Scale and Nutritional Terrain

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1. Metrics of Food Access

Rates of obesity have risen to alarming levels in the United States. As epidemiologists and public health officials continue to investigate the causes of overweight and obesity in the USA, an increasing number of researchers are devoting more attention to the role of spatial and environmental contexts in food consumption patterns (Shaw 2006; Beaulac et al. 2009). At the core of these investigations is the idea of how an individual's food environment can influence his or her diet. Furthermore, within a single urban area there may be substantial geographic variation in access to healthy food choices. In general, economically disadvantaged and minority-dominated neighborhoods in the USA, have lower than average access to large retailers, including supermarkets, and thus generally experience higher prices for narrower selections of food items (Inagami et al. 2006). Second, these physical and economic constraints affect dietary choices, such that diet-related health problems tend to be higher in economically disadvantaged and minority-dominated neighborhoods (Laraia et al. 2004; Andreyeva et al. 2008).

While these recent investigations represent important advance in public health, many of these studies are geographically simplistic, and, as a result, may produce misleading results. In this work we argue that public health-oriented researchers must give greater attention to the influence of spatial scale on accessibility metrics in their investigations. Spatial access metrics are intended to identify the spatial relationship between a source of demand, which could be a geographic area or a specific population, and a source of supply, such as one or more facilities. A range of spatial access metrics have been proposed and implemented. These have been classified into five distinct categories, with potentially quite different objectives and results (Talen, 2003). *Container methods* measure the number of facilities (e.g., food retail locations) contained within a spatial unit. This unit might be a predefined areal unit such as a municipality or a census tract. Conversely, one might establish spatial units defined by the facilities themselves, such as the ten-minute walkshed around each facility, and count the total population falling within these units. *Coverage methods* identify the number of facilities within a given distance of a point of origin. One might identify the number of food retailers within 1 km of a particular location, or alternatively calculate this value for points in a dense regular mesh across a metropolitan region. *Minimum distance methods* calculate the minimum distance between a point of origin and the closest facility. *Travel cost methods* are concerned with identifying the total distance between a point of origin and all facilities. *Gravity weighted methods* employ an index calculating the (weighted) sum of all facilities to a point of origin, weighted by distance. For example, an index could be generated measuring general produce variety for a specific location by summing the number of produce items available at each store divided by the distance to that store.

2. Scale and Produce Access

This study is concerned with the manner in which demand is specified and modeled – in this case, demand is the residential population in the region of interest. Typically, research on nutritional terrain employs aggregate, neighborhood level data (Morland and Filomena 2007). The use of areal units to aggregate individual-level data is widespread in the social sciences, though these units pose difficulties for the measurement of variables and the association and modeling of groups of those variables due to the modifiable area unit problem (MAUP). Access-based research, which frequently relies upon aggregated data, may be quite prone to MAUP-effects. For example, in a study of access to health care, Langford and Higgs (2005) identified lower estimates of acessibility using dasymetric population mapping.

We have a 2008 survey of 94 food retailers in metropolitan Lansing, Michigan, USA selling fresh produce (vegetables and fruits). Locations and produce availability (for nearly 477 types of produce) were verified by site visits by one of the authors and a colleague. The subsequent dataset is relatively complete and accurate, making it especially suitable for this study.

We employ 2008 US Census block group population estimates to develop initial measures of access to fresh produce. Figure 1 is a map demonstrating just one metric for the approach.

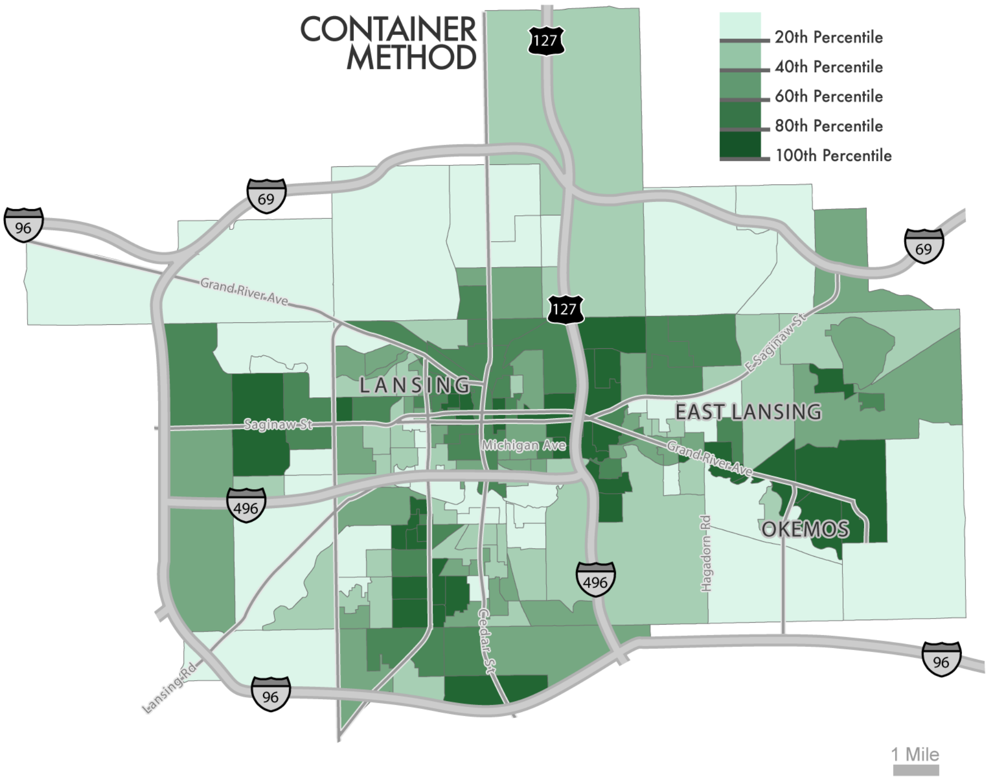

Figure 1. Access to fresh produce in Lansing, Michigan, USA.

In this figure, darker colors indicate block groups with greater access to fresh produce. Light-colored areas might be indicative of "food deserts" with poorer geographic access, especially for households without automobiles. However, the aggregation of both stores and populations into block groups limits subsequent interpretation, and presents a misleading picture of individual household access to fresh produce.

3. Dasymetric Mapping and Analysis

A more sophisticated approach relies upon much finer-scale estimation of the distribution of households across the Lansing metropolitan area. Dasymetric mapping, employs secondary data about land cover and other factors to interpolate population data to a finer resolution (Mennis 2003, Eicher and Brewer 2001). In this study, we employ a basic dasymetric mapping model with census block populations and 30m resolution land cover data which includes high, medium, and low-intensity developed land cover classes to apportion the population to fine raster cells. We follow a similar approach to that used by Mennis (2003), assigning 70% of the population of each census block to high-intensity developed cells, 20% to medium-intensity developed cells, and 10% to low-intensity developed cells. The population of a cell can be estimated by the following equation, modified from Holloway et al. (1997):

$$P_C = (R_A \times N * P_A) / (E \times A_T) \quad (1)$$

where P_C is the modeled population of a cell C, R_A is the relative population density of cell C with land cover type A, N is the actual population of the enumeration unit covering C, P_A is the proportion of cells with land cover type A in the enumeration unit, E is the expected population of the enumeration unit calculated using the relative densities, and A_T is the total area of all inhabitable cells in the enumeration unit.

We then develop access metrics for this modeled population distribution to facilities with fresh produce. We will compare the aggregated block-group-derived access metrics with the dasymetric model-derived access metrics to show how the aggregation of demand into enumeration districts manifests itself for metropolitan-scale studies of food access. The cumulative distance distribution of these access metrics will be directly and quantitatively compared, while maps of the metrics will indicate fundamental differences in spatial variability of access.

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