Quantifying access to local food

An independent study by
Alex Linthicum
Urban and Environmental Planning
University of Virginia

Independent study advisor
Timothy Beatley
Urban and Environmental Planning
University of Virginia

Fall Semester, 2007

Introduction

Interest in local food systems is growing in popular culture (Pollan, 2006a; Kingsolver, 2007; Mackinnon & Smith, 2007); however, the definition of *local food* is imprecise (Anderson & Cook, 1999; Jones et al., 2004; Kingsolver, 2007). This study investigates the definition of local food and attempts to improve upon current practices of quantifying access to local food, specifically those that drawing a 100 mile circle around an origin. To address local food from a perspective of transportation and accessibility, this study reviews the literature concerning local food and quantitative accessibility measures. It conducts a case study of the Thomas Jefferson Planning District Commission and analyzes the results. It discusses the approaches followed during the case study and suggests improvements. Finally this study offers several recommendations for future work and provides conclusions.

Literature Review

The literature review is in two parts. The first part briefly discusses the rationale for strengthening local food systems. Current issues with conventional food systems, including food safety, food security, and land use are introduced. Definitions of local food are discussed. The second part examines several measures of accessibility. Quantitative methods for assessing accessibility are reviewed. Both parts provide guidance and focus for the case study that follows.

Local food systems

The APA Policy Guide on Community and Regional Food Planning (2007) summarizes several issues related to the largely industrialized food system in the U.S. These include loss of farmland, aging of farmers, globalization of the food system, rural decline, obesity, energy consumption, water issues, concentrated animal feeding operations (CAFOs), loss of biodiversity, food system wastes, and hunger and food insecurity. These issues and others are covered at length in the literature (Kingsolver, 2007; Pollen, 2006a; Smith and Mackinnon, 2007; Robbins, 2001; and Nabhan, 2002).

One noticeable trend is greater concentration of ownership in all parts of the food industry. Hendrickson et al. (2001) report that in 2000, the top five food retailers accounted for 43 percent of sales, up from 24 percent in 1997. Today 80 percent of America's beef is slaughtered by four companies, 75 percent of the precut salads are processed by two and 30 percent of the milk by just one company (Pollan, 2006b). Vertical integration has led to consolidation of food production, processing, and distribution under the control of single entities.

Such consolidation heightens concerns for both food safety and security. With respect to safety, recent food recalls highlight the vulnerability of a highly consolidated food system. Natural Selection Foods, widely known for its Earthbound Farm brand, recalled all its fresh spinach products in September 2006. The processing facility in question washes 26 million servings of salad every week (Pollan, 2006b). Recent voluntary recalls of beef from American Food Groups of 96,000 lbs in November 2007 and from Topps of 22 million lbs in summer 2007 further demonstrate the vulnerability of a consolidated food system ("Health Highlights: Nov. 25, 2007", 2007). The Centers for Disease Control and Prevention estimates our food supply sickens 76 million Americans every year, putting more than 300,000 in the hospital and killing 5,000 (Pollan, 2006b).

With respect to food safety, when a top official retired from the Department of Health and Human Services in 2004, he was quoted as follows: "For the life of me, I cannot understand why the terrorists have not attacked our food supply, because it is so easy to do." A 2003 G.A.O. report to Congress on bioterrorism remarked "The high concentration of our livestock industry and the centralized nature of our food-processing industry" make them "vulnerable to terrorist attack." (Pollan, 2006b)

Food systems also have an interdependent relationship with land use. The APA Policy Guide on Community and Regional Food Planning (2007) recognizes that food system activities require a significant amount of land metropolitan areas, but development pressure is eroding capacity to produce food for local and regional markets. Vallianatos et al. (2004) assert farms are vulnerable to sprawl because the agricultural economy fails to provide small farmers with a sustainable livelihood. As a result thousands of farmers each year give up farming and sell their land, sometimes to developers. A 2002 study by the American Farmland Trust finds the U.S. is losing two acres of mostly prime farmland every minute to development, the fastest such decline in the country's history. While the nation's population grew 17 percent from 1982 to 1997, the amount of land turned into urban areas increased 47 percent. Keith Collins, the chief economist for the Agriculture Department, said that the loss of farmland has been a concern for years because it destroys open spaces and local food production (Becker, 2002).

Although local food systems are important, the definition of what is local is unclear. It appears to depends on whether the perspective is that of a community-based effort or an individual. Pothukuchi (2004) reviews nine community food assessments (CFA) which consider local food as food grown and consumed within a community. Pothukuchi notes the benefits of examining multiple geographic scales, including neighborhood, small area, city, or county boundaries, at which different community-food links or problems manifest. The APA Policy Guide on Community and Regional Food Planning (2007) is written from a communitywide perspective and does not define the term local. Instead it supports the creation of local and regional food planning mechanisms that integrate major local planning functions such as land use, economic development, transportation, environment, parks and recreation, public safety, health and human services, and agricultural preservation. This position suggests the APA defines local food as food within the bounds of a local or regional planning organization.

Community food security advocates are inconsistent regarding their definition of 'community' and are advised to devise goals, objectives, and measures for achieving community food security (Anderson & Cook, 1999).

The Slow Food Movement does not explicitly define local food, but does look to shorten the distance that food travels from production to consumption, both literally in terms of miles and figuratively in terms of relationships (Slow Food USA, 2007). Jones et al. (2004) investigate definitions, benefits, issues, and routes of local food from farmers to consumers in the UK. They identify several categories of definitions of local food, one of which is wholly subjective and is based on individual perception and emotions. In a similar vein, Kingsolver (2007) defines local food as the following:

> Local food is a handshake deal in a community gathering place. It involves farmers with names, who show up week after week. It means an open-door policy on the fields, where neighborhood buyers are welcome to come have a look, and pick their food from the vine. Local is farmers growing trust.

Joel Salitin is often described as one such trustworthy farmer (Pollen, 2006a; Petrilli, 2007). Salitin is a grass farmer and producer of organic pork, beef, chicken, and eggs, refuses to ship his products long distances. As of a year ago, customers could only obtain his meat from direct sales at his farm, farmer's markets, metropolitan buying clubs, a few small shops in Staunton, VA, and nearby restaurants (Pollen, 2006). Recently his farm began supplying pork to Chipotle and a variety of products to Whole Foods, both in Charlottesville (Petrilli, 2007).

Initiatives designed to inspire changes in individual consumption habits are often are more specific in their definitions of what is local, relying on calculation of 'food miles'. Various studies suggest the average food product consumed in the U.S. travels between 1200 and 1500 miles. Such long distance travel may have significant implications on energy usage, climate change, local and global economics, nutrition, food security, and labor rights. Pirog and Benjamin (2003) compare distance travel of local with conventional food items and find conventional pumpkins may travel eight times farther than local pumpkins, while conventional broccoli may travel up to 92 times farther than local broccoli. The authors suggest using food miles along with mode of distribution to provide consumers with a relative indicator of fuel used and CO^2 emissions during food transport.

In keeping with the notion of 'food miles', Alisa Smith and James MacKinnon started a movement called the '100-mile' diet to encourage people to start thinking about local seasonal food. The 100-mile radius was chosen because it is large enough to reach beyond a big city and small enough to feel truly local (100 Mile Diet, The, 2007). The movement's website has a website that maps consumers' 100-mile radii, noting that people should use it as a starting point to decide their own idea of 'local.'

'Locavore' organizations in San Francisco and Vermont organize 'eat local challenges' that encourage participants to eat food grown within 100 miles for a month (Locavores, 2007; Upper Valley Locavores, 2007). Beavan is currently experimenting with a lifestyle he calls 'No Impact'. The experiment aims to lessen the impact on the earth by reducing greenhouse emissions, consumptions and waste of goods, and eating local organic food, among other things. For the purposes of the experiment, Beavan defines local food as food that is grown and travels within 250 miles of New York City (Beavan, 2007). Nabhan (2002) also suggests a radius of 250 miles in the American Southwest. Tod Murphy, owner of The Farmers Diner in Vermont, who cooks only with local ingredients, defines local as 70 miles or an hour's drive (Kingsolver, 2007). Jones et al. (2004) assert the threshold identifying *local food* is inexact.

Given transportation of products from producers to consumers is enabling factor for both global and local food systems, there is surprisingly little mention of local food distribution in the transportation literature. Authoritative transportation research database TRISOnline returns only two entries related to "local food". One combines a cost evaluation with a demand analysis for different store categories in grocery retailing in Europe (Svensson, 2003). Another Canadian paper from 1975 briefly investigates local food production in the northern territories (Problems of the North, 1975). Similarly, popular academic search engine Google Scholar failed to return a single article with the words "local food" and "accessibility" in the title.

The lack of transportation literature regarding food is not unsurprising. The traditional emphasis on road building in the U.S. has been oriented toward *mobility* rather than *accessibility*. The aim of planning for mobility is to accommodate growing levels of travel and increase the potential for movement. Planning for mobility has allowed for the widespread production, consolidation, and transportation of goods, including food, without much concern for distance or location of origin or destination. Planning for accessibility considers the ends rather than the means (thus supporting the mantra that transportation is a derived demand) and focuses on the traveler rather than the system (Handy, 2002). This perspective broadens the range of possible strategies beyond road building to strategies that enhance accessibility to goods and services, such as local food, without necessarily increasing travel.

Accessibility

Accessibility is a measure of the spatial distribution of activities about a point, adjusted for the ability and desire of people to overcome spatial separation (Handy and Niemeier, 1997). Accessibility consists of two parts: a transportation element representing resistance or impedance, and an activity element representing motivation or attractiveness. Several efforts describe accessibility, review various accessibility measures, provide case studies, and present novel methods (Levinson & Krizek, 2005; Bhat et al., 2002; Handy & Neirmeier, 1997; Pirie, 1979).

Christaller's central place theory, first conceived in the 1930's, (1966) provides a philosophy supporting accessibility. Central place theory states that towns function as regional centers of commerce, and there are different orders of towns. Smaller order towns, or villages, may be larger in number but offer fewer specialized goods. Larger order towns, such as cities, are less in number but larger in size and offer more specialized goods. Each type of good will attract consumers by a distance determined by four factors: 1) the size and importance of the center and the spatial distribution of the surrounding population, 2) the price-willingness of purchasers, 3) subjective economic distance, and 4) quantity and price of the good at the central place. In general, central place theory suggests the willingness of people to travel from point A to B is directly proportional to both the number of opportunities available at a destination and the distance between the points. Distance and number of opportunities are elastic. This point is synonymous with the attractiveness component of accessibility.

Handy and Neirmeier (1997) and Bhat et al. (2002) describe four formulations of accessibility measures. *Cumulative opportunity* measures are generally the simplest and count the number of opportunities within a given travel time or distance. Examples of cumulative opportunity measures are found in the literature (O'sullivan et al., 2000; Sherman et al. 1974; and Wachs and Kumagai, 1973). Common criticisms of this measure is that there is no behavioral dimension, and near and far opportunities are treated equally (Voges and Naudé 1983).

Gravity measures are more complicated, building on the cumulative opportunity method by considering weight of opportunities and travel costs from the origin. Gravity measures devalues attractions based on their distance from the origin. Hansen (1959) is generally credited with first applying the gravity approach to transportation and land use planning. Examples of gravity measures are found in the literature (Yang & Ferreira, 2005; Ingram, 1971; Hansen, 1959). Criticisms include those of environmental justice two people in a zone may experience different levels accessibility (Handy and Niemeier 1997)

Utility measures the probability that an individual will make a particular choice depending on the utility of that choice relative to the utility of all choices. In other words, they are based on an individual's perceived desire or necessity for different travel choices. Bhat et al. (2002) develop an accessibility measure based on both the gravity and logsum utility methods.

Space-time measures add additional constraints to previous types of accessibility measures to account for capability (people have to sleep), coupling (people have time sensitive commitments), and authority (opportunities are available only at certain times of day) (Pirie, 1979). Hägerstrand (1970) devised space-time prisms and Lenntorp (1976) applied space-time prisms to particular activity programs and noted the approach was data intensive, useful only for small-scale applications. Lee & McNally (2002) explore space-time prisms using GIS. These measures are difficult to aggregate and thus difficult to interpret effects of large scale changes of transportation and land use (Voges and Naudé 1983). While person-based approaches such as that of the space-time approach are more realistic and detailed, they may be less practical than place-based methods due data availability and privacy concerns (Miller, 2005).

Choice among these measures and parameter decisions when using any one of these measures is dependent on evaluating trade-offs among three sets of issues: *specification*, *calibration*, and *interpretation* (Handy and Neirmeier, 1997).

Specification of requirements for an accessibility measure can be considered in four categories. *Disaggregation* is the most important factor. Disaggregation determines how the analysis is broken up among the population. For instance zonal or place-based studies geographically aggregate people together for the purpose of modeling. Besides geographical aggregation, it is possible to aggregate about socio-economic segments (Wachs and Kumagai, 1973) and trip purpose (Hanson & Schwab, 1987).

The second category of specification is that of selecting *origins and destinations*. Most approaches can accommodate home-based trips. The space-time method is particularly suited to explore multi-purpose trips and trip-chaining opportunities. Acquiring data for the latter is often more difficult than the former. Destinations may be aggregated by destination types such as workplace, grocery stores, or healthcare facilities (Handy and Niermeier, 1997).

The third category of specification is that of cost represented by distance or time (Handy and Neirmeier, 1997). Distance can be represented by straight-line distances, network models that simulate travel demand, or field surveys. Travel times are preferable to distance costs because they explicitly consider congestion. When travel times are used either peak or off-peak travel times must be considered.

The fourth category related to specification is that of representing attractiveness. Attractiveness may be considered as the diversity, quantity, or quality of opportunities of opportunities. Number of jobs is an example of an attractiveness specification.

Several studies have examined accessibility of populations to food. Donkin et al. (1999) use GIS to study access to food in an urban setting. The authors disaggregate by four major ethnic groups in the study area and identify populations with poor walking access to stores providing healthy food consistent with their traditional diets. Pothukuchi (2004) use GIS and notions of accessibility to document the number, density, and location of particular resources for several community food assessments. They examine the spatial relationships among food resources and populations in need, suggest locations for resources and programs and explore possible sales outlets for gardens in neighborhoods. Resulting maps of such efforts are effective tools for exploratory, community-organizing, or policy-advocacy purposes (Pothukuchi, 2004).

This literature review has examined the importance of local food systems and has found the definition of 'local food' to be inconsistent among definitions. It has found there are few mentions in the transportation literature about local food. It has investigated quantitative measures of accessibility and reviewed established accessibility measures. The remainder of this study investigates local food from a perspective of accessibility.

Methods for investigating accessibility

This study investigates accessibility to local food using several methods. First, it examines the technical definition of local food itself by comparing foodsheds defined by straight-line distances with those defined by network distances. Second, it explores accessibility to local food using the cumulative opportunities approach. Third, it explores accessibility to local food using the gravity model approach.

The cumulative opportunity and gravity approaches were chosen for several reasons. First, data were sufficient to explore accessibility to local food using these measures. Data were not available to provide examples of the utility or space-time measures. Second, the results of these methods are easily explained and suitable for use in community discussions. Third, the results are more easily generalized about the population (as opposed to person-based methods).

Specifications and assumptions of both approaches are as follows. Both models investigate home-based trips to farms. Trips are disaggregated by eight types of food described below. Trips are assumed to be using automobiles, either as farmers bring food to a central place, or as consumers travel to farms. The data does not consistently report points of sale other than the farms themselves, thus farmers markets, CSAs, and grocery stores selling local food are not explicitly considered.

The study area consists of the five counties and single independent city within the boundary of Thomas Jefferson Planning District Commission, a regional planning commission in central Virginia. A map of the study area is provided in Figure 1. Major transportation corridors in the study include Interstate 64 and US 29.

Figure 1 - Study area

Data for the cumulative opportunity and gravity model approaches were obtained from a joint effort conducted by the Piedmont Environmental Council and the University of Virginia's Institute for Environmental Negotiation. These organizations collected data about individual farms located within the boundaries of the Thomas Jefferson Planning District Commission (TJPDC), a regional planning commission in Virginia. Farms were identified by contacting the Virginia Farm Bureau and the Virginia Cooperative Extension, attending farmers markets, inquiring at grocery stores, and through word of mouth. Surveys were mailed to all farms identified and were followed with up to three phone calls. The dataset consists of those farms that returned surveys. This information is publicly available in the Charlottesville Area Buy Fresh Buy Local guide (http://www.buylocalcville.com/).

Straight-line vs. network distance

As explored in the literature review, local food is often defined using a travel distance such as 100 miles and represented as a circle of this radius drawn around a central point (100milediet, 2007). This may be misleading as people must use roads to travel to their destinations, and 100 miles of road travel is always shorter than a straight-line distance of 100 miles. An example is shown in Figure 2.

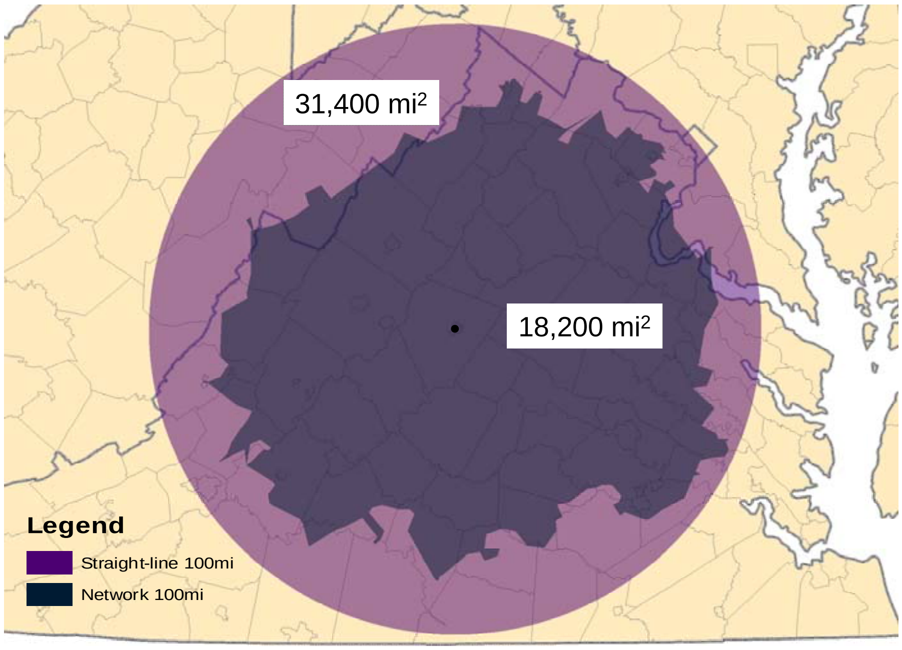


Figure 2 - Comparison of coverage areas defined by straight-line and network distances

In Figure 2, the light purple circle is a coverage area covering 31,400 square miles defined by a straight-line distance of 100 miles. The dark purple polygon is a coverage area covering 18,200 square miles using a network distance of 100 miles. The difference in coverage areas is 13,200 square miles, thus the straight-line method over-estimates the local foodshed by more than 70%.

Cumulative opportunities approach

The cumulative opportunities approach calculates an accessibility index for each block group using *isochrons*. An isochron is defined in the Meriam-Webster Dictionary as "an imaginary line or a line on a chart connecting points at which an event occurs simultaneously or which represents the same time or time difference." In other words, an isochron is a line connecting points which represent the same time or time difference, such as those points that represent a given network distance from an origin, in this case, the centroid of a census block. The cumulative opportunities approach counts the number of opportunities that fall within a the local, network-based distance surrounding each block group. A distance of 10 miles, rather than 100 was used, due to limitations in the data. Because the geographical scope of the farm data did not extend past the boundaries of the study area, and because the study area itself was only roughly 80 miles across at its widest point, local food is defined to be that within 10 miles of a census block group rather than 100 miles. The cumulative opportunity index was calculated for each block group, for each of eight types of food: cheese, eggs, fruit, herbs, meat, other (including flowers and honey), vegetables, and wine.

Due to the data limitation described above, the results, shown in Figure 2, should not be used to inform transportation or land use decisions in the study area. But the results can be analyzed to demonstrate concepts. Several block groups, particularly those in eastern Albemarle County which are shown to have very good access to local eggs, meat, fruit, and wine, good access to vegetables and herbs, and some access to cheese. Several block groups do not have any access for specific food types. Far western Louisa County and much of Fluvanna appear to suffer poor accessibility to several food types, though this is likely due to data limitations addressed in the discussion section. The maps can be superimposed on one another as shown in Figure 3 to show which block groups have the best overall accessibility to all the food types, and which block groups have little or no accessibility to local food. Block groups with good access may be good candidates for farmers markets. Block groups with poor access and high population may be good candidates for urban farms.

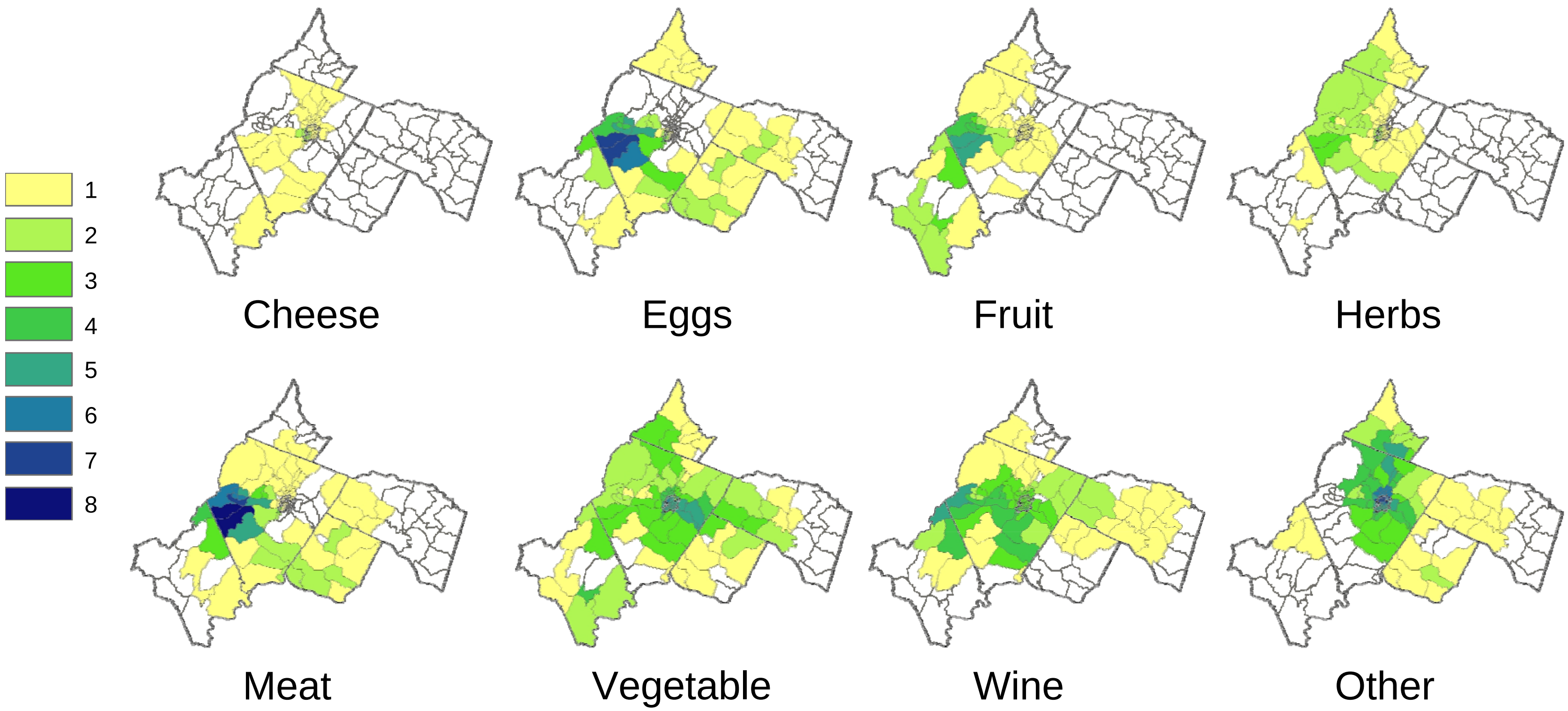


Figure 3 - Number of farms within 10 miles of census blocks using the cumulative opportunity method

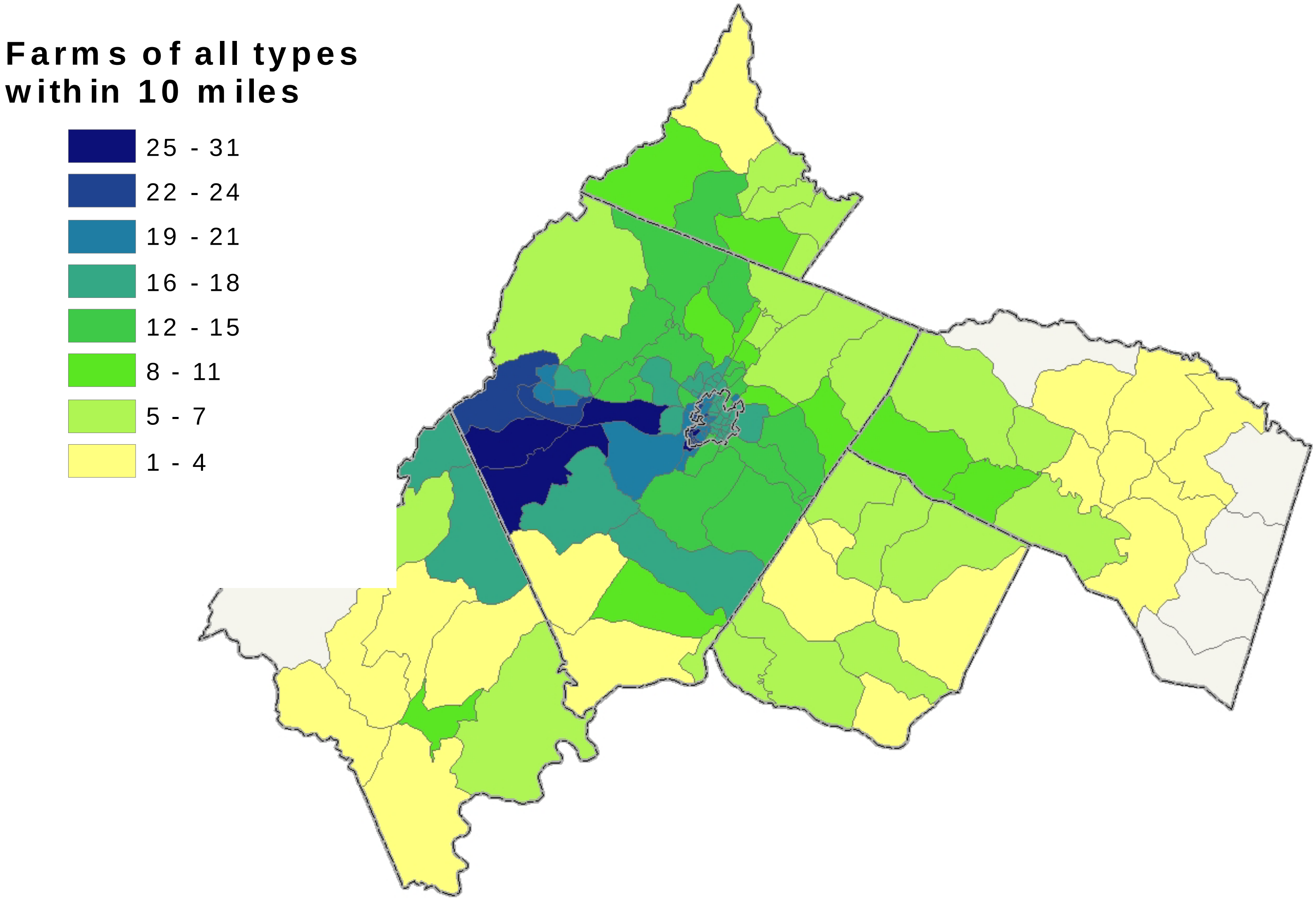

Farms of all types
within 10 miles
25 - 31
22 - 24
19 - 21
16 - 18
12 - 15
8 - 11
5 - 7
1 - 4

Figure 4 – Total number of farms of all farm types within 10 miles of census blocks using the cumulative opportunity method

Gravity model approach

The gravity model approach calculates an accessibility index value for each block group. The index value represents the number of local food producers within 'local' distance of a block group weighted by their distance from that block group, the population of the block group, and the amount of food produced at the farm. This effort calculated a separate index for each of the eight types of food defined in the previous section.

The following formulation of the gravity model was used to calculate accessibility from consumers to sources of local food. An example study area is shown in Figure 5.

$$A_i = \sum_j \frac{O_i D_j}{d_{ij}^{\lambda}}$$

where

A_i is the accessibility of place i

O_i is the number of people at place i

D_j is the amount of food produced at each place j

d is the cost of traveling between i and j (not to exceed a cutoff value)

λ is a friction factor representing willingness to travel

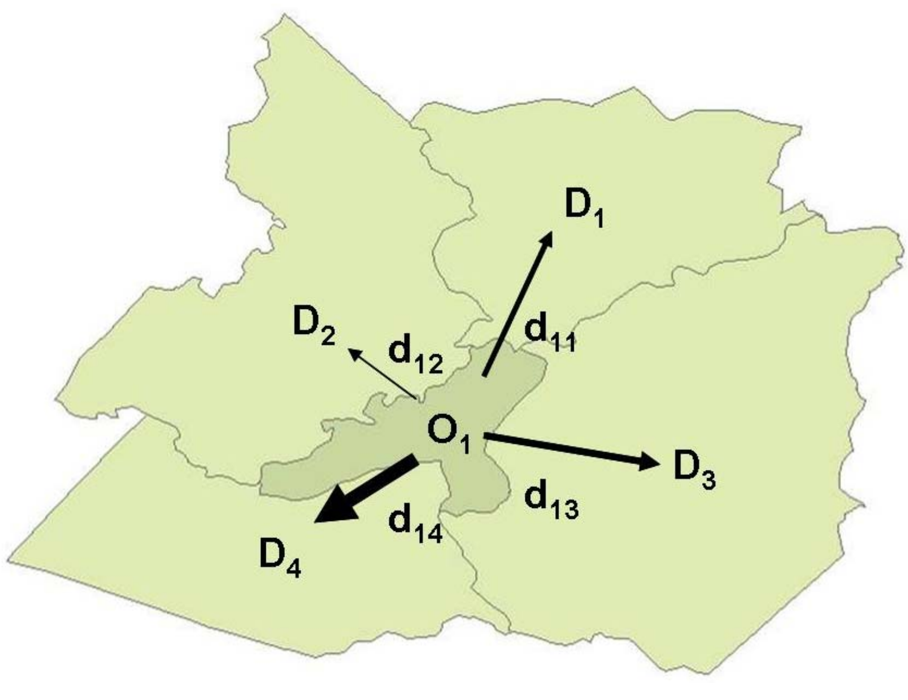


Figure 5 - Example geography for gravity model

The results of this example are not meant to inform decision makers in the Charlottesville-Albemarle Metropolitan Planning Organization. Due to limitations in the data, several assumptions were made. First, local food is defined to be within 10 miles of a census block group rather than 100 miles, as explained in the previous section. Second, because the farm data did not indicate amount produced at each farm, farms producing a given food product were assumed to produce the same amount of that product. These limitations are addressed further in the discussion section of the study.

Although the results of this example are not to be used for analysis, a sample analysis can be provided as if the results were legitimate. Figure 6 shows the accessibility of people within block groups to farms producing eight food products located within 10 miles by road. The individual maps demonstrate which block groups have relatively good access and which groups have no access (that meets the 10 miles by road condition).

The results of the cumulative opportunity method may be compared with those of the gravity method. From an implementation perspective, the cumulative opportunity measure is the simpler and less data intensive of the two. This is because the cumulative opportunity model is insensitive to variations in weights of origins and opportunities as well as insensitive to traveler behavior dictated by travel cost (time or distance), thus the gravity model provides more granularity in its depiction of accessibility as shown in Figure 7. These trade-offs and others must be considered when selecting an accessibility measure (Handy & Niermeier, 1997).

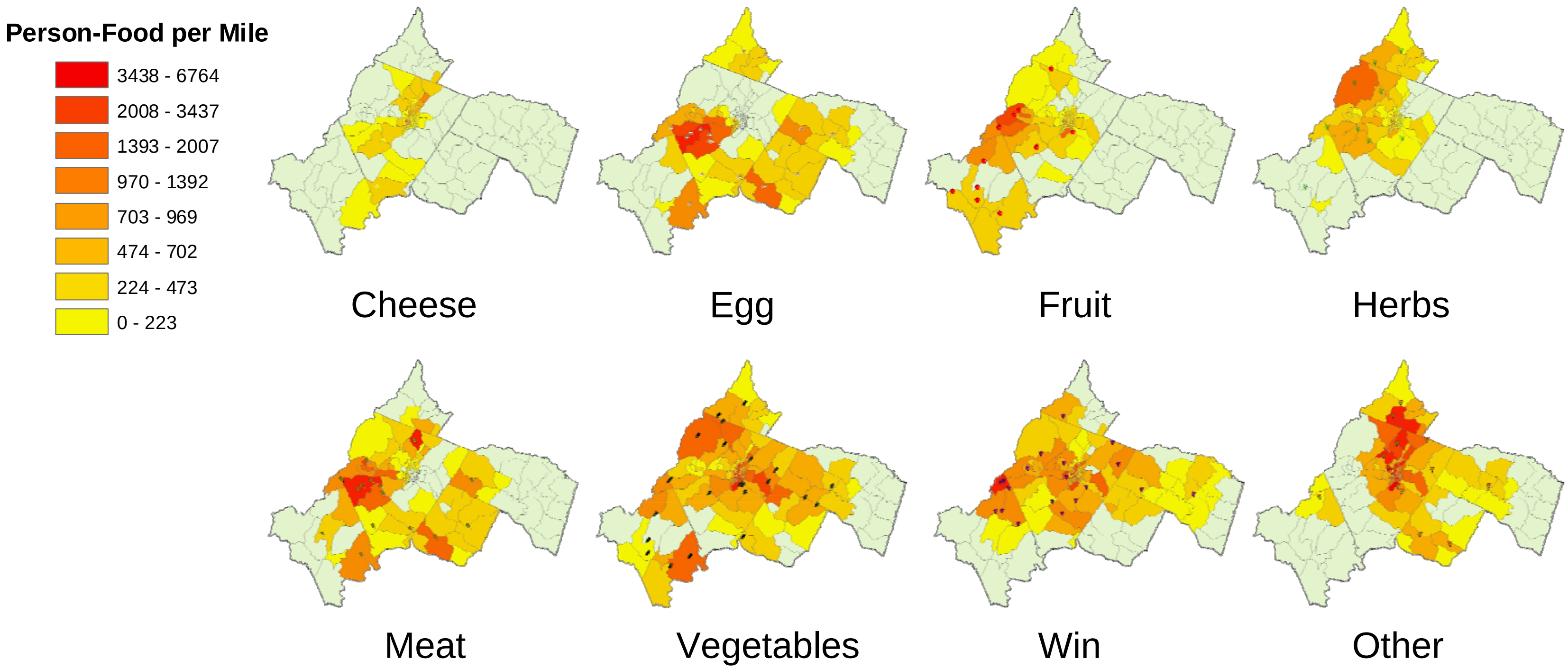
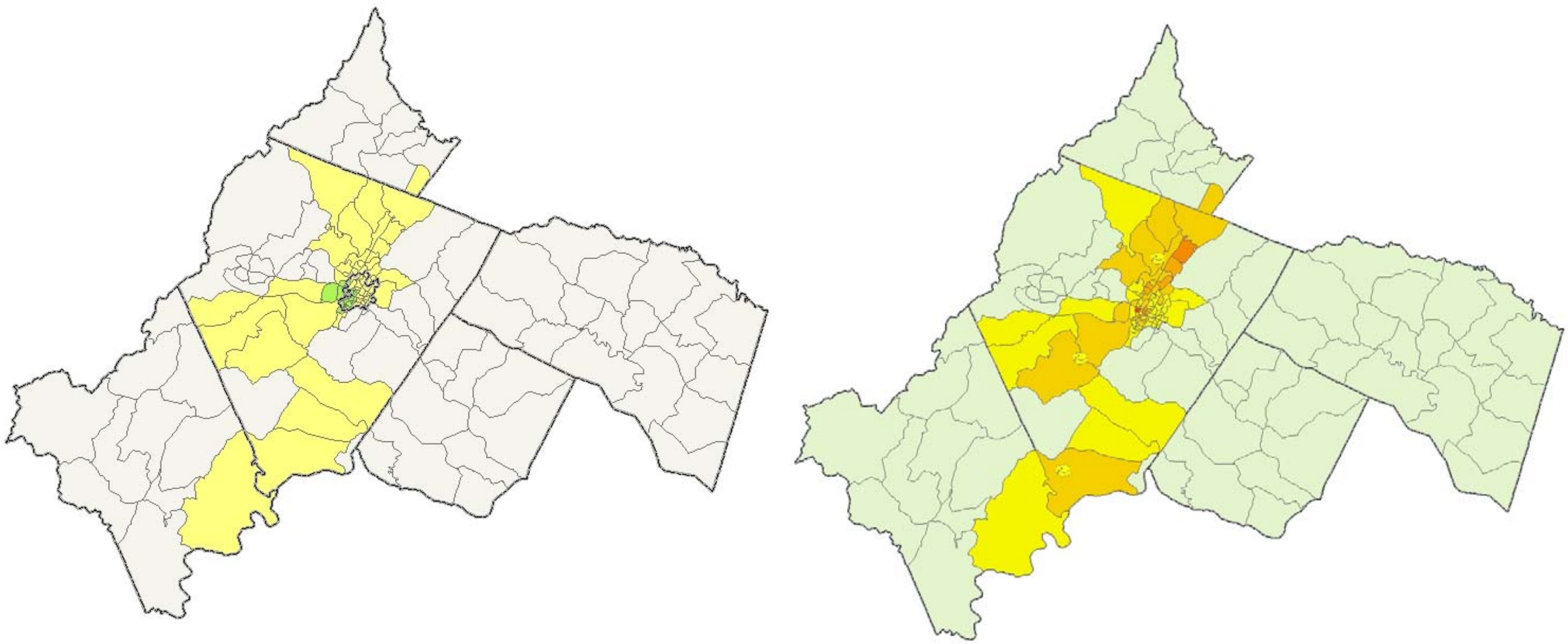


Figure 6 – Accessibility index of farms within 10 miles of census blocks using the gravity method



Cumulative Opportunity

Gravity

Figure 7 – Comparison of cumulative opportunity and gravity approaches

Discussion

This study has investigated the definition of local food and measures of accessibility from multiple perspectives. Several discussion topics resulted from the effort.

First, though this effort set out to more precisely quantify and compare local foodsheds, there remains a question of whether such precision is necessary. Jones et al. (2004) report the UK's Department of Food and Rural Affairs Working Group offers the following four reasons for clarifying the definition of local food:

- To improve public understanding and to better inform consumer buying behavior;
- To assist in setting and maintaining standards and in protecting local food producers from exploitation;
- To determining eligibility for public grant aid and support; and
- To provide a basis for establishing future accreditation or assurance schemes.

But to borrow a concept from Shoup (2002), is it better to be roughly right or precisely wrong? As demonstrated in the review of literature, foodsheds are most often defined for individuals hoping to align their procurement and consumption patterns with social, economic, and environmental concerns. These foodsheds vary from distances of 30 miles to 250 miles depending on the amount of food available in a given locality and the intensity of the challenge desired by the individual. But for the common consumer, the concept of food miles is likely less important in an absolute sense than it is conceptually. The local food movement will benefit more from people beginning to think about where their food comes from rather than people fretting about whether their apples come from 100 or 150 miles away. Even a distance of 250 miles may be considered a significant improvement over the 1200 to 1500 miles that conventional food typically travels (Pirog and Benjamin, 2003).

Though exact distance may not be the most important component of local food, the technology to provide more accurate network distances or travel times rather than straight-line distances does exist. Tools such as that found on 100milediet.org (100 Mile Diet, 2007) could easily be altered to consider actual driving distances or times. Multiple distance bands could show good, better, and best food coverage areas. As more information about farms is collected, farms could be mapped for consumers within their individual coverage areas. The advantage of these improvements would be to provide more accurate information for consumers.

Tools such as the one found on 100milediet.org, even in an improved state, are most valuable for individuals but are less useful for communitywide efforts. Additional measures of accessibility, such as those mentioned in the literature review and those demonstrated in this paper, are designed to highlight spatial advantages and disadvantages and inform policy with respect to local food. They simultaneously measure access to local food sources from multiple discrete communities, identify the diversity of local foods available in each community, and help individual farmers identify their local market areas as well as help groups of farmers identify overlapping market areas which may be potentially locations for farmers' markets. Accessibility measures also identify gaps in the local food market throughout the study area. This analysis can also help localities determine critical farmland to preserve, thus maintaining areawide accessibility to local food.

It should be noted that this study demonstrates a concept and results shown in the maps above are not representative of actual accessibility to local food for several reasons. Both measures demonstrated in this paper would require a significantly larger data set to render them useful to transportation and/or local food systems planning. As discussed in the literature review, local food is commonly defined by a distance of 100 miles. The study area itself was only 80 miles in length in its longest direction. Thus to demonstrate the measures and show variation among block groups, local food was defined to be that which was grown and consumed within a distance of 10 miles. Even this adaptation was imperfect because farm data was not collected for those counties outside the study area. Thus the accessibility reported for block groups along the borders of the study area are artificially low because they do not consider farms in neighboring counties. In order for a realistic assessment of local food, transportation and farm data would have to be collected for an area at least 100 miles larger than the borders of the study area.

Although the concepts of food miles is most tangible for individuals looking to change their consumption patterns, the realization of the need for more data may significantly impact community food system studies. The boundaries for a 'locality' are often those of a city or a county. The concept of local may include a multi-county region as defined by a regional planning commission. But the definition of local as it applies to food systems is much larger than what is traditionally considered local. Though programs such as Buy Fresh Buy Local are generally local efforts, they must expand their boundaries of data collection. This could necessitate a more coordinated approach to collecting data in the future. It may not be efficient for every locality interested in local food systems to collect its own data. Doing so would require farmers to provide information to a potentially large number of efforts. Instead, a statewide coalition should be formed to collect, maintain, and distribute data about small farmers who wish to distribute directly to consumers via any number of models such as direct farm sales, CSAs, farmers markets, or grocery stores.

In addition to widening the scale of collected data, several additional attributes could improve the measures demonstrated in this paper, especially the gravity model. First, both models suffer from a lack of data regarding packaging and processing facilities and point-of-sale locations including CSA drop-off points, farmers markets, and grocery stores. Given a mileage constraint of 100 miles, if a farmer sends his food 80 miles to a grocery store, the distance consumers could travel to the grocery store to purchase the food and have it remain local would be 20 miles (this does not consider the trip home from the grocery store). Although this paper stressed the importance of network distances, straight-line approximations may be used to show the difference in coverage areas between the farm and the grocery store. The farm had a coverage area of $\pi 100^2$, while the grocery store has a coverage area of $\pi 20^2$. Thus the coverage area of the farm is roughly 25 times larger than that of the grocery store. Thus the coverage area of each point of sale would depend on its distance from the farm. Incorporating point of sales into the analysis would considerably alter the results of both the cumulative opportunities and gravity measures.

The gravity measure is hindered by an additional lack of data. The gravity model should be weighted by the size of the origins (people in each block group) and opportunities (amount or quality of food at each farm), but a weight for the opportunities was not present in the data. Amount of each food type was not collected, and thus each farm that produced eggs was considered the same as all other farms that produced eggs. Variations in accessibility to local food thus rested only on number of farms, distance to those farms, and number of people residing in a block group. Future surveys of farmers should include questions regarding roughly how much of each product is produced at each farm. Surveys should also ask how much food is sold at each point of sale. Thus aggregate totals of each food product from multiple farms could be calculated for each point of sale. Surveys could also including questions about growing seasons, thus enabling accessibility maps to be created for each month. Doing so would reflect the seasonality of food and educate consumers and the public.

The accessibility measures in this study were disaggregated by type of food. Mode of access was assumed to be automobile. Further disaggregation by mode, income, and age can and should be undertaken to reflect the accessibility to local food of various populations.

Finally, these measures of accessibility are place-based (as opposed to person-based) and they do not consider trip-chaining or space-time elements. Though place-based measures are acceptable approximations of accessibility for a large study area, person-based measures can complement them and provide food accessibility case studies of individuals.

Recommendations

Several recommendations stem from this research effort.

First, additional farm data is needed. The results of the accessibility measures used for this study were insufficient because a definition of ten miles was used to define local food. The standard definition varies but is usually of a magnitude larger. Furthermore, the results of census block groups near the borders of the study area were skewed because farm data was not collected for farms in adjoining counties. To rectify this localities and communities must extend their definition of what is local beyond traditional county or multi-county areas. Perhaps a statewide entity would be more efficient than current local efforts at collecting information from small farms that wish to connect directly with consumers. This study should be repeated once more data is obtained.

Second, more detailed data concerning points-of-sale and either production or sales volumes can enhance accessibility studies even further. Because most consumers travel to grocery stores or farmers markets rather than farms themselves, a study taking these factors into consideration would be much more realistic. Donkin et al. (1999) conduct a study that is comparable to this suggestion, although local food is not the subject.

Third, once these measures are investigated using updated data, future comprehensive plans can use this accessibility information to direct future growth and prioritize farms for preservation in local-food-vulnerable areas.

Fourth, there are many opportunities to investigate the environmental justice issues associated with accessibility to local food. Census income, age, race, and ethnicity data could be used to disaggregate the population further. Once information about points of sale is available, additional modes of transportation may be considered. For instance, a future study may be able to ascertain how many people can walk to a point of sale and how many people are forced to drive. Socio-economic data may be layered upon these results to estimate how many people are carless in areas that require cars to access local food.

Fifth, this study may be enhanced by collecting data for each month and showing the change of accessibility to local food as the growing seasons change. Doing so could be a strong educational and outreach tool and could prompt people to buy more local food during the summer and fall seasons and preserve it for the winter months.

Sixth, an extension of this study could examine the accessibility of counties on a nationwide scale using data from the 2002 Census of Agriculture. The results would be useful to larger number of cities, towns, and even states, as they plan for future growth in their areas.

Conclusions

Support for local food systems is growing in popularity, but definition of what constitutes local food remains vague. Current methods of quantifying access to local food generally measure the straight-line distance from a single origin (either an address or an entire town or city) to food production sites within a given mileage. This method many be improved upon by considering network distances instead of straight-line distances and by extending the concept to methods that quantitatively compare multiple origins among each other.

The measures of accessibility presented improve upon the current practice of identifying local food by considering ability and desire of people to overcome spatial separation. Once perfected, the results of these methods will inform decision makers on several topics. Environmental justice may be considered and will identify populations with poor access to local food. Transportation planners will be informed as to the ability of various modes to provide access to local food opportunities. Land planners can use the results to guide growth away from critical farms that local communities may rely on for local food.

Though the results of this research are conceptual, the study has provided several suggestions for additional data requirements and enhancements to the demonstrated methodologies. Once enhanced, accessibility measures should become common tools used to identify access to local food.

Acknowledgements

This research was completed under the guidance of Tanya Denckla Cobb of the Institute for Environmental Negotiation and Timothy Beatley professor in the Department of Urban and Environmental Planning at the University of Virginia. I wish to acknowledge the hard work of their graduate students, Sara Thurman and Anne Bedarf who helped compile the farm data, and Melissa Wiley of the Piedmont Environmental Council of Virginia who maintains it. The author would also like to thank Harrison Rue, Ann Whitham, Melissa Barlow, and the members of the Charlottesville-Albemarle Metropolitan Planning Organization for reviewing the results of this study and providing insightful comments.

References

100 Mile Diet, The (2007). *100 Mile Diet: Local Eating for Global Change >> Map*. Accessed online at http://100milediet.org/map/. Last accessed on December 15, 2007.

American Planning Association (2007). *American Planning Association Policy Guide on Community and Regional Food Planning*.

Anderson, M. D., & Cook, J. T. (1999). Community food security: Practice in need of theory? *Agriculture and Human Values*, 16(2), 141-150.

Beavan, C. (2007). *Eating Local vs. Organic. No Impact Man*. Available online at http://noimpactman.typepad.com/blog/2007/03/eating_local_vs.html. Accessed on November 13, 2007.

Becker, E. (2002). 2 Farm Acres Lost per Minute, Study Says. *The New York Times*. Section A. p 22 col 4.

Bhat C., Handy, S., Kockelman, K., Mahmassani, H., Gopal, A., Srour, I., Weston, L. (2002). *Development of an urban accessibility index: formulations, aggregation, and application*. Center for Transportation Research The University of Texas at Austin. Report No. FHWA/TX-02-4938-4.

Christaller, W., (1966). *Central Places in Southern Germany*. Translated by Carlisle W. Baskin. Prentice-Hall, Inc. Englewood Cliffs, NJ.

Donkin, A. J. M., Dowler, E. A., Stevenson, S. J., & Turner, S. A. (1999). Mapping access to food at a local level. *British Food Journal*, 101(7), 554-564.

Hägerstrand, T. (1970). What about People in Regional Science? *Regional Science Association Papers*, No. 24, 7 – 21.

Handy, S. (2002). *Accessibility- vs. mobility-enhancing strategies for addressing automobile dependence in the U.S*. Department of Environmental Science and Policy, University of California at Davis. Prepared for the European Conference of Ministers of Transport.

Handy, S. & Niermeier, D. A. (1997). Measuring accessibility: an exploration of issues and alternatives. *Environment and Planning A*, Vol 29. pp 1175 – 1194.

Hansen, W. G. (1959). How Accessibility Shapes Land Use. *Journal of the American Planning Institute*, No. 25, 73 – 76.

Hanson, S. and Schwab, M. (1987). Accessibility and Intraurban Travel. *Environment and Planning A*, 19, 735 – 748.

Health Highlights: Nov. 25, 2007. (25 November 2007). Washington Post. Accessible online at http://www.washingtonpost.com/wp-dyn/content/article/2007/11/25/AR2007112500679.html. Last accessed December 15, 2007.

Hendrickson, M., Heffernan, W. D., Howard, P. H., Heffernan, J. B. (2001). Consolidation in food retailing and dairy. British Food Journal. Vol. 103 No. 10. pp 715-728.

Ingram, D. R. (1971). The Concept of Accessibility: A Search for an Operational Form. *Regional Studies*, 5, 101 – 107.

Jones, P., Comfort, D., & Hillier, D. (2004). A case study of local food and its routes to market in the UK. *British Food Journal*, 106(4), 328-335.

Kingsolver, B. (2007). *Animal, Vegetable, Miracle: A Year of Food for Life*. HarperCollins, New York, NY.

Lee, M. S. & McNally, M. G. (2002). *Measuring Physical Accessibility with Space-Time Prisms in a GIS: A Case Study of Access to Health-Care Facilities.* Institute of Transportation Studies, Center for Activity Systems Analysis, University of California, Irvine. Project UCI-ITS-AS-WP-02-8.

Levinson, D. M., & Krizek, K. J. (2005). Access to Destinations. Kidlington, Oxford, UK : Elsevier Ltd.

Lenntorp, B. (1976). Paths in space-time environments: a time-geography study of movement of possibilities of individuals. *Lund Studies in Geography*, B, 44. Gleerup, Lund, Sweden.

Locavores (2007). *Foodshed for Thought, Celebrate Your Foodshed, Eat Locally*! Available online at http://www.locavores.com/. Accessed on November 13, 2007.

Mackinnon, J. B., Smith, A. (2007). *The 100-Mile Diet: A Year of Local Eating*. Vintage Canada, Toronto, ON.

Miller, H. J., (2005). Place-Based Versus People-Based Accessibility. *Access to Destinations*, edited by D. M. Levinson and K. J. Krizek. Editors. Kidlington, Oxford, UK : Elsevier Ltd.

Nabhan, G. P. (2002). *Coming Home to Eat: The Pleasures and Politics of Local Foods*. W. W. Norton & Company, New York, NY.

O'Sullivan, D., Morrison, A., and Shearer, J. (2000) Using desktop GIS for the investigation of accessibility by public transport: An isochron approach. *International Journal of Geographical Information Science*, 14, 2002, pp. 85-104.

Petrilli, P. (2007). Interview. November 6, 2007.

Pirie, G. H. (1979). Measuring Accessibility: A Review and Proposal. *Environment and Planning A*, No. 11**,** 299 – 312.

Pirog, R. & Benjamin, A. (2003). *Checking the food odometer: Comparing food miles for local versus conventional produce sales to Iowa institutions*. Leopold Center for Sustainable Agriculture

Pollan, M. (2006a). *The Omnivore's Dilemma: A Natural History of Four Meals*. The Penguin Press, New York, NY.

Pollan, M. (15 September 2006b). The Vegetable-Industrial Complex. *The New York Times*, Section 6. p17.

Pothukuchi, K. (2004). Community Food Assessment: A First Step in Planning for Community Food Security. *Journal of Planning Education and Research*; 23; 356

Robbins, J. (2001). *The Food Revolution: How Your Diet Can Help Save Your Life and Our World*. Conari Press, Berkeley, CA.

Sherman, L., Barbara, B., Kondo, W. (1974). Method for evaluating metropolitan accessibility. *Transportation Research Record* No. 499, 70 – 82.

Shoup, D. (2002). Roughly Right or Precisely Wrong. *Access: Transportation Research at the University of California*, 20-25.

Slow Food USA, (2007). *Live the Slow Life*. Available online at http://www.slowfoodusa.org/change/index.html. Accessed on November 13, 2007.

Upper Valley Locavores (2007). *Upper Valley Locavores: The 100 Mile Diet in the Upper Valley*. Available online at http://www.uvlocalvore.com/. Accessed on November 14, 2007.

Vallianatos, M., Gottlieb, R., Haase, M. A. (2004). Farm-to-school: Strategies for urban health, combating sprawl, and establishing a community food systems approach. *Journal of Planning Education and Research*, Vol 23. pp 414 – 423.

Voges, E. M. and Naudé, A. H., (1983). *Accessibility in Urban Areas: An Overview of Different Indicators*. Technical Report RT/21/83, National Institute for Transport and Road Research, CSIR, South Africa.

Wachs, M. and Kumagi, T. G., (1973). Physical Accessibility as a Social Indicator. *Socio Economic Planning Science*, No. 7**,** 437 – 456.

Yang, J. & Ferreira, Jr., J. (2005). Evaluating measures of job-housing proximity: Boston and Atlanta, 1980-2000. In *Access to Destinations*, Levinson, D. M. & Krizek, K. J. Editors. Kidlington, Oxford, UK : Elsevier Ltd. pp 171 – 192.