Article

Congruence and Coverage: Alternative Approaches to Identifying Urban Food Deserts and Food Hinterlands

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Abstract

Recent literature identifies disadvantaged neighborhoods lacking access to healthy food as "food deserts" where limited food choices may affect health and socioeconomic outcomes. Researchers have applied varying definitions of food deserts, however, making generalizations problematic. We use GIS methods to examine the congruence and coverage of different definitions for Portland, Oregon. Each identifies somewhat different neighborhoods as food deserts, with none accounting for the majority of socioeconomically vulnerable populations living with low food access. To supplement, we introduce the concept of the food hinterland—home to a significant share of the vulnerable population living with low food access.

Keywords

food deserts, food environment, food access, spatial analysis

Introduction

In recent years, research on food systems has begun to appear in the planning literature, reflecting a growing community concern with the relationship among place, food, and social well-being. This concern rises out of a tangle of emerging issues surrounding food production and consumption as they relate to health outcomes, social equity, and environmental sustainability (e.g., Morgan 2009). Activists and authors alike have attempted to address this multifaceted food system by focusing on strategies to improve community food security (Blay-Palmer 2009; Pothukuchi 2004, 2009; Reynolds 2009), defined as "a situation in which all community residents obtain a safe, culturally appropriate, nutritionally adequate diet through a sustainable food system that maximizes community self-reliance and social justice" (Hamm and Bellows 2003, p. 37).

Within this context, one concern has been access to appropriate, affordable, and healthy food for low-income households. This issue has drawn the attention of planners and others, who have considered, among other things, the range of food outlets that constitute the food system in an area (e.g., Short, Guthman, and Raskin 2007; Raja, Ma, and Yadav 2008), the extent and feasibility of initiatives to develop grocery stores in inner-city areas (Pothukuchi 2005), transportation options available to low-income families shopping for food (e.g., Clifton 2004), and processes for assessing community food security (e.g., Campbell 2004; Pothukuchi 2004; American Planning Association 2007). A number of authors have looked directly at the correspondence between various aspects of the food environment (regional sprawl and the presence or absence of supermarkets, convenience stores, and fast-food restaurants) and a variety of health indicators (e.g., Lathey, Guhathakurta, and Aggarwal 2009; Raja et al. 2010).

Alongside this work, a considerable literature has zeroed in on the idea of and identification of "food deserts"—predominately low-income, urban neighborhoods, often centrally located, with inadequate physical or economic access to healthy food (e.g., Whelan et al. 2002; Wrigley 2002; Wrigley et al. 2002; Wrigley, Warm, and Margetts 2003; Guy and David 2004; Smoyer-Tomic, Spence, and Amrhein 2006; Apparicio, Cloutier, and Shearmur 2007; Larsen and Gilliland 2008).[1] Most recently, the U.S. Congress requested a nationwide study of food deserts in the United States (Ver Ploeg et al. 2009). This focus on food deserts has raised two unresolved issues, however: First, different studies have

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applied a variety of methodologies to identify food deserts and there has been no assessment of the comparability of these methods. As Smoyer-Tomic, Spence, and Amrhein (2006) note, comparison across extant studies of different metropolitan areas is therefore difficult; thus, broader generalizations about patterns of access across cities have been infrequent. Each study is left to stand on its own, hampering the development of generalizable ideas about differential causes and consequences of, or policy remedies for, food deserts. Second, the focus on food access in areas identified as food deserts has come at the expense of an examination of food access issues for low-income households more generally, including those who live outside food deserts. In particular, no authors have applied food access measures to the broader question of how low-income households living outside food deserts fare in this regard, or even how many low-income households live outside of food deserts. In turn, this has limited the range of planning and policy options that have been considered as remedies for the food access issues of lower-income households.

In this paper, we address both of these issues in the hope of both fine-tuning and broadening the policy and planning framework for addressing food access questions for low-income households. Focusing on the Portland, Oregon metropolitan area, we use geographic information systems (GIS) methods to construct multiple measures of neighborhood food access. We utilize these measures as inputs to three commonly used methods of identifying food deserts. We examine the resulting food desert classifications as to whether or not they yield congruent results, both in terms of the areas identified as food deserts and the characteristics of populations living in those areas. We find that the three methods yield sufficiently comparable results regarding the extent of food deserts in a metropolitan area that one could reasonably compare results from disparate methods across regions. However, if the goal is to identify specific neighborhoods within a metropolitan area for policy or planning intervention, the congruence across methodologies is insufficient to recommend reliance on any one method.

We also examine the extent to which the food deserts (identified by any method) are in fact home to a significant share of the low-income population experiencing low food access in the Portland area. Surprisingly, we find that the vast majority of socioeconomically challenged households with low food access are located outside the areas identified as food deserts, which are usually located in the central city. This finding leads us to propose the concept of food *hinterlands* to juxtapose with that of food deserts, where the term *hinterland* refers to low-food-access areas typically away from more centrally located food deserts. These are often less dense, dispersed suburban areas. They lack the concentrated poverty and the empty shells of defunct grocery stores that are visible reminders of food access issues in food deserts. As such, food access for low-income households in such areas remains unexamined and has not entered policy or planning discussions in any serious way.

Food Deserts: Conceptual and Operational Definitions

Researchers and policy makers have proposed a variety of conceptualizations of food deserts. Virtually all the definitions put forward involve common elements, yet they differ in nuance and emphasis. In this section, we discuss the range of ways in which food deserts have been conceived, the conceptual points for which there is or is not consensus, and the evolution of those concepts into operational definitions for the purposes of empirical research on food deserts.

The first definition of food deserts (put forth for policy purposes in the United Kingdom) referred to "areas of relative exclusion" where residents face "physical and economic barriers to accessing healthy food" (Reisig and Hobbiss 2000). Guy and David (2004) suggest that food deserts are "areas where no food retail outlets exist, or those that do exist are of unacceptable quality. Such areas may also be characterized by social deprivation, low incomes and poor levels of nutrition amongst local residents." (p. 222). Perhaps most recently, the 2008 Farm Bill passed by the U.S. Congress described a food desert as an "area in the United States with limited access to affordable and nutritious food, particularly such an area composed of predominantly lower income neighborhoods and communities" (Title VI, Sec. 7527).

While each of these definitions differs slightly, all convey the same basic flavor by emphasizing two components: First, food deserts are physical areas—for example neighborhoods or communities in urbanized areas. And second, residents of food deserts lack access to retail outlets offering a wide range of healthy (nutritious) foods. There is less consensus concerning two additional issues, however: whether food deserts are explicitly defined as low-income areas, as areas of socioeconomic deprivation or as home to those who are disadvantaged in some other way, such as not having access to an automobile (perhaps because of age or disability), and whether the lack of access to healthy food in food deserts is a lack of a physical access, economic access (because of some low incomes or high prices), or both.

An operational definition for food deserts requires four elements: (1) a geographic unit of analysis, (2) a definition of what constitutes a sufficiently wide range of nutritious foods items, (3) a threshold for determining low access to food, and finally, (4) a threshold for determining which populations with low food access will lack the resources to access food from more distant retail outlets. Researchers have addressed each of these elements in a variety of ways. With regard to the first issue, most researchers in the United States and Canada have focused their analysis on census tracts as a proxy for neighborhood (e.g., Apparicio, Cloutier, and Shearmur 2007; Larsen and Gilliland 2008),[2] although others have used city-defined neighborhood boundaries (e.g., Smoyer-Tomic, Spence, and Amrhein 2006); UK researchers have typically used electoral divisions, geographic areas of approximately the same population as a U.S. or Canadian census tract, or the much smaller postal code

sectors or enumeration districts (e.g., Guy and David 2004; Clarke, Eyre, and Guy 2002; Cummins and Macintyre 1999).[3] The main motivation for this choice is likely the availability of data on population characteristics, although in the United States, such data are also available at a greater level of disaggregation, the census block group level.

In addressing the second issue, most food desert studies have focused on the presence of a chain supermarket as a proxy for the availability of a wide array of food types at competitive prices (Clarke, Eyre, and Guy 2002; Guy and David 2004; Smoyer-Tomic, Spence, and Amrhein 2006; Apparicio, Cloutier, and Shearmur 2007; Larsen and Gilliland 2008). Guy and David (2004) argue that food deserts are not necessarily entirely void of food retailing. Rather, "'food deserts' do include some food retailing. . . . However, stores that can provide a wide range of food and grocery items at low prices, typically run by large multiple retailers [chains], are lacking" (p. 223). Researchers looking at food access issues more generally have also investigated the role of other types of food providers such as farmers markets, bakeries, ethnic food markets, corner stores, convenience stores, restaurants, and independent grocers (e.g., Algert, Agrawal, and Lewis 2006; Short, Guthman, and Raskin 2007; Raja, Ma, and Yadav 2008); still others have explicitly examined the variability of food prices across different neighborhoods (e.g., Donkin et al. 1999; Ball, Timperio, and Crawford 2009).

The third issue in defining food deserts hinges on determining what constitutes adequate access to healthy, affordable food. While various authors have noted that access has both physical and economic aspects, quantitative researchers have generally used socioeconomic or price data (discussed below) to address the economic aspects of access, and spatial data on store locations to address the physical aspects. In food access research more generally, measurement of physical access to food outlets in a neighborhood has included computing the number or density of food outlets in a given area (e.g., Alwitt and Donley 1997; Cummins and Macintyre 1999; Moore and Diez Roux 2006; Berg and Murdoch 2008; Franco et al. 2008), or mapping clusters of grocery stores and fast-food restaurants (Baker et al. 2006). Food desert studies, however, have focused primarily on distance-based measures, computing variously the average distance from a given neighborhood to one or more stores and/or identifying neighborhoods in which a set share of the residents do or do not live within what would be considered a reasonable walking distance to a store (Guy and David 2004; Smoyer-Tomic, Spence, and Amrhein 2006; Apparicio, Cloutier, and Shearmur 2007; Larsen and Gilliland 2008).

The final issue faced by researchers is defining which populations can be expected to experience challenges in accessing healthy food sources from more distant retail outlets. Assuming that socioeconomically deprived residents are most likely to face transportation and time–cost barriers in seeking out more-distant shopping options, food desert researchers have used a variety of different proxies for disadvantage including poverty rate, unemployment rate, percentage of residents with low levels of education, or presence of single-parent or immigrant households. Others have used various socioeconomic indices: Guy and David (2004) used the Welsh Multiple Deprivation Index; Clarke, Eyre, and Guy (2002) used the Carstairs index; Apparicio, Cloutier, and Shearmur. (2007) and Larsen and Gilliland (2008) both constructed indices from underlying socioeconomic data. Furthermore, there is also concern that those lacking physical mobility for noneconomic reasons (e.g., age or disability) should similarly be considered vulnerable to the vagaries of the food desert and indices to reflect these factors are also employed.

To date, each published study that has explicitly identified food deserts has used somewhat different measures in dealing with each of these four definitional issues. In the work that follows, we replicate and compare three alternative methodological approaches previously used in the literature. Our goal is not to critically evaluate these food desert definitions but rather to accept each definition as given and then to determine whether or not different empirical approaches in fact yield different conclusions regarding the coverage of food deserts. In addition, we will determine the extent to which any definition of food desert captures a significant share of the disadvantaged population that experiences inadequate food access within the metropolitan region.

Data and Methodology

For this study, we compile GIS-based data on neighborhood demographic characteristics and supermarket locations for Portland, Oregon, and replicate and compare the definitions of food deserts used for Edmonton, Alberta (Smoyer-Tomic, Spence, and Amrhein 2006); Cardiff, Wales (Guy and David 2004); and Montreal, Quebec (Apparicio, Cloutier, and Shearmur 2007). To our knowledge, these three methods represent the only formalized and replicable approaches to identifying food deserts in the existing literature. Methodology used by Guy and David (2004) is indicative of that used in other UK studies as well (e.g., Clarke, Eyre, and Guy 2002); Larsen and Gilliland (2008) also model food deserts in London, Ontario, but do not provide sufficient methodological detail that we are able to replicate their definition here. The Edmonton and Montreal studies use relative standards for inadequate food access, while the Cardiff study uses an absolute standard. The detail of our methodology for identifying food deserts is followed by a discussion of our strategy for identifying food hinterlands.

Identifying Food Deserts and Food Hinterlands

Our first definition of food deserts is drawn from the study of the Edmonton area by Smoyer-Tomic, Spence, and Amrhein (2006). As they do, we construct a relative measure of food access for which the threshold for inadequate food access is the quartile of census tracts with the greatest distance to the nearest supermarket. Social deprivation is defined

based on the values of three variables: poverty rate, the percentage of the population age 65 and older, and percentage of households without access to an automobile. Census tracts meet the definition of social deprivation if the tract poverty rate exceeds the 75th percentile of poverty across all tracts, and if the census tract is either in the highest quartile ranking for percentage elderly or the highest quartile for households lacking automobile access.

Our second definition of food deserts is based on Guy and David's (2004) discussion of food deserts for Cardiff, Wales. Guy and David adopt an absolute definition of food access based on what they consider a "reasonable" walking distance for food access purposes—distances of one-half kilometer or less. However, we adapt their approach to North American standards—in virtually all North American studies this standard has been loosened to 1 kilometer. In addition, the Cardiff study uses an index of social deprivation that is standard in Wales, the Welsh Index of Multiple Deprivation (WIMD), but unavailable in the United States. We substitute other comparable criteria for social deprivation: a food desert is a census tract in which at least 50 percent of tract residents do not have a supermarket located within 1 kilometer[4] and are considered socioeconomically vulnerable by the criteria as used in the Edmonton case.

Our third and final definition of food deserts is based on the study of Montreal by Apparicio, Cloutier, and Shearmur (2007). This food desert designation departs from the notion of identifying two distinct thresholds for food access and social deprivation. Instead, the authors base their food desert designation on cluster analysis of four variables—three food access measures (M1, M2, and M3, defined in the section "Food Access Measures") and a constructed index of social deprivation.[5] Cluster analysis is a hierarchical method for the classification of observations (in this case census tracts) based on the degree of similarity among included variables, assigning observations to clusters so that the average "distance" between clusters is maximized.[6] Cluster analysis transforms the classification exercise—instead of asking whether a specific census tract is a food desert, we are now asking whether a specific cluster of census tracts constitutes a food desert. After creating clusters, we compute the population-weighted means for the four clustering variables for each cluster of census tracts. Clusters are designated as food deserts if the cluster's mean values of the four variables indicate relatively high social deprivation and relatively low food access; thus cluster analysis implicitly relies on relative standards for both food access and social deprivation.[7]

Implicit in this discussion is the understanding that food access involves either walkable distances to grocery stores *or* access to appropriate transportation for food shopping. Clarke, Eyre, and Guy note that "an area might only be classified as a 'food desert' if the residents of that area have little or no means of travelling significant distances in order to purchase food" (2002, p. 2049). In defining food deserts, researchers have primarily relied on the assumption that residents of high-poverty neighborhoods are less likely to have access to automobiles for food shopping. With the exception of Larsen and Gilliland (2008), however, none have explicitly modeled the relationship between transportation access and food access.

In this article, we also set forth the concept of food hinterland. Food hinterlands are defined in juxtaposition to the idea of food deserts. We define hinterlands as neighborhoods that lack adequate access to supermarkets (according to the standards set out in food desert definitions), but that are not considered food deserts because they do not have concentrated socioeconomic vulnerability. However, of the three food desert definitions used in this paper, only the Edmonton and Cardiff definitions include clearly identifiable standards for what constitutes inadequate supermarket access according to food access (the Montreal definition relies on cluster analysis and does not incorporate one specific food access threshold). Thus, we apply the food access thresholds employed in the Edmonton and Cardiff definitions to generate two possible definitions of food hinterlands.

Study Area and Demographic Data

We follow the general practice in North American studies and use census tracts as an accepted proxy for neighborhood;[8] we later test the sensitivity of our findings to this practice, substituting block group–level analysis for census tract–level analysis.[9] Our study area consists of the 243 census tracts that are completely contained within Portland, Oregon's metropolitan area urban growth boundary (UGB), an area encompassing 685.6 square kilometers (see Figure 1).[10] The 243 tracts within the UGB contain 722 census block groups and 18,203 census blocks;[11] the 2000 Census population of the area was 1,071,817 residents. Population data for census blocks is drawn from Summary File 1 of the 2000 U.S. Census; neighborhood characteristic data at the block group and census tract level comes from Census Summary File 3. Neighborhood characteristics examined include percentage of the population below the poverty line or with low levels of education; percentage of the population that is elderly, recently immigrated, or unemployed; and percentage of households headed by single-parents or without access to an automobile.

Supermarket Data

As discussed previously, one issue in the designation of a food desert is the determination of what constitutes a sufficiently wide range of nutritious foods items. The presence of a supermarket is an accepted proxy for the availability of a broad range of healthy, fresh foods at competitive prices and has generally been the focus of food desert studies (Chung and Meyer 1999; Nayga and Weinberg 1999;

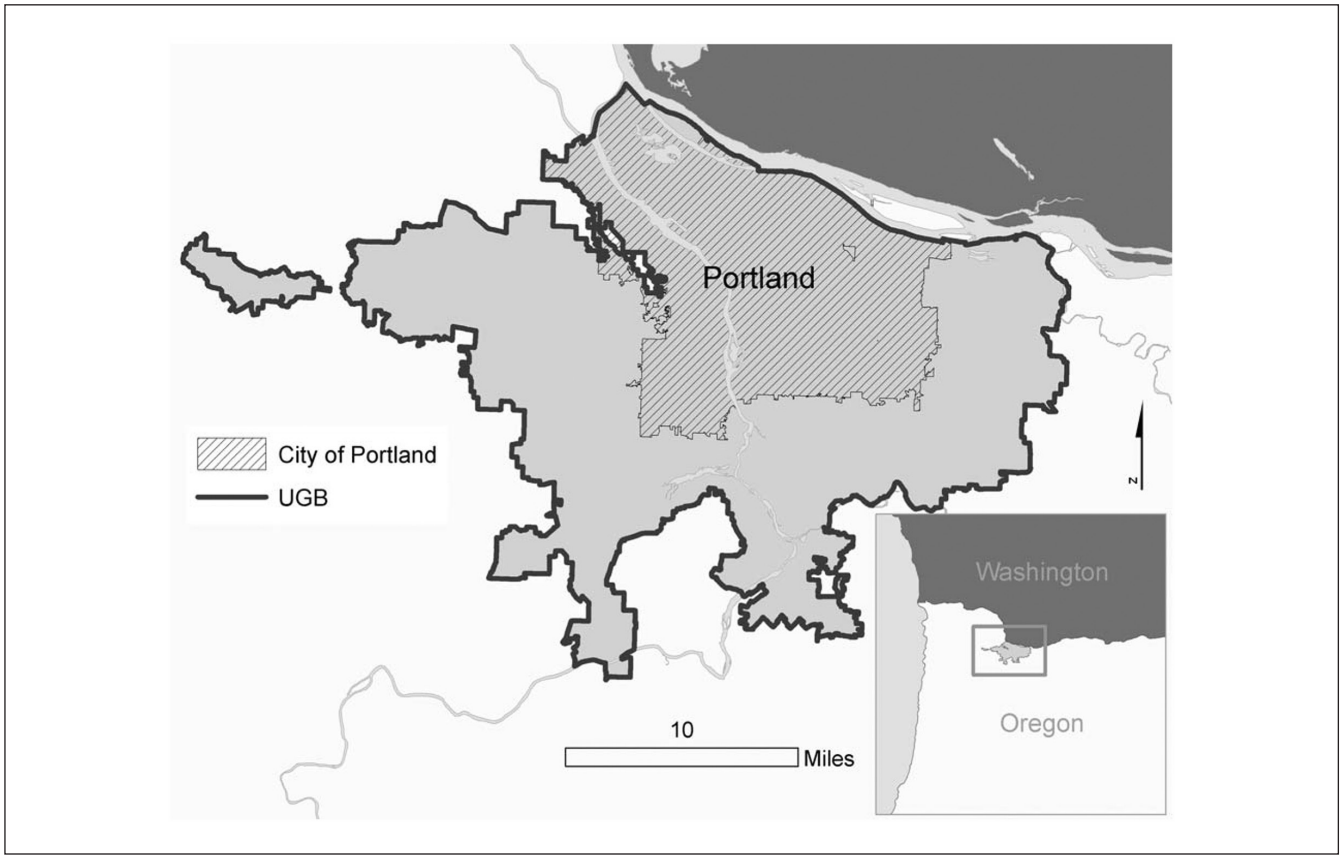

Figure 1. Portland, Oregon's metropolitan urban growth boundary (UGB)

Eisenhauer 2001; Cummins and Macintyre 2002). As such, the food access measures used here are measures of proximity to supermarkets that meet criteria consistent with the extant literature (see, e.g., Apparicio, Cloutier, and Shearmur 2007). We acknowledge, however, that in some urban environments a broad range of nonsupermarket food retailers may also be found to provide adequate food access. Furthermore, it is unclear whether supermarkets can be assumed to provide culturally appropriate food in all contexts (Short, Guthman, and Raskin 2007; Raja, Ma, and Yadav 2008). For the purposes of our study, to qualify as a supermarket stores must be selling a full range of products, including fresh fruit and vegetables, dairy and meat, and be part of a chain or be directly affiliated with a distribution system responsible for supplying multiple stores. Supermarket business characteristics and addresses were collected via ReferenceUSA, an online database of business information compiled from phone books, public records, and U.S. Postal Service records ("ReferenceUSA: An infoUSA Company"). Searches within the database were conducted using the 2007 North American Industry Classification System (NAICS) code for supermarkets, 445110. The resulting database of stores was checked for completeness and accuracy by visiting each chain's corporate website; in some cases, the extent of products carried and ownership details were confirmed by telephone. Store addresses were geocoded to street files made available by Portland's metropolitan regional government and planning agency (using ArcGIS 9.2), resulting in a database of 145 supermarkets associated with 18 distinct supermarket chains.

Food Access Measures

To replicate the three alternative food desert designations discussed previously, we use three different food access measures. In addition to the Cardiff, Edmonton, and Montreal studies (Guy and David 2004; Smoyer-Tomic, Spence, and Amrhein 2006; Apparicio, Cloutier, and Shearmur 2007), these specific measures have been widely used in the literature (Clarke, Eyre, and Guy 2002; Larsen and Gilliland 2008; Zenk et al. 2005; Fan et al. 2009). Each of the three food access measures serves as an indicator of different dimensions of access (Apparicio, Cloutier, and Shearmur 2007). Measure 1 (M1) captures proximity by measuring the distance to the nearest supermarket. Measure 2 (M2) evaluates both competition and variety by measuring the number of supermarkets located within a 1-kilometer radius (the distance taken to be a reasonable walking distance for an adult in an

Table 1. Descriptive Statistics and Spatial Autocorrelation for Food Access Measures and Selected Demographic Variables, Portland, Oregon (Census Tracts within Urban Growth Boundary, n=243, Population Weighted)

Access Measure	Mean	Median	Minimum	Maximum	Spatial Autocorrelation Measures	
					Moran's *I*[a]	z-Score[b]
M1: Distance to nearest supermarket (meters)	1,058	991	187	4,676	0.32	7.35
M2: Number of supermarkets within 1 km	0.52	0.40	0.00	3.25	0.67	15.14
M3: Average distance to three closest supermarkets (meters)	1,641	1,569	362	5,927	0.48	10.91
Percentage below poverty line	10.6	8.9	0.0	62.3		
Percentage age 65 and older	10.6	9.9	0.9	36.2		
Percentage without car in household	9.4	7.1	0.0	90.3		

[a]Calculated with a weighted connectivity matrix with a lag distance of 1.5 km.
[b]All z-scores significant at the .001 level or higher.

urban setting). Measure 3 (M3) measures variety and competition by evaluating the mean distance to the nearest three supermarkets belonging to different chains. Our measures are based on population-weighted block-level Euclidean distance inputs aggregated to create tract-level access measures.[12]

For each of the three measures, food access for the *i*th census tract is constructed as

$$m_{Ni} = \frac{\sum_{b \varepsilon i} p_b X_{Nb}}{\sum_{b \varepsilon i} p_b} \quad (1)$$

where $N = 1$ through 3 indicates Measure 1 through Measure 3, and X_{Nb} represents the block-level distance input specific to that measure. In each case, p_b is the total population of block b entirely included in census tract i. In the case of Measure 1, $X_{1b} = \min(D_b)$, where D_b is a vector of the distances between the centroid of block b and each of the 145 supermarkets in the sample. For Measure 2, X_{2b} is the number of supermarkets located within 1 kilometer of the centroid of census block b. In the construction of Measure 3, X_{3b} is the mean distance between the centroid of census block b and the three nearest supermarkets associated with distinct supermarket chains.

In the following sections we present the results of our investigation, first looking at food access for census tracts in the Portland area and then asking whether neighborhoods match the criteria for being classified as a food desert under each of the three definitions discussed. We examine the extent to which the three definitions paint the same picture of food deserts in the area. Finally, we examine the extent to which any definition of food desert captures a significant proportion of the disadvantaged population that experiences low food access within the Portland region.

Findings

Food access in Portland appears to be considerably lower than in Montreal but higher than in Edmonton. For the average Portland census tract, the mean distance to a supermarket is just more than 1 kilometer, but ranges from 0.19 to 4.7 kilometers (Table 1). The mean distance to the nearest three different supermarkets is 1.6 kilometers and the average census tract has just 0.52 supermarkets within a 1-kilometer radius. Apparicio, Cloutier, and Shearmur (2007) report an average distance from Montreal census tracts to the nearest supermarket to be 0.91 kilometers, with 1.2 supermarkets within a 1-kilometer radius and an average distance of 1.5 kilometers to the nearest three different supermarkets. In contrast, Smoyer-Tomic, Spence, and Amrhein (2006) report that in Edmonton the median distance to a supermarket was 1.4 kilometers and the median number of supermarkets within a 1-kilometer radius was 0.10 (compared with 0.40 in Portland). In Table 1, we also show Moran's *I*—a measure of the spatial autocorrelation, or spatial clustering—for the food access measures. The high level of statistical significance for each of the Moran's *I* measures indicates that there is significant spatial clustering of food access throughout the metropolitan area. Food access is not randomly distributed throughout the metropolitan area; instead, census tracts with high levels of access are more likely to neighbor one another, as are census tracts with low levels of access.

Congruence of Food Desert Definitions

Using the various measures of food access and socioeconomic vulnerability as inputs, we apply the three different food desert definitions to the Portland area. The three definitions each identify between 5 and 12 different census tracts as food deserts (see Table 2). Following the first definition,

Table 2. Mean Characteristics of Food Deserts (Census Tracts) in Portland Study Area (Population Weighted)

		Food Access Measure					Percentage of Population		
Food Desert Definition	*N*	M1 (Meters)	M2 (Stores)	M3 (Meters)	Land Area (km^2)	Percentage of Study Area Land	Below Poverty Line	Age 65 and Older	Without Car in Household
All tracts	243	1,058	0.52	1,641	685.6	100.0	10.6	10.6	9.4
Type I: Edmonton	5	1,548	0.002	2,030	7.2	1.1	20.9	10.9	20.7
Type II: Cardiff	12	1,115	0.22	1,755	15.0	2.2	28.4	7.3	22.6
Type III: Montreal	5	1,117	0.17	1,633	8.8	1.3	24.9	6.1	17.5
Type I, II, or III	15	1,188	0.18	1,793	22.4	3.3	25.0	7.8	18.9

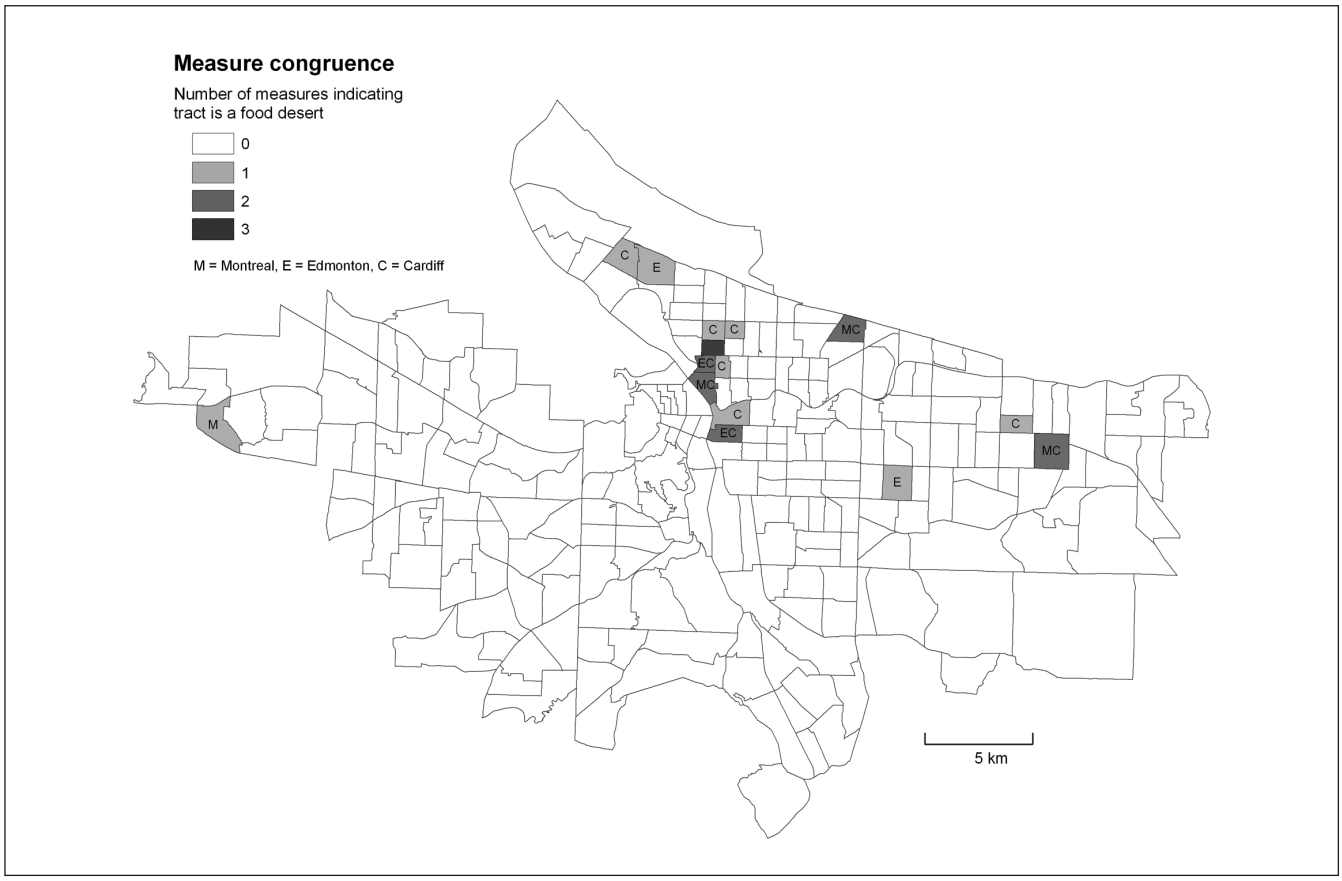

Figure 2. Congruence of food desert definitions for Portland, Oregon, study area

based on Edmonton, 5 of 243 Portland-area census tracts are assigned food desert status. Identifying food deserts with the other two definitions yield similar results. The Cardiff definition identifies 12 census tracts as food deserts, while the Montreal food desert definition identifies 5. In the case of each food desert definition, residents of food deserts have worse than average food access by one or more measures and higher than average poverty (as might be expected), and worse than average access to an automobile. None of the food desert definitions, however, identify above average concentrations of the elderly population.

While the characteristics of food deserts identified by different methods are not dissimilar, we are interested in whether there is spatial congruence across methods. Figure 2 displays a map of the study area showing the fifteen census tracts which are identified as food deserts by one or more

Table 3. Coverage of Food Deserts (Census Tracts) in Portland Metro Area (Percentage, Population Weighted)

Food Desert Definition	*N*	Total	Below Poverty Line	Age 65 and Older	Without Car in Household
All Tracts	243	100	100	100	100
Type I: Edmonton	5	1.4	2.8	1.5	3.0
Type II: Cardiff	12	3.3	9.0	2.3	7.2
Type III: Montreal	5	1.8	4.4	1.1	2.6
Type I, II, or III	15	5.1	12.1	3.7	8.9

methods; shading indicates whether tracts are identified as a food desert by one, two or all three definitions. Of the fifteen tracts identified, only one is considered a food desert by all three methods, five are identified by two out of three methods, and the remaining nine are designated as food deserts by only one method. Thus, there is some concurrence across methods, but it is not complete. As seen in Figure 2, food deserts are found to be located in six distinct portions of the study area; four of these areas contain census tracts identified as food deserts by at least 2 definitions (although in some locations, tracts identified by different definitions are adjacent instead of being identical). The most consistently identified food desert tracts are in a cluster in a low-income inner-city area of northeast Portland. The remaining food desert locations consist of only one or two census tracts, and all are located in outlying corners of the city of Portland itself or in suburbs. We conclude that the three different approaches to defining food deserts yield somewhat similar, but by no means identical, pictures of food deserts in Portland.

Coverage: Food Deserts and Food Hinterlands

Aside from the question of congruence across food desert definitions, we are also interested in the question of coverage—the extent to which any food desert definition reflects food access concerns across the entire poor or socioeconomically vulnerable population of an area. In Table 3, we show the share of the area's poor population, elderly population, or population without household access to an automobile, that live in food deserts according to each of the three food desert definitions employed. In most cases, the definitions used here account for only a small share (1 to 5 percent) of these populations; only with the second definition of food deserts is a larger share of any of these groups accounted for (9 percent of the poverty population and 7.2 percent of the population without an automobile). Even when the union of all three methods is considered, food deserts account for only 12.1 percent of the entire area poor population, 3.7 percent of the elderly population, and 8.9 percent of all those without access to an automobile.

These findings raise the question of what level of food access is experienced by the remaining 85 to 95 percent of the poor, elderly, or those without cars who reside *outside* designated food deserts. To the extent that a metropolitan area has disadvantaged or socioeconomically vulnerable populations that are spatially dispersed and yet still lack adequate food access, they will not be identified as residents of food deserts. To answer this question, we examine areas we define to be food hinterlands—portions of the metropolitan area that lack adequate access to supermarkets (according to the standards set out in food desert definitions), but are not considered food deserts because they lack concentrated socioeconomic vulnerability.

In identifying food hinterlands, food access standards can be borrowed from either the Edmonton or the Cardiff definition of food deserts. Of the two, the Cardiff standard identifies a broader swathe of 129 census tracts that lack adequate food access but are nevertheless not considered food deserts. These tracts include all 55 census tracts identified by the Edmonton standard (based on M1). The food hinterlands identified by one or both definitions are shown in Figure 3. As can be seen on the map, they are likely to lie in the less densely populated outlying areas of the city and suburban areas.

Characteristics of food hinterlands according to either definition are shown in Table 4. Census tracts identified as hinterlands account for approximately one-third or two-thirds of the land area of metropolitan area, and 22 or 58 percent of the overall population, respectively. The population in these areas is representative of the population of the entire region along the lines of poverty rate, percentage elderly, and percentage without an automobile. In this regard, these areas appear to be unremarkable. However, average food access levels in these hinterlands are substantially below the area average on all three food access measures (M1, M2, and M3). And, depending on which food access threshold is employed, these hinterlands are home to either 16.6 or 47.3 percent of the area's poor population, 22.4 or 56 percent of the elderly population, and 11.6 or 35.6 percent of those without automobile access. Comparing these figures with the population shares covered by the corresponding food desert definitions indicates that between 5 and 6 times as many poor persons live in food hinterlands than in food deserts. When we make the same comparison for the elderly population and for those without access to automobiles, we find almost 15 to 25 times as many elderly in food hinterlands than in food deserts, and approximately 4 to 5 times as many individuals without access to cars. Thus, in terms of the shear number of persons vulnerable to either socioeconomic deprivation or lack of

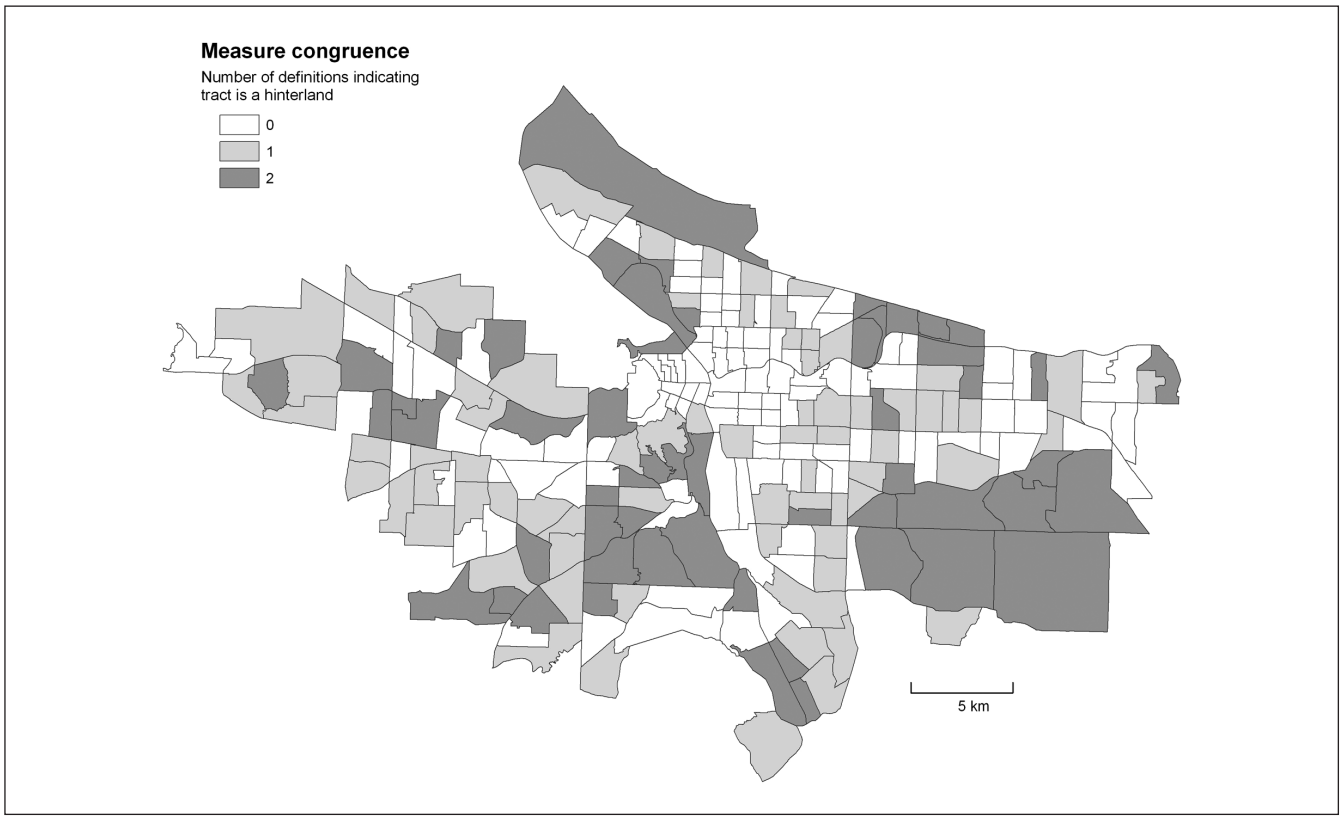

Figure 3. Congruence of food hinterland definitions for Portland, Oregon, study area

access to transportation that may lack adequate food access, food hinterlands may account for a much larger food access problem than areas specifically defined as food deserts, regardless of the food desert definition employed.

Food Desert Coverage Comparisons

The reproduction of food desert definitions from other studies allows for comparisons of food desert coverage among Portland, Montreal, and Edmonton; such comparisons are absent from the literature to date.[13] However, because no other study has explicitly examined the food hinterlands, we cannot directly compare coverage in low-access areas outside of designated food deserts. Smoyer-Tomic, Spence, and Amrhein (2006) report for the city of Edmonton (population 647,000, land area of 663 square kilometers) on six neighborhoods that meet the Edmonton food desert criteria; these neighborhoods are home to 2.9 percent of the city's population, 1 percent of the cities' low-income population,[14] and 0.5 percent each of the elderly population and the population without access to an automobile. Applying the same definition to the Portland area yields 5 census-tract food deserts, with 1.4 percent of the area population, 2.8 percent of the poor population, 1.5 percent of the elderly population, and 3 percent of those without cars. While the food desert coverage does not correspond precisely across the two areas/cities, taking into account that the Edmonton study reports on the city only while the Portland figures encompass the entire metropolitan area, one might conclude that presence of food deserts in the two places is of roughly the same magnitude. In contrast, the food deserts identified in Montreal are far more extensive than those identified in Portland using comparable methods. Apparicio, Cloutier, and Shearmur (2007) report on the island of Montreal (population 1.8 million, land area of 365.1 square kilometers); they identify 82 census tracts that constitute food deserts and are home to 17 percent of the city's population and 27.5 percent of the low-income population. Applying the same methods to the Portland area, we identify only 5 census tracts as food deserts with 1.8 percent of the area's population and 4.4 percent of the poor population. The fact that Montreal has a greater share of its population living in food deserts but also exhibits higher levels of food access (discussed above) is likely a function of higher population densities and more highly concentrated poverty there.

Sensitivity Analysis

In our analysis thus far, we have replicated (as closely as possible) the methodologies used in the Edmonton, Cardiff, and Montreal food desert studies. One question is whether

Table 4. Characteristics and Coverage of Food Hinterlands (Census Tracts) in Portland Study Area (Population Weighted)

Food Hinterland Definition	*N*	Mean Food Access Measure			Percentage of Study Area Land	Percentage of Population			Percentage of Metro Area Population			
		M1 (Meters)	M2 (Stores)	M3 (Meters)		Below Poverty Line	Age 65 and Older	Without Car in Household	Total	Below Poverty Line	Age 65 and Older	Without Car in Household
All Tracts	243	1,058	0.52	1,641	100.0	10.6	10.6	9.4	100.0	100.0	100.0	100.0
Type I: Edmonton	55	1,665	0.09	2,237	35.6	7.9	10.8	5.4	22.1	16.6	22.4	11.6
Type II: Cardiff	129	1,298	0.21	1,900	68.7	8.6	10.3	6.4	58.0	47.3	56.0	35.6

our findings are sensitive to possible variants in the food desert definitions employed, or to methods used to construct them. To examine this, we look at several methodological variations—we consider the effect of constructing food desert definitions from census block group–level data instead of census tract–level data, and we consider a range of alternate thresholds for the levels of social deprivation and food access that define food deserts. We then evaluate whether these changes influence our findings regarding the congruence of food desert definitions and the coverage of food hinterlands.

North American food desert studies have largely relied on census tract–level data, while U.K. studies have relied on postal codes. These are relatively large spatial definitions of neighborhoods: the U.S. Census Bureau identifies the optimal census tract size to be a population of 4,000, while an optimal census block group population is 1,500 (U.S. Census Bureau 2009). To examine whether our findings depend on the definition of neighborhood employed, we replicate our analysis using census block group–level data for all inputs (full replication results available from the authors). Under both the first and second food desert definitions (based on Edmonton and Cardiff), the use of block group–level data identifies food deserts in a somewhat altered set of block groups than identified in the census tract analysis. For instance, under the tract-based definition of food deserts based on Cardiff, the 12 census tracts identified as food deserts contain 29 block groups. Seventeen of these original 29 block groups are identified as food deserts when the analysis is conducted at the block group level, as are another 14 block groups that were not tagged in the census tract–level analysis. These additional 14 block groups are typically adjacent to or nearby previously identified food deserts, however. Under both the first and second food desert definitions, the land area and population covered by food deserts and their characteristics are virtually the same, whether food deserts are defined at the block group or census tract level. Furthermore, the correspondence between the first and second food desert definition is still approximately the same. As before, the two definitions identify overlapping but not identical areas as food deserts. Thus, the food desert picture at the block group level is a minor adjustment of the picture painted at the census tract level, not a major overhaul. The same is also true of the food hinterlands associated with each of these two definitions. While the exact block group composition of hinterlands changes some, their characteristics and general coverage do not. And regardless of the level of analysis, an equivalent share of the area's poor and disadvantaged live in food hinterlands by both definitions.

The substitution of block group data for census tract data has a somewhat different effect when considering the food desert definition based on cluster analysis along the lines of the Montreal study (Apparicio, Cloutier, and Shearmur 2007). As when census tract data are employed, the cluster analysis of block group data yields a distinct "food desert" cluster—areas that exhibit both the lowest levels of food access and the highest levels of social deprivation. The coverage of the food desert cluster is considerably different, however, when block group data are used. While tract-level cluster analysis identified 5 census tracts containing 14 block groups as food deserts, the block group–level analysis identified 84 block groups. The mean characteristics of block group–level food deserts are considerably different from census tract–level food deserts—those identified at the block group level have worse food access but are wealthier and less likely to have households without automobile access. While a mapping shows these block group food deserts in areas that are also identified as food deserts by other definitions, it also shows food deserts in outlying portions of the metropolitan area not previously identified as such. Thus, we conclude that food desert definitions based on cluster analysis approaches may not be robust to changes in scale; at a minimum, the question deserves further investigation.

A second check on sensitivity involves altering the thresholds for social deprivation used to identify food deserts. We reconstruct our definitions of food deserts with the thresholds for the social deprivation measures alternately set at the 90th, 80th, and 65th percentile. As expected, as the threshold is raised, the number of census tracts identified as food deserts decreases and the characteristics of food deserts change accordingly, but these changes are again relatively minor.

For example, raising the threshold on all three deprivation measures from the 75th to the 90th percentile for the first food desert definition decreases the number of census tracts identified as food deserts from five to three. The corresponding definition of food hinterlands increases accordingly (from 55 to 57 census tracts) and the correspondence between the first two food desert definitions remains roughly the same regardless of the threshold level used.

A third question involves the sensitivity of food desert and food hinterland coverage to the threshold set for adequate food access. While increasing or decreasing these thresholds leads to a corresponding decrease or increase in the number of areas identified as a food desert, these changes are not large. According to our second definition of food deserts, applying the original threshold of 50 percent identifies 12 census tracts as food deserts; when that threshold is raised to 75 percent or lowered to 25 percent, the number identified rises to 15 or drops to 8. However, in each case, because the same standards of social deprivation are being applied, the characteristics of tracts designated as food deserts remain largely unchanged.

Changes in the threshold set for adequate food access do have considerable impact on the coverage of food hinterlands, however. Because food hinterlands are identified as neighborhoods that do *not* meet the social deprivation standards of food deserts but *do* meet the low food access standard of food deserts, any change in what constitutes inadequate food access will be directly reflected in the food hinterland designation. For example, under the second food desert definition when the threshold for one kilometer grocery store access is altered from 25 to 50 and then to 75 percent of the neighborhood population, the corresponding number of census tracts designated as food hinterlands rises from 82 to 129 and to 152. While the mean characteristics of these food hinterlands are virtually unchanged, their coverage—shares of land area, population, or poor, elderly, or population lacking auto access—shifts with the number of census tracts.

Finally, we ask whether we would continue to identify food hinterlands under a wide range of methodological variants. To this end, we reestimate the coverage of food deserts and hinterlands using block group–level data, applying a full range of thresholds for both food access and social deprivation in the context of either an Edmonton- or Cardiff-style definition of food deserts. While the relative coverage of food deserts and hinterlands shifts with the combination of thresholds applied, when social deprivation thresholds are low, food hinterlands are still home to 30 to 100 percent more of the area's poor population than are food deserts, depending on which food access threshold is applied. In contrast, when social deprivation thresholds are high, the share of the poor population living in food hinterlands is five- to eightfold greater than that living in food deserts, again depending on the food access threshold applied. Thus, we conclude that while the relative coverage of food deserts and hinterlands varies with the methodological approach, the concept of food hinterlands is robust to methodological variation, as is the fact that food hinterlands are consistently home to a greater share of the area's poor population experiencing low food access than are food deserts.

Conclusion

Interest among researchers and policy makers in the relationship between food environment and health outcomes has emerged in recent decades. In response, researchers have pursued a number of agendas directed at understanding this relationship. One such agenda has focused on the concept of the food desert—socioeconomically disadvantaged urban neighborhoods that lack easy access to retail outlets selling healthy and competitively priced food. The examination of food deserts is based on the concern that such environments may alter the range of choices facing disadvantaged populations, potentially leading to poor health, social, and economic outcomes. This literature to date is incomplete, however, in that it is characterized by lack of a common definition of food deserts, and thus there is no basis for knowing whether results across studies are comparable. Furthermore, the focus on food deserts has come at a cost: the failure to consider other urban or suburban locations that may also lack adequate access to food shopping for low-income populations.

In this article, we have addressed these two issues. When we apply the three commonly used definitions of food deserts (involving both relative and absolute standards for food access) to the Portland metropolitan area we find that there is a degree of congruence between food deserts identified by each definition, but that there is also considerable divergence. Depending on the definition adopted, the share of the land area or population accounted for by food deserts can double, and the share of the poor population accounted for can triple. This suggests that food desert studies to date, which have applied various definitions and have each focused on an individual metropolitan area, in fact cannot be readily compared. Future research along these lines would benefit from the adoption of a single food desert definition. To some extent, *which* food desert definition is used may be less important than the adoption of a single standard. However, among the three definitions examined in this article, the Cardiff definition may be preferable as it avoids problems associated with the other two. The Montreal definition suffers from aggregation bias—the definition yields substantially different results when census blocks are used as the geographic unit of analysis instead of census tracts. The Edmonton measure is a relative measure that will always identify some neighborhoods as food deserts regardless of the distribution of food access and social disadvantage.

Our adoption of multiple definitions of food deserts allows us to make the first cross-study comparison of food deserts. Comparing like definitions of food deserts for Portland and Edmonton, we find very similar results. Food deserts in both places account for only a fraction of the overall population as well as of various vulnerable populations. When we compare Portland with Montreal, however, we find a different story; food deserts are home to a significant share of the overall population and the low-income population in Montreal but not in Portland.

In cases where practitioners and researchers are interested in identifying specific neighborhoods as food deserts within a single metropolitan area (for planning or policy purposes, for instance), the most robust approach, generating the most accurate picture of local food deserts, would be to use multiple food desert definitions combined with sensitivity checks. In most cases, the goal will be to minimize false negatives—the failure to identify a neighborhood as a food desert that truly is one. Researchers can accomplish this by focusing on the union of food deserts identified by the three methods examined here.

The second focus of this article is to ask whether or not the food desert concept, or one or more versions of it, captures a significant share of the low food access that might be experienced by disadvantaged populations across the entire metropolitan area. For the Portland area, we find that no food desert definition, or even the union of all definitions, provides this coverage. The union of food deserts identified here by three different methods identifies neighborhoods that are home to 12.1 percent of the poor population, while up to 58 percent of the poor population resides in what might be construed to be food hinterlands—urban areas with low food access that would not be identified as food deserts because they lack concentrated socioeconomic deprivation. Our paper is the first to explicitly examine this concept. Future studies of food deserts should not ignore the plight of the social disadvantaged who have poor access to food but who reside in the outlying food hinterlands—away from the food deserts that are typically located in more central areas. Our research shows that the great majority of low-income households with poor access live in the food hinterlands and not in the food deserts and, because of the suburbanization of poverty, the food hinterlands may be increasing in importance relative to food deserts.

We subject our analyses to a number of sensitivity checks, including substituting block group–level analysis for census tract–level analysis and altering the thresholds for determining social deprivation and food access. For the first two food desert definitions (based on the Edmonton and Cardiff studies), the correspondence between food desert definitions and the coverage of the associated food hinterlands is little changed by any methodological variant. Of course, changes in the thresholds for food access do change the areas identified as food deserts or food hinterlands and the relative coverage of the two types of areas. Nevertheless, we find that the concept of food hinterlands holds up to considerable methodological variation and that hinterlands continue to identify a nontrivial share of the poor population even when threshold levels are stringent enough to substantially shrink food deserts. The third method of identifying food deserts (based on the Montreal study) is sensitive to changes in the level of aggregation, however. In this case, block group–level cluster analysis yields a considerably different picture of food deserts than when analysis is conducted at the census tract level.

Food deserts and food hinterlands may have distinctly different implications for policy and planning practice. Urban areas of concentrated poverty tend to have high population densities and to be relatively centrally located. Thus, food deserts tend to be relatively compact, densely populated areas that lend themselves to place-based solutions. Planners tackling this challenge have worked on, among other things, zoning, parking solutions, traffic patterns, and the accumulation of land parcels and access to redevelopment funds to promote the installation of grocery stores. In addition, grassroots efforts to promote the provision of culturally appropriate food and/or fresh produce in existing retail establishments, community gardens and the development of neighborhood farmer's markets and food stands have also been established in an effort to bring improved food selection into the food desert (e.g., Bolen and Hecht 2003; Glanz and Yaroch 2004; Winne 2004; Community Food Security Coalition 2007). In contrast, food hinterlands are more likely to be dispersed locations with lower population densities. As such, the effectiveness of place-based solutions in the hinterland may be relatively limited compared with the same approach in a food desert. Instead, transportation-based solutions may be important, either taken alone or coordinated with dispersed place-based approaches. As Pothukuchi and Kaufman noted (1999), food systems are inextricably linked to other community systems, including housing, transport, land use, and economic development. While full-scale public transportation may not be a viable option in low-density areas, small-scale alternatives may be appropriate. This might include public or nonprofit provision of food shopping van services for low-income, elderly, or disabled populations, mobile markets or produce delivery by Community Supported Agriculture farms (e.g., Bolen and Hecht 2003; Winne 2004). In addition, planners might work toward the colocation of dispersed, flexible retailing such as farmer's markets with existing employment or transit nodes.

Of course, our conclusions regarding food desert and food hinterland coverage are inherently limited to the Portland experience and might only be suggestive of a broader relationship between food deserts and food hinterlands. Modern-day food access in urban areas is clearly a result of a myriad of political, economic, and financial institutions, decisions and forces that have influenced patterns of urban development,

including the disinvestment in central city grocery stores (e.g., Pothukuchi 2005). These complex forces no doubt generate outcomes that can be unique to a given urban area. Furthermore, spatially concentrated disadvantage has been a key component of food desert definitions from their inception. If poverty and associated disadvantage are more or less spatially concentrated in different regions as a result of historical and regional patterns of urban development, then the relative coverage of food desert and food hinterland concepts will vary accordingly. Are younger, less compact North American cities that developed after the advent of the automobile more likely to be home to sprawling and suburbanized food hinterlands, while older cities are home to more spatially concentrated poverty and food deserts? A rough comparison of food desert patterns in Portland with those in Edmonton and Montreal would suggest so. Furthermore, in the U.S. concentrated urban poverty declined between 1990 and 2000, especially in older (midwestern and northeastern) central cities, and spatially dispersed suburban poverty is on the rise (Jargowsky 2003; Kingsley and Petit 2003). This suggests that the importance of food deserts per se may be on the decline, while the role of food hinterlands may be increasing. Future research should include a more systematic examination across metropolitan areas of these relationships between food deserts and hinterlands, patterns of spatially concentrated or dispersed poverty, and patterns of grocery retail development. The result is likely to be broadly informative for policies to improve food access for disadvantaged populations both in and beyond the food desert, thereby providing greater prospects for healthy choices with regard to food purchases.

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Notes

1. The term *food desert* was first put forth in social and health policy documents published by the U.K. government in the 1990s to describe areas of "relative exclusion where people experience physical and economic barriers to accessing healthy food" (Reisig and Hobbiss 2000, p. 138). See Wrigley (2002) for a discussion of the development of this concept in the British context.
2. Several other studies focusing on food access have also used census tracts as the unit of analysis, e.g., Baker et al. (2006), Berg and Murdoch (2008), Block, Scribner, and DeSalvo (2004), and Moore and Diez Roux (2006).
3. U.S. and Canadian census tracts average 4,000 persons; U.K. electoral divisions average 5,000 persons, while U.K. postcode sectors and enumeration districts are much smaller, averaging 450 persons.
4. This is a census block–level measure. We compute the Euclidian distance from each census block centroid to the nearest grocery store. If this distance is less than 1 kilometer, the census block is deemed to have a grocery store within walking distance. Our census tract–based measure is then a population-weighted mean aggregated from the individual census blocks located within each census tract.
5. We followed Apparicio, Cloutier, and Shearmur (2007) in constructing the index of social deprivation as the sum of five standardized variables (percentage recent immigrants, percentage single parents, percentage unemployed, percentage education at the ninth grade or less, and poverty rate).
6. We used the average linkage technique in SAS (version 9.2) to implement cluster analysis of the Portland data.
7. Clusters were considered to have relatively high social deprivation if the population-weighted mean deprivation index for that cluster was above the population-weighted mean deprivation index for the entire metropolitan area. Clusters were classified as having low access if two of the three access measures indicated below-average food access (measured by the population-weighted mean).
8. Smoyer-Tomic, Spence, and Amrhein (2006) conduct their analysis at the city neighborhood level for Edmonton's 212 neighborhoods. With an average neighborhood population of 3,445, Edmonton neighborhoods are approximately equivalent in size to U.S. and Canadian census tracts, which average population of 4,000.
9. A related question concerns the relative accuracy of access measures based on more or less disaggregated inputs. Sparks, Bania, and Leete (2011) conclude that the aggregation of inputs has little effect on the relative conclusions drawn from food access data. Others reach the same conclusion for non-food-access measures (e.g., Hewko, Smoyer-Tomic, and Hodgson 2002; Apparicio et al. 2008).
10. Oregon's 1973 urban growth boundary legislation creates a statewide framework for land-use planning requiring each city or metropolitan area to have an urban growth boundary controlling development and separating urban land from rural.
11. Tracts that contain census blocks lying outside the UGB were excluded.
12. Sparks, Bania, and Leete (2011) show that Euclidean distances generate the same relative pattern of food access as do network distances. Euclidean distances are used here because of the more manageable computations involved.
13. Guy and David (2004) do not report food desert characteristics for Cardiff; thus, no comparison with Cardiff can be made.
14. Canadian studies apply a pretax low-income standard as defined by Statistics Canada, which is roughly comparable to the U.S. poverty line standard.

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