individuals living in areas of economic deprivation have access to all tiers of food stores by bus. Consequently, 62% is an underestimate of the actual proportion of individuals with access to public transit

This study has shown that food deserts seem to be absent in the Hamilton CMA. A suggestion for further research would be to focus in on the areas identified as potential food deserts

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to determine the demographic characteristics of the population. Furthermore, with the available data there was no way to determine if in actuality residents are making healthy food choices when purchasing groceries. One way to improve this analysis would be to conduct a qualitative ground-truthing analysis that surveys customers at food stores and the items purchased. This would help to better understand the non-spatial dimensions of access to grocery retail and whether greater public education is needed to ensure healthy dietary lifestyles.

Given that most of the areas in the Hamilton CMA have a relatively high level of accessibility to food stores by private automobile and public transportation no areas can be defined as food deserts. For any disadvantaged individuals that do not have access or cannot afford a vehicle, other feasible options for longer distance shopping trips include taking the bus, bicycling, carpooling, making larger shopping trips less frequently, taxicabs and short-term car rentals. The high level of accessibility can be attributed to Tier Three and Tier Four stores filling in the gaps where Tier One and Tier Two stores are lacking. If poor dietary choices are being made by individuals living in the Hamilton CMA, it is not attributable to accessibility. This study revealed the importance of local, independent neighbourhood stores as vital players in the grocery retail landscape of cities. If poor diet is a public policy concern, it may be that people are either choosing to shop at Tier One and Tier Two stores but not purchase healthy foods or they are choosing to purchase the majority of their food from convenience stores where few healthy food options are available. Therefore, more government action is necessary to better educate the public on the importance of healthy diet and lifestyle choices. Furthermore, cities should foster economic policies that encourage and support local independent providers of grocery retail.

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