DASYMETRIC MAPPING METHOD AND

DETERMINING FARMERS' MARKET DEMOGRAPHICS AND ACCESSIBILITY

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ABSTRACT

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JENNIFER M. ZANONI

A national push toward eating healthy and locally has corresponded with a rise in the popularity of farmers' markets. As of 2015, more than 8,000 farmers' markets were in operation around the United States. This thesis examines the service area demographics of farmers' markets proximity on a national scale as well as the demographics of communities that do not have access to a market. Dasymetric mapping techniques were implemented using census tracts with supplemental American Community Survey data as well as the National Land Cover Dataset as an ancillary data source. Comparing the results of this method to national population data and previous farmers' market demographic research indicated the study area created around each farmers' market was too broad for conclusive demographic results.

KEYWORDS: Demographics, Farmers' Markets, Dasymetric Mapping, Census Tracts, National Land Cover Dataset

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Chapter One: Introduction

"Go to the farmers' market and buy food there. You'll get something that's delicious. It's discouraging that this seems like such an elitist thing. It's not. It's just that we have to pay the real cost of food. People have to understand that cheap food has been subsidized. We have to realize that it's important to pay farmers up front, because they are taking care of the land."

Chef Alice Waters (McMannus 2004)

Background

For many Americans, going to the farmers' market is a weekly tradition. Motivations for this vary from buying directly from a local grower, to the availability of organic products, to feeling a sense of community (Brown 2002; Andreatta 2002). The eating local movement has been increasing in popularity and, along with farmers' markets, has led to a spike in the number of farm-to-table restaurants, CSAs (community supported agriculture) and community gardens.

The number of farmers' markets has been on the rise in the U.S. in recent decades. In 1970, there were 340 markets nationwide and according to the USDA National Farmers' Market Directory in 2014, there were 8,144 markets listed (Brown 2002; Tropp 2014). This represents a more than 2,000 percent increase over 44 years.

With a nationwide push for healthier dietary habits, questions have been raised regarding the availability of local, fresh produce for minorities and lower income neighborhoods, yet little research has been done at a national scale regarding the accessibility of farmers' markets. This thesis examines which demographics are currently being served by farmers' markets. By looking at the inverse, this research could be

additionally be used to help to identify those communities that could most benefit from the establishment of new farmers' markets.

Purpose and Objectives

The purpose of this research is to determine the demographics of the service areas around farmers' markets in the contiguous United States (excluding Alaska, Hawaii, or any U.S. territories) using the dasymetric method of mapping. The more than 8,000 farmers' markets in this study area are distributed across all 48 states and the District of Columbia, with the highest density near urban areas (Figure 1).

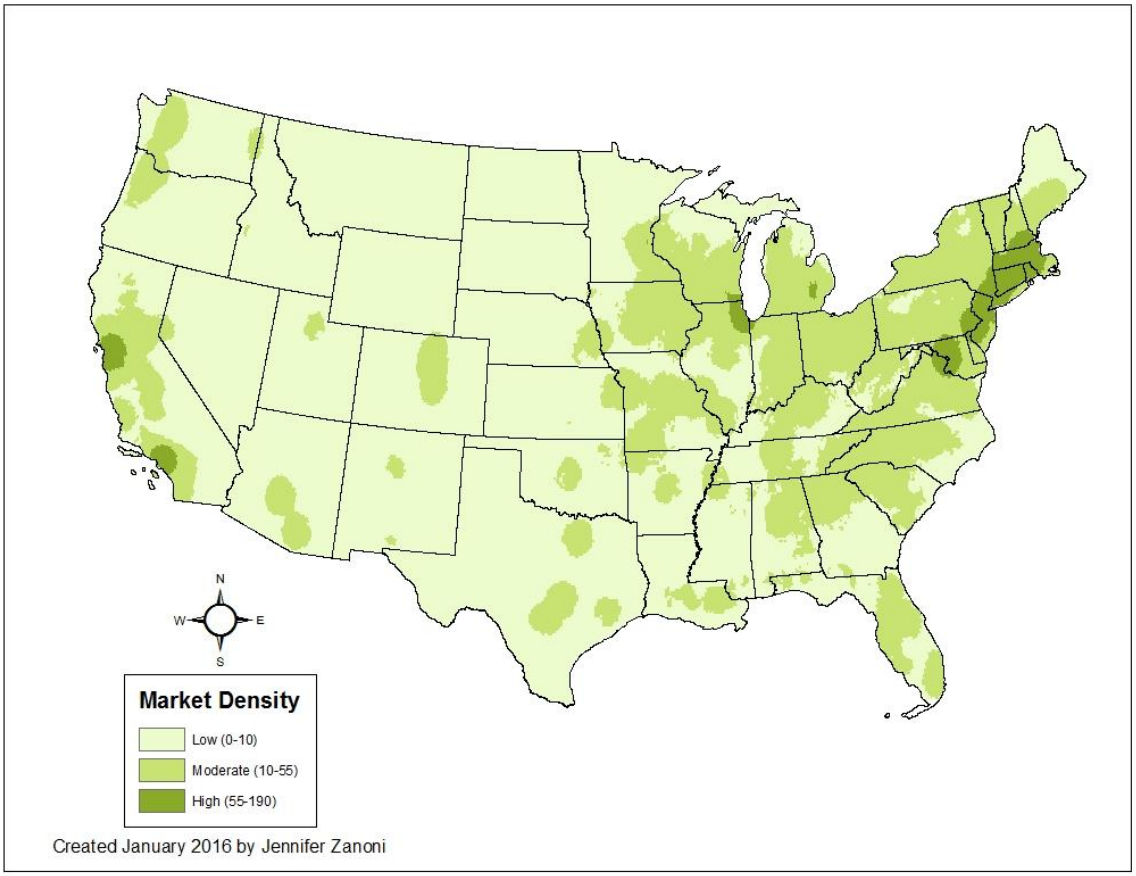

Figure 1: Density of farmers' markets

For the purpose of this study, the service area for each farmers' market is the area surrounding a market from which a consumer is likely to travel. These areas were determined using "Consumer Distance" data from the USDA's "Mapping competition zones for vendors and customers in US farmers' markets" publication and do not follow the arbitrary boundaries of established census tracts (Lohr 2011). Each service area could be encompassing portions of multiple census tracts therefore interpolation of the data will be necessary. This research applies methods of dasymetric mapping to interpolate the percentage of the population of the census tract within the farmers' market service area. This method, which incorporates ancillary data (usually land use) along with the census data, generally should produce more accurate results than interpolation without ancillary data (Hu 2012). In Figure 2, the A depicts the population distribution via a census unit (tract, block, etc.) and B represents the population of only the developed areas of the unit. Previous farmers' market demographic research does not utilize dasymetric interpolation methods.

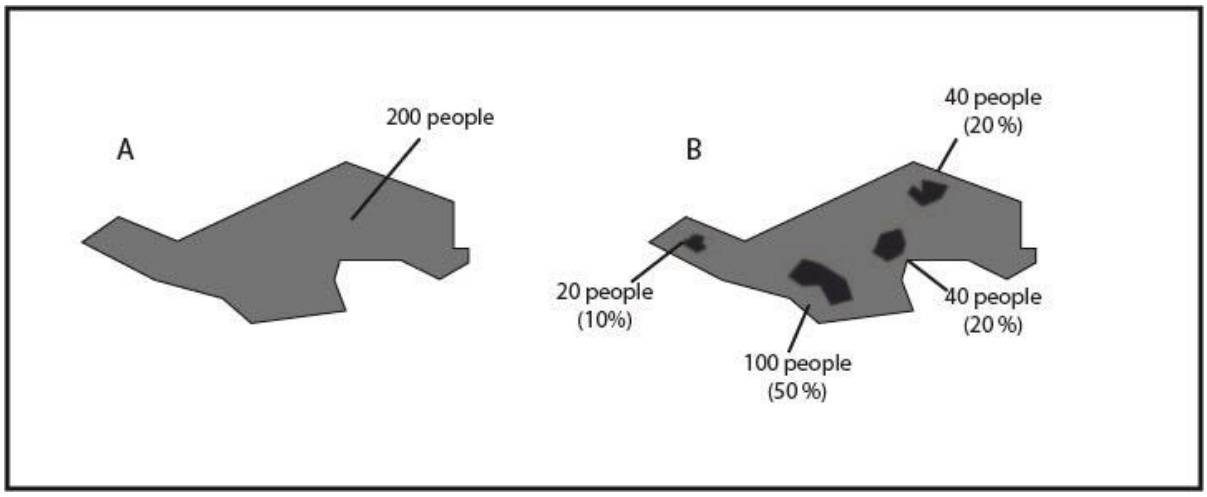

Figure 2: Dasymetric mapping (adapted from Sleeter and Gould 2007)

This research will also result in the determination of populations and areas currently unserved by farmers' markets. By eliminating the unpopulated areas from the data, the dasymetric method allows for a more accurate assessment of this population percentage.

The objective of this thesis is to evaluate the effectiveness of the dasymetric mapping method in determining the demographics of farmers' markets. In particular, it looks to assess the feasibility of using this method on a national dataset.

Research Questions

The research questions this thesis examines are the following:

1. What demographics are proximal to farmers' markets in the contiguous United States?
2. What are the demographics of the population that is currently not farmers' market accessible?
3. How do the farmers' market demographics obtained through a dasymetric method compare to previous research?
4. How well does the dasymetric method work when analyzing national datasets?

Determining the demographics of communities that are not served by a farmers' market can help determine locations for future markets, potentially providing fresh food to those currently without access.

Definitions

According to the U.S. Department of Agriculture (USDA), a farmers' market is a "multi-stall market at which farmer-producers sell agricultural products directly to the

general public at a central or fixed location, particularly fresh fruit and vegetables (but also meat products, dairy products, and/or grains)" (2015c).

Dasymetric mapping is a "technique in which attribute data that is organized by a large or arbitrary area unit is more accurately distributed within that unit by the overlay of geographic boundaries that exclude, restrict, or confine the attribute in question. For example, a population attribute organized by census tract might be more accurately distributed by the overlay of water bodies, vacant land, and other land-use boundaries within which it is reasonable to infer that people do not live" (Esri n.d.-c).

Scope

The scope of this research is limited to the contiguous United States and 2010 demographics. The 2010 census was the most recent census that was not an estimate and was the closest in date to the USDA customer distance travel study (2007) and to the National Land Cover Database (2011). The American Consumer Survey data was also obtained for 2010 so that all data was temporally aligned.

Chapter Two: Literature Review

History of Farmers' Markets

In 1976, the Farmer to Consumer Direct Marketing Act was passed spurring growth of farmers' markets nationwide (Brown 2002). This act was "designed to give farmers higher returns and consumers cheaper, fresher food" and was considered "significant in view of increasing concerns over energy limitations, loss of prime farmland, and dependence on out-of-region food sources" (U.S. General Accounting Office 1980). Before this act was passed, small and medium sized farms were struggling. The years between 1950 and 1970 saw an increase in the number of failing farms (Pirog 2014). These farms did not have access to traditional methods of marketing because they were unable to meet the product standards required of larger farms (size, color, uniformity). The ability to sell directly to consumers allowed smaller farms new opportunities to grow profits (Payne 2002). Rapidly, the number of farmers' markets increased and as of 2014, there were more than 8,000 markets nationwide (Figure 2) (Tropp 2014). These markets typically sell organic and non-organic produce as well as baked goods, dairy products, meats, prepared foods and crafts.

Eating Locally

Each week, three million people will shop at a farmers' market (Egan 2002). People choose to shop at farmers' markets for various reasons. Some consumers want fresh, organic and non-GMO (genetically modified organism) food and others want the ability to speak directly with the farmer. Some people are interested in supporting their neighbors and feel a sense of community by shopping at the market (Brown 2002; Andreatta 2002).

Research by Rushing and Rhuele indicates that more than 60% of shoppers are interested in "buying local to support local economies" (Pirog 2014). These shoppers are a part of a recent trend of buying locally due to concern regarding the sourcing of the produce they consume. In 2005 a new word was coined to describe these people: Locavore (Holben 2010).

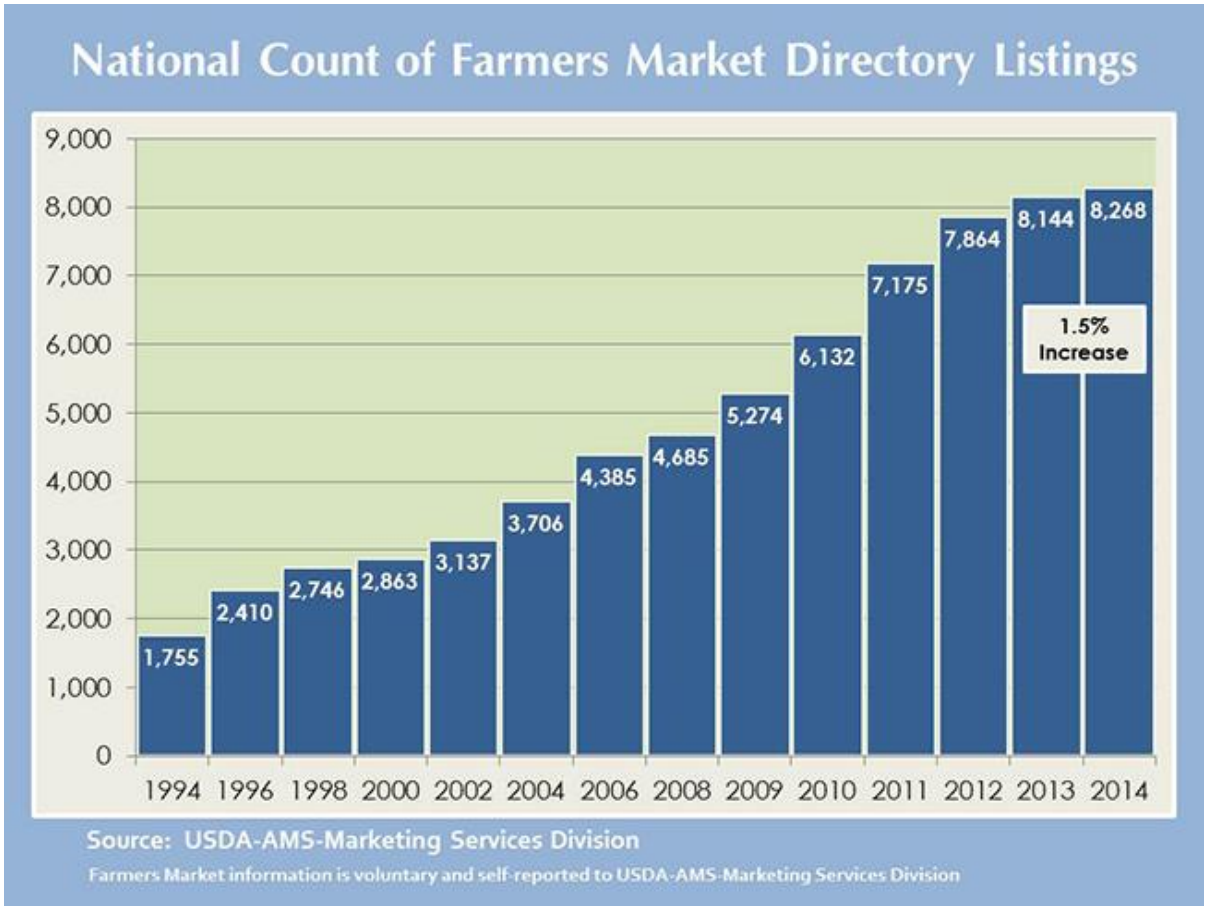

Figure 3: National count of farmers' market directory listings

Eating locally grown foods may also have a positive effect on the environment. Most of the food purchased from a grocery store has travelled thousands of miles (food miles) to reach the shelves. A 2003 report from the Leopold Center for Sustainable Agriculture found that in the U.S., food travels almost 1,500 miles from source to table

(Pirog 2003). Produce that is out of season locally has been shipped in from other parts of the country or the world; the average American meal has foods from 5 countries outside the United States (Natural Resource Defense Council 2007). Large amounts of fossil fuels are being burned in this transportation process adding to climate change and poor air quality. By sourcing locally produced foods, the food miles are dramatically decreased (Link 2008).

Not everyone wants to or is able to shop at a farmers' market. The basic ability to shop at a farmers' market is determined by access. Without transportation, a nearby market, or the time to attend, shopping at a farmers' market can be inaccessible to many (Zepeda 2009). Market distance and inconvenient locations are the top two reasons people cite for not shopping at a farmers' market. Additional reasons are: high prices, poor quality, limited variety, not clean, don't accept checks, don't accept food stamps, don't accept credit/debit cards, prefer supermarkets, limited hours, grow my own {food}, don't feel safe (Eastwood 1999).

Food Security and Food Deserts

According to the World Health Organization (WHO), food security is based on food availability, access and use. Is there regularly enough food? Is the food nutrient rich? Is the food properly prepared and safe for consumption (World Health Organization n.d.)? In 2014, the U.S. Department of Agriculture estimated that 14% of households experienced food-insecurity at some point during the year (Coleman-Jensen 2015). Farmers' markets

support the sense of food security in the event of a disruption in the industrialized food market due to “weather or political instabilities” (Link 2008).

The accessibility of fresh food to all demographics is an issue currently being extensively discussed and researched. Neighborhoods with inadequate sources of “affordable and nutritious food” are defined as food deserts (Farm Bill 2008). A lack of supermarket access has designed many urban, usually minority-populated, communities into food deserts (Larsen 2009).

In the last fifty years, there has been a 22% increase in the adult obesity rate. This is linked to the increased access of “cheaper, commodity-based, less nutrient-dense foods” (Pirog 2014). Without fresh and healthy food available in their immediate neighborhoods, residents of food deserts are more likely to obtain food from convenience or fast food sources (Walker 2010).

Residents of food deserts are more likely to not have access to farmers’ markets. They are less likely to have transportation to take them to a farmers’ market, either via their own vehicles or public transportation, which is typically less frequent on weekends. They are also more likely to work on a weekend, particularly Saturdays which is historically when markets are held. (Zepeda 2009).

Most food desert research focuses on improved access to supermarkets and not to other sources of healthy foods, such as farmers’ markets and community gardens. Two studies, both in Canada, looked at the effect of a farmers’ market on a neighborhoods access to fresh foods. Wang *et al* (2014) found that by including farmers’ markets when

locating the nearest healthy food source in Edmonton, Alberta, Canada the distances were smaller. The nearest distance to a supermarket was 1.76 km but when including farmers' markets, this distance was lowered to 1.68 km. Larsen and Gilliland (2009) researched the impact of establishing a new farmers' market in a food desert. The new market located in London, Ontario, Canada was found to provide improved access to healthy food and lower food costs for those living in the food desert neighborhood.

As the number of farmers' markets has increased over the years, they have also become more accessible to more diverse populations, in particular, low income. Several programs are in place to help provide assistance for purchase of fresh food. The Supplemental Nutrition Assistance Program (SNAP), Women, Infants and Children (WIC) Farmers' Market Nutrition Program (FMNP), and the Senior Farmers' Market Nutrition Program (SFMNP) all allow recipients to shop at farmers' markets using their benefits.

SNAP (formerly food stamps), allows for the use of benefits at participating markets (U.S. Department of Agriculture 2010). The WIC provides assistance to women who are pregnant or post-partum, infants and children up to 5 years. The WIC FMNP program began in 1992 and allows qualified WIC recipients to use benefits at farmers' markets (U.S. Department of Agriculture 2016b). SFMNP is a grant program allowing states and tribal governments to issue coupons to qualifying seniors. These coupons can be used for the purchase of fruits, vegetables, honey and herbs (U.S. Department of Agriculture 2015b).

Out of the more than 8,000 farmers' markets in 2016, more than a quarter of them accept SNAP, WIC FMNP, or SFMNP benefits (U.S. Department of Agriculture 2016a).

Farmers' Market Demographic Research

Previous research has looked at the demographics of who shops at a farmers' market using various methods. A 2013 study by Singleton *et al* (2015) evaluated farmers' markets demographics nationwide on a county level utilizing U.S. Census data. The research used the following demographic and health measures: median household income, percentage residents over age 65, percentage under age 18, percentage non-Hispanic black, percentage Hispanic, percentage below the national poverty level, percentage obese, and percentage with diabetes mellitus. This research indicated that non-Hispanic blacks, Hispanics and those living below the poverty line did not have as many farmers' markets available and that there were disparities in the availability of farmers' markets.

A 1995 study of a farmers' market in Orono, Maine utilized surveys to obtain demographic data from shoppers. The consumer survey was completed by 239 farmers' market visitors and asked questions regarding gender, age, household size, education, income and marital status. The significant results of the survey were education and household income. Both of these categories were higher than the demographics of the surrounding area using census data indicating that the typical customer had above average education and income. Similar to other studies, it found that the average shopper was a woman (Kezis 1998).

In Tennessee, six farmers' markets around the state were selected as survey locations for a 1997 study. The questionnaires were distributed to 1,000 shoppers at each market but also mailed to 1,000 random residents within 15 miles of the markets. In

addition to questions about shopping habits and preferences, the survey requested age, race, gender, and income information. The study found that the average farmers' market shopper is a white female, at least 45 years old, with at least a college education and above average income (Eastwood 1999).

Another survey based study was done in San Luis Obispo, California in 2004. San Luis Obispo County was chosen because of its designation as the best test market in the U.S. The survey was conducted at grocery stores rather than any of the county farmers' markets and looked at gender, age, marital status, income, employment, and education. The results showed that the average farmers' market shopper is female, married, and has obtained a post-graduate degree (Wolf 2005).

The majority of the previous farmers' market demographic studies found the majority of shoppers are female. This tends to be true of all food shopping, not just at farmers' markets. According to the U.S. Bureau of Labor Statistics (2014), women spent more than twice the amount of time grocery shopping than men and were also twice as likely to do the food shopping than men.

Geodemographics

In the U.S., the Census Bureau compiles demographic information about a population as statistical data. The decennial census (every 10 years) provides basic information regarding household size, relationships, race, ethnicity, age, and gender. Further demographic information is collected in the American Community Survey (ACS). This is conducted every 3 to 5 years, depending on the population size of a given area. This

survey is more comprehensive, yet only 3 million surveys are conducted compared to the nationwide surveys of the decennial census (Shaffer 2015). When this data is linked to a spatial location (geo-referenced), it is referred to as geodemographic.

Three of the geographic reporting areas for U.S. Census data are tracts, block groups and blocks. A tract is the largest of the three, usually composed of about 1,200 to 8,000 individuals. Block groups and blocks are both subdivisions of tracts, the smaller nesting inside the larger. A block is the foundation for all demographic data (U.S. Census Bureau n.d.).

Dasymetric Mapping

A common problem associated with determining demographics is the arbitrary boundaries of census data. There are many methods to interpolating the data, including areal weighting interpolation and dasymetric mapping. Areal weighting assumes that the population is evenly distributed across a census reporting area. The population of a section of that area can be interpolated using proportions:

$$P_t = \sum \frac{A_{ts} P_s}{A_s}$$

"where P_t is the estimated population count of target zone t, P_s is the population count of source zone s, A_{ts} is the area of the intersection of target zone t and source zone s, and A_s is the area of source zone s" (Hu 2012).

The obvious issue with areal weighting is the assumption that population is distributed evenly across an area. Dasymetric mapping utilizes ancillary data to first

determine populated areas and unpopulated areas. The interpolation of population can then be limited only to the areas of population. This method, while more complicated than areal weighting, has been shown to be more accurate (Horner 2008).

A study in 2004 evaluated the effectiveness of dasymetric mapping. "Mapping Population Density using a Dasymetric Mapping Technique" used 1990 census block groups and the 1992 National Land Cover Database to compare the results of dasymetric mapping with the demographics of census blocks. A block is the smallest U.S. Census enumeration area whereas a block group is the aggregate of many blocks. The results of this research showed high correlation between the dasymetric method and the census blocks indicating that dasymetric mapping is a reliable method of areal interpolation (Trusty 2004).

Research using the dasymetric method was done to determine the urban growth of the Lower Rio Grande Valley in Texas. This study used census tracts from 1990, 2000 and 2010 for population change data. Landsat 5 Thematic Mapper imagery from each corresponding year was used as ancillary data. The images were processed and reclassified to represent high, medium and low density and an uninhabited land cover. The resulting data showed the populated areas of the study area and the change in density over the 20 year study period (Pena 2002).

Chapter Three: Methodology

Data Collection

This object of this thesis was to determine the demographics of those with and without access to farmers' markets. It compared the demographic data obtained through the dasymetric mapping method to the survey methods used by previous research. In order to answer the research questions posed, data was obtained from various sources.

Farmers' market location data from the USDA National Farmers' Market Directory was obtained as an Excel spreadsheet (U.S. Department of Agriculture 2016a). This includes city, state and zip code for each market as well as x and y coordinates. Markets in Alaska, Hawaii or Puerto Rico were removed to correspond to the land cover used as ancillary data for the dasymetric mapping which only covers the contiguous United States. A total of 8,290 farmers' markets remained after eliminating 178 markets that were outside the geographic scope of this study.

Demographic data was downloaded from the U.S. Census Bureau in the form of tracts. These TIGER files (Topologically Integrated Geographic Encoding and Referencing) were created from the 2010 census data and include selected demographic data with the shapefile (U.S. Census Bureau 2015). The attribute data in the shapefile is coded to refer back to demographic data descriptions; this research used the fields in Table 1.

Table 1: US Census 2010 demographic profile table descriptions

Code	Description
DP0010001	Total Population
DP0010020	Male
DP0010039	Female
DP0020001	Median age
DP0080003	White
DP0080004	Black or African American
DP0080005	American Indian and Alaska Native
DP0080006	Asian
DP0080014	Native Hawaiian and Other Pacific Islander
DP0080019	Some Other Race
DP0100002	Hispanic or Latino (of any race)
DP0160001	Average household size
DP0210001	Total Occupied Housing Units
DP0210002	Owner-occupied housing units
DP0210003	Renter-occupied housing units

Additional demographic information was obtained via the U.S. Census' American Community Survey (ACS). Prior to the 2000 Census, there were two census forms, long and short. The long form was only administered to a subset of the population and included more in-depth questions than the short form. After 2000, this long form became the ACS; it includes the same questions as the short form and also more comprehensive questions regarding population and housing (U.S. Census Bureau 2013). This thesis utilized the following data from the 2010 ACS 5 year estimate by joining the data to the 2010 Census data using the GEOID10 field (Table 2).

Table 2: Additional fields for analysis from 2010 ACS

Description
Median household income (dollars)
Food Stamp/SNAP benefits in the past 12 months
Percentage of People whose income was below the poverty level in the past 12 months

Dasymetric mapping methods require utilizing an ancillary data source to determine the populated and unpopulated areas of the country. For this thesis, the National Land Cover Database (NLCD) served as the ancillary data as it is the only dataset that has comprehensive coverage for the contiguous United States. This Multi-Resolution Land Characteristics (MRLC) Consortium product is derived from Landsat and is 30 m resolution (U.S. Geologic Survey 2012). The dataset contains 584 unique values related to land cover. Values 581-584 are developed lands, however value 581 corresponds primarily with developed open space (parks, golf courses, and vegetation planted in developed settings). Only the classifications of low intensity to high intensity development (values 582-584) were be used to reclassify the NCLD into populated areas (Table 3).

Table 3: NCLD description of ecological system or land use class

582	Developed, Low Intensity	Includes areas with a mixture of constructed materials and vegetation. Impervious surfaces account for 20-49 percent of total cover. These areas most commonly include single-family housing units.
583	Developed, Medium Intensity	Includes areas with a mixture of constructed materials and vegetation. Impervious surfaces account for 50-79 percent of the total cover. These areas most commonly include single-family housing units.
584	Developed, High Intensity	Includes highly developed areas where people reside or work in high numbers. Examples include apartment complexes, row houses and commercial/industrial. Impervious surfaces account for 80 to 100 percent of the total cover.

The population served by a farmers' market is not limited to the traditional demographic boundaries established by the U.S. Census Bureau tracts. Multiple tracts or parts of multiple tracts may be within the area serviced by a market. The service area used by this thesis was determined by a distance buffer.

Several steps were followed to create this buffer. First the RUC (Rural-Urban Continuum) code data was downloaded as an Excel spreadsheet (U.S. Department of Agriculture 2015a). Each county in the United States has been assigned an RUC code that indicates how rural or urban a county using values from 1 to 9 (Table 4). The metro counties are those with one or more urban areas of at least 50,000 residents (a central county) or a neighboring county that has at least 25% of the workers commuting to the central county for work (outlying county). The non-metro counties are those with a population less than 50,000 (U.S. Department of Agriculture 2015d). These values were applied to each farmers' market in ArcGIS by joining county data to the market points.

Table 4: Rural-Urban Continuum codes

2013 Rural-Urban Continuum Codes	
Code	**Description**
Metro Counties:	
1	Counties in metro areas of 1 million population or more
2	Counties in metro areas of 250,000 to 1 million population
3	Counties in metro areas of fewer than 250,000 population
Non-metro Counties:	
4	Urban population of 20,000 or more, adjacent to a metro area
5	Urban population of 20,000 or more, not adjacent to a metro area
6	Urban population of 2,500 to 19,999, adjacent to a metro area
7	Urban population of 2,500 to 19,999, not adjacent to a metro area
8	Completely rural or less than 2,500 urban population, adjacent to a metro area
9	Completely rural or less than 2,500 urban population, not adjacent to a metro area

A 2007 USDA study determined the average distance that a consumer would travel to a farmers' market. This study links RUC codes to the distance travelled, as shown in Table 5 (Luhr 2011). These distances the basis for buffers around each market, determining that market's service area.

Table 5: Average vendor and customer travel distances

Code	Description	Vendor Distance (mi.)	Customer Distance (mi.)
RUC1	Metro – population ≥ 1 million	46.8	10.4
RUC2	Metro – population 250,000 - 1 million	33.1	12.0
RUC3	Metro – population < 250,000	32.4	12.0
RUC4	Urban – population ≥ 20,000, adjacent to Metro	25.6	11.9
RUC5	Urban – population ≥ 20,000, not adjacent to Metro	35.6	14.6
RUC6	Urban – population 2,500 - 19,999, adjacent to Metro	24.2	12.3
RUC7	Urban – population 2,500 - 19,999, not adjacent to Metro	24.3	10.2
RUC8	Rural – adjacent to Metro	24.7	12.9
RUC9	Rural, not adjacent to Metro	23.2	19.2

Additional data was required in order to compare the study results of Wolf *et al* (2005) to the demographics of San Luis Obispo County using the dasymetric method of this thesis. This data was obtained from the 2010 ACS 5 year estimate. With the exception of the "Total" fields, the data is in percentages (Table 6). Using Excel, these data fields were converted to exact numbers by multiplying each percentage by the total population for that data category. In order to make the education data comparable to the 2005 Wolf *et al* data, the sums of corresponding fields of the age subsets were calculated.

Table 6: Additional demographic data for San Luis Obispo County

Education	
Age 18-24	
	Total; Estimate; Population 18 to 24 years
	Less than high school graduate
	High school graduate (includes equivalency)
	Some college or associate's degree
	Bachelor's degree or higher
Age 25+	
	Total; Estimate; Population 25 years and over
	9th to 12th grade, no diploma
	High school graduate (includes equivalency)
	Some college, no degree
	Bachelor's degree
	Graduate or professional degree
Employment	
	Total; Estimate; Population 16 years and over
	Employed; Estimate; Population 16 years and over
	Unemployment rate; Estimate; Population 16 years and over
Income	
	Households; Estimate; Total
	Less than $10,000
	$10,000 to $14,999
	$15,000 to $24,999
	$25,000 to $34,999
	$35,000 to $49,999
	$50,000 to $74,999
	$75,000 to $99,999
	$100,000 to $149,999
	$150,000 to $199,999
	$200,000 or more
Marital Status	
	Total; Estimate; Population 15 years and over
	Now married (except separated)
	Widowed
	Divorced
	Separated
	Never married

Data Analysis

A geodatabase was created to store the data used for the thesis analysis. The farmers' market data was imported to ArcGIS using the longitude and latitude coordinates given in the spreadsheet, linked by county to the appropriate RUC code and attributed with the appropriate consumer travel distance. Buffers for each farmers' market were created based on the consumer travel distance and dissolved to create the farmers' market service area.

The following geoprocessing steps were taken in order to answer the question "what demographics are proximal to farmers' markets." The reclassified NLCD raster was converted to a polygon, dissolved and then used to clip the census tracts. The tracts feature class was projected to the USA Contiguous Albers Equal Area Conic projection. This projection was chosen due to its' minimal distortion in area. It is commonly used when depicting the contiguous United States (Florida Geographic Data Library n.d.).

The area of each tract was calculated (the original area).The tracts were clipped again to the service area. The new area of the tracts was divided by the original area to obtain a multiplier used for calculating the proportion of a population within the new area. This multiplier was applied to every demographic field with the exceptions of Median Age, Average Household Size and Median Income. Unlike the other demographic fields, these values are medians or averages and would not benefit from the areal weighting calculation.

The clipped census tracts were spatially joined to the service area. The demographic fields were merged following the policies in Table 7. The attribute table was then exported

from ArcGIS to Excel to tabulate results for nationwide demographics. Percentages for each demographic were calculated by dividing the population of that demographic by the total population. The exception to this was occupied housing units in which case the total owner occupied or renter occupied units were divided by the total occupied units.

Table 7: Spatial join merge policies per field

Sum	Total Population Male Female White Black or African American American Indian / Alaska Native Asian Native Hawaiian / Pacific Islander Some Other Race Hispanic or Latino (of any race) Total occupied housing units Owner-occupied housing units Rent-occupied housing units Snap Benefits Below Poverty Level	**Average**	Median age Average household size Median household income

A simple geoprocess was used in order to answer the question "What percentage of the population is not accessible to a farmers' market." Instead of clipping the census tracts to the farmers' market buffers in the process used to answer the first research question, the erase tool was used to remove those areas from the tract polygons. The same areal weighting calculations were done to determine the population proportions living outside of the farmers' market service areas. The attribute table was again exported from ArcGIS to Excel to tabulate the results.

In order to compare the demographic data obtained by this thesis to the results of 2005 Wolf *et al* study the following process was used. First, the additional demographic data (Table 6) was joined to the clipped census tracts. The county boundary was used to select the tracts within San Luis Obispo County and this selection was saved as a new feature class. The area multiplier was applied to the demographic fields to determine the proportion of the population of the census tracts in the clipped area. The attribute table was exported from ArcGIS to Excel to tabulate the results.

Chapter Four: Study Results

Farmers' Market Demographics

The first question this study sought to answer is "What are the demographics currently proximal to a farmers' market." The demographics analyzed to answer this question were gender, race, Hispanic, occupied housing units, average household size, median age, median income, percent below poverty level and percent receiving SNAP benefits.

Race demographics are reported by the U.S. Census Bureau in accordance with Office of Management and Budget requirements. This standard requires a minimum of five categories: White, Black or African American, American Indian or Alaska Native, Asian and Native Hawaiian or other Pacific Islander. Census respondents can chose from one or more race categories (U.S. Census 2013).

The census reports the Hispanic population separate from race. It is defined as a "person of Cuban, Mexican, Puerto Rican, South or Central American, or other Spanish culture or origin regardless of race" (Ennis 2011). The 2010 census questionnaire allowed respondents to identify as any of the following: non-Hispanic; Mexican, Mexican American or Chicano; Puerto Rican; or Cuban. It also permitted the selection of "another Hispanic, Latino or Spanish origin" (Ennis 2011).

Gender

The average gender of the population in proximity of a farmers' market was determined (Table 8). The resulting percentages were almost evenly split between male and female (Figure 4).

Table 8: Total population with access to a farmers' market: gender

Total Population	Male	Female
282,627,969	138,597,746	144,030,223

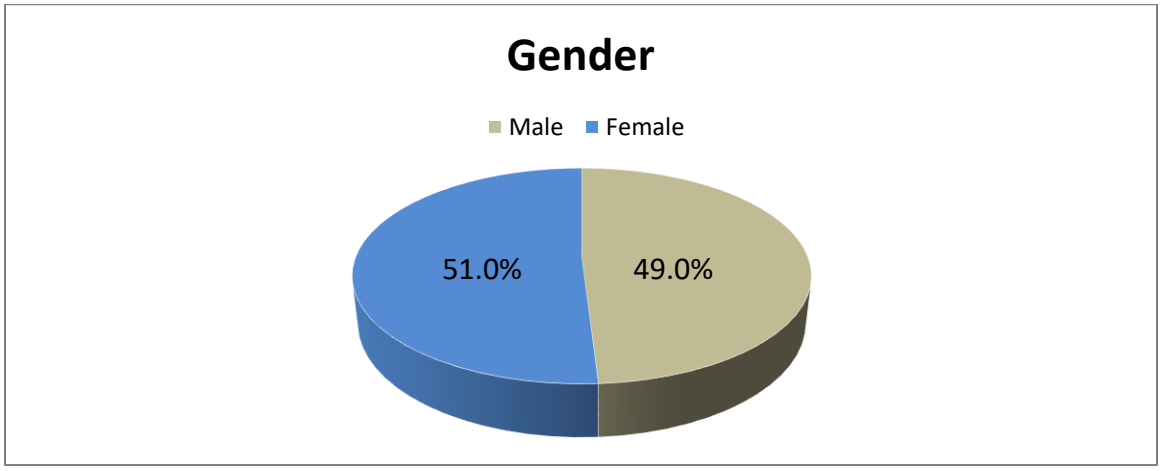

Figure 4: Population with access to a farmers' market: gender percentages

Race

The percentage of each race of the population in proximity of a farmers' market was determined (Table 9). The resulting percentages are show that the majority are white, followed by black and multi-racial (Figure 5).

Table 9: Total population with access to a farmers' market: race

Total Population	White	Black	Asian
282,627,969	185,526,206	32,866,715	13,918,099
Multi-Racial	**American Indian**	**Hawaiian / Pacific Islander**	**Other**
30,023,764	1,981,687	379,587	17,931,912

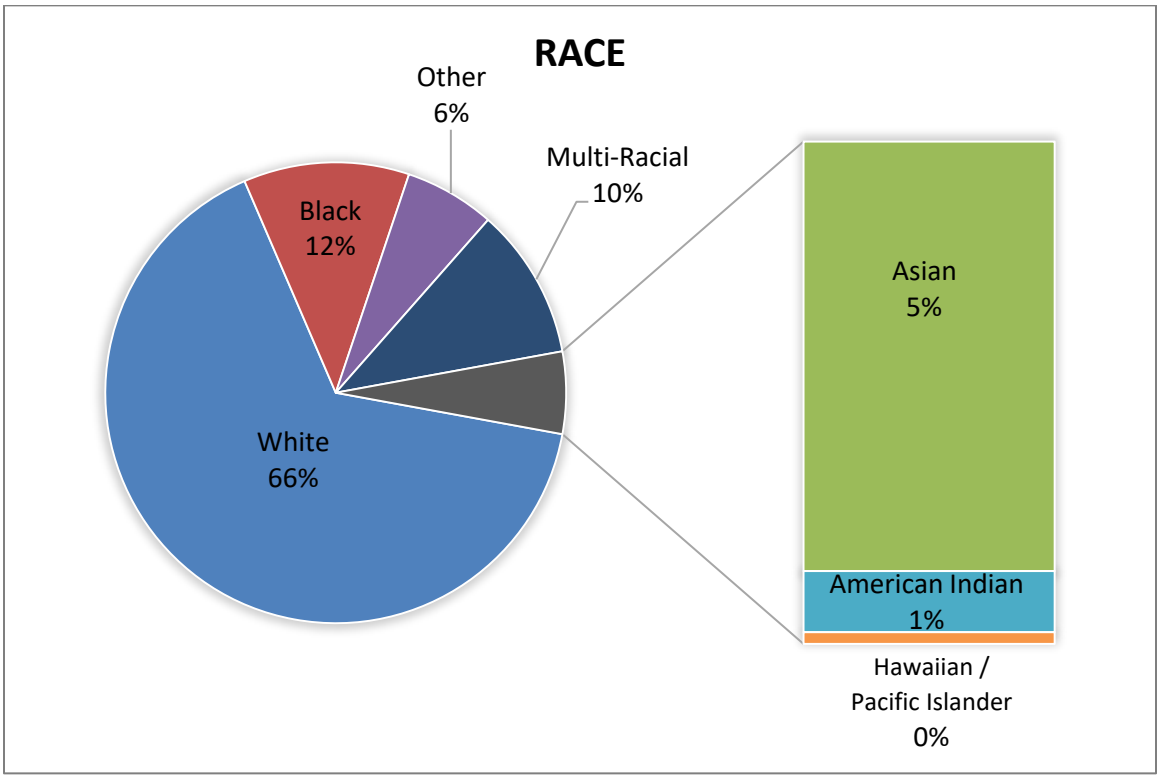

Figure 5: Population with access to a farmers' market: race percentages

Hispanic

The proportion of the population in proximity of a farmers' market that is Hispanic was determined (Table 10). The resulting percentages are show that Hispanics make up only 17 percent of those living near a farmers' market (Figure 6).

Table 10: Total population with access to a farmers' market: Hispanic

Total Population	Hispanic
282,627,969	46,979,424

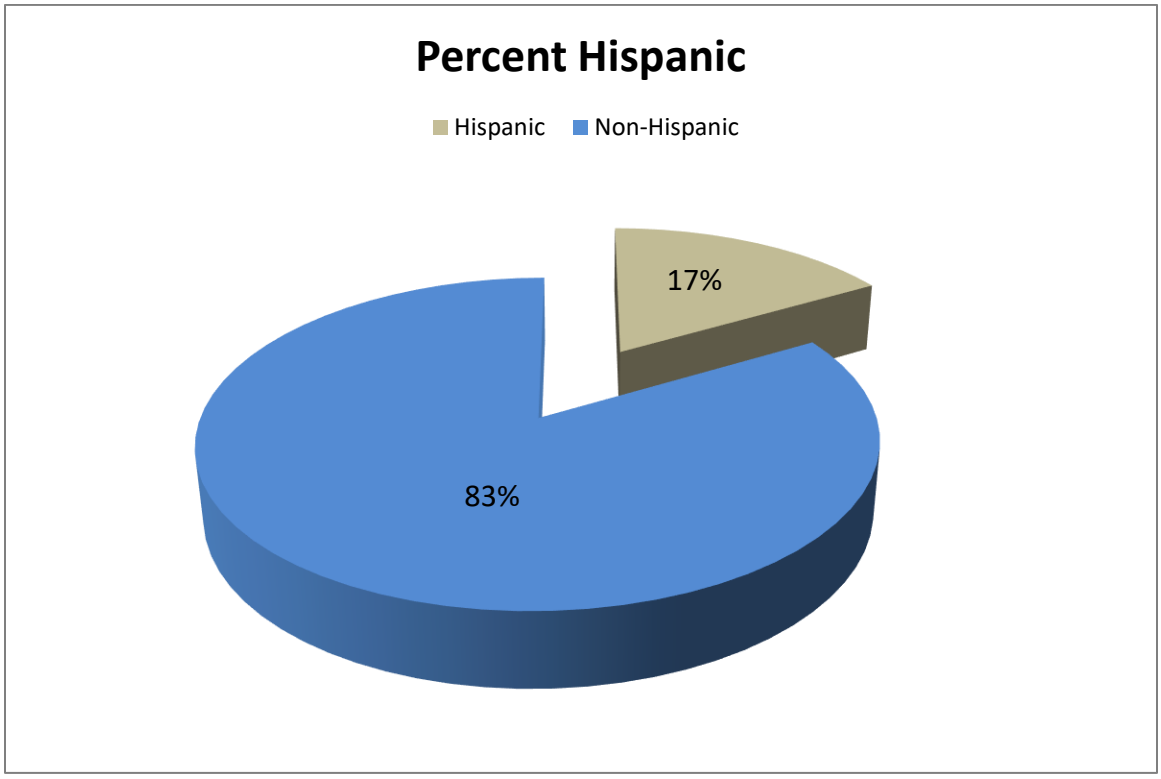

Figure 6: Population with access to a farmers' market: percent Hispanic

Occupied Housing Units

The proportion of the population in proximity of a farmers' market that lives in owner occupied or renter occupied housing units was determined (Table 11). The resulting percentages are show that more people own the homes they live in than rent (Figure 7).

Table 11: Total population with access to a farmers' market: total occupied units

Total Occupied Units	Owner Occupied	Renter Occupied
97,562,852	59,385,820	37,177,032

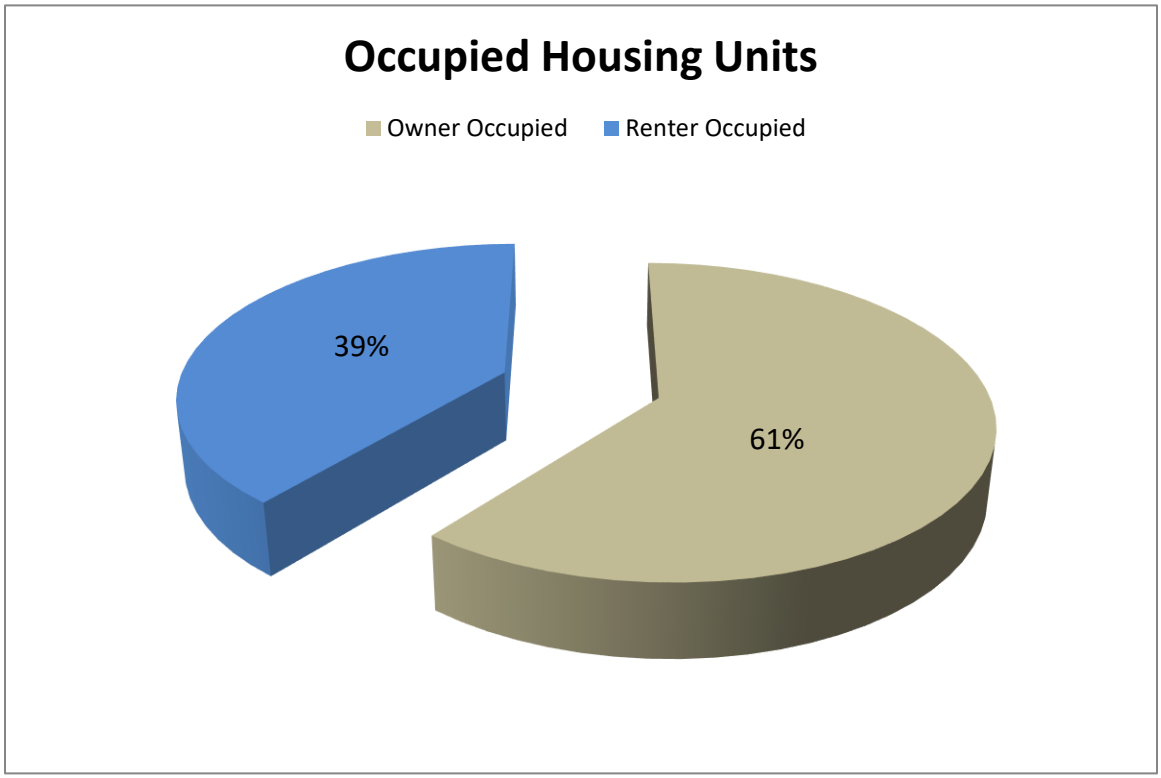

Figure 7: Population with access to a farmers' market: occupied housing

Median Age

The median age of the population in proximity of a farmers' market was determined in ArcGIS by averaging the median ages of the tracts that were spatially joined to each farmers' market. When exported to Excel, the total average median age was calculated to be 38.1 years old. Figure 8 shows the median age distribution.

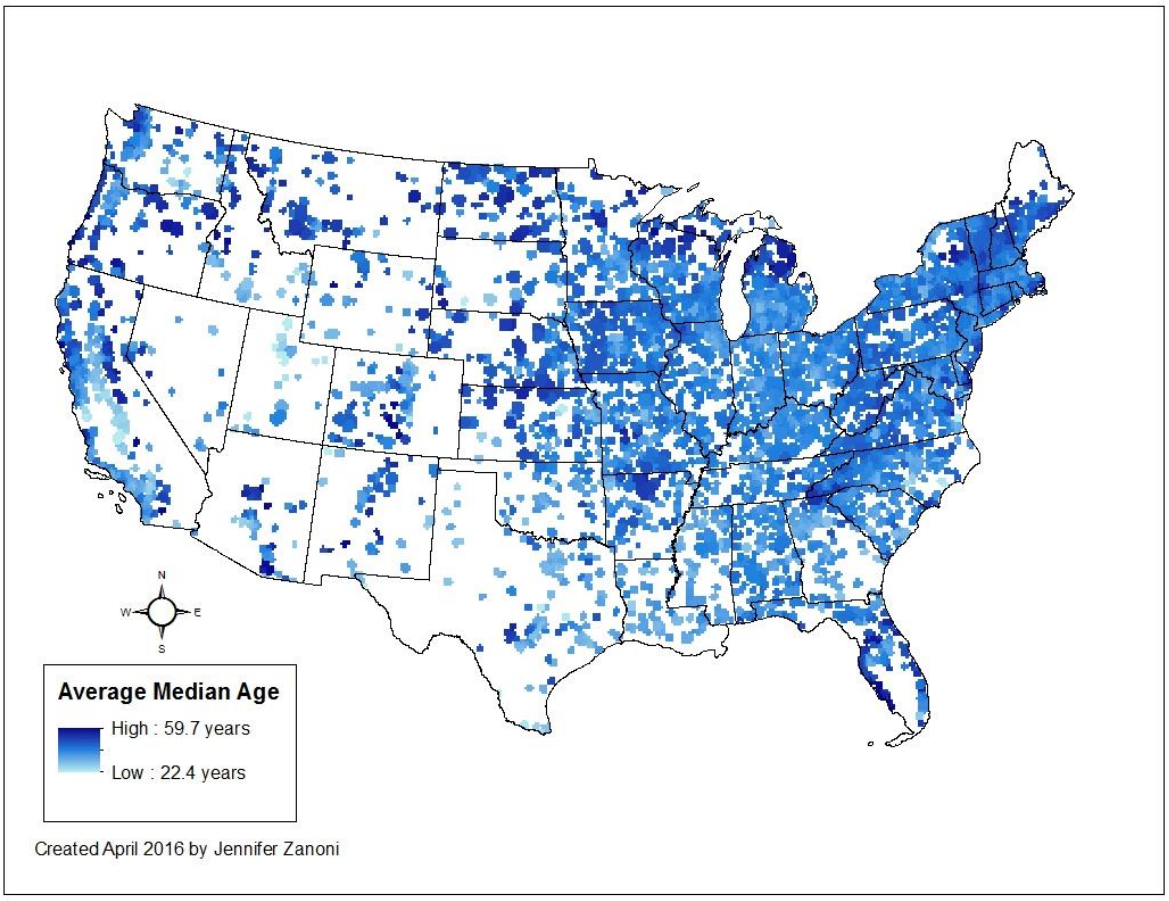

Figure 8: Population with access to a farmers' market: average median age

Household Size

The average household size of the population in proximity of a farmers' market was determined in ArcGIS by averaging the mean household size of the tracts that were spatially joined to each farmers' market. When exported to Excel, the total average household size was calculated to be 2.6 people. Figure 9 shows the distribution of average household size.

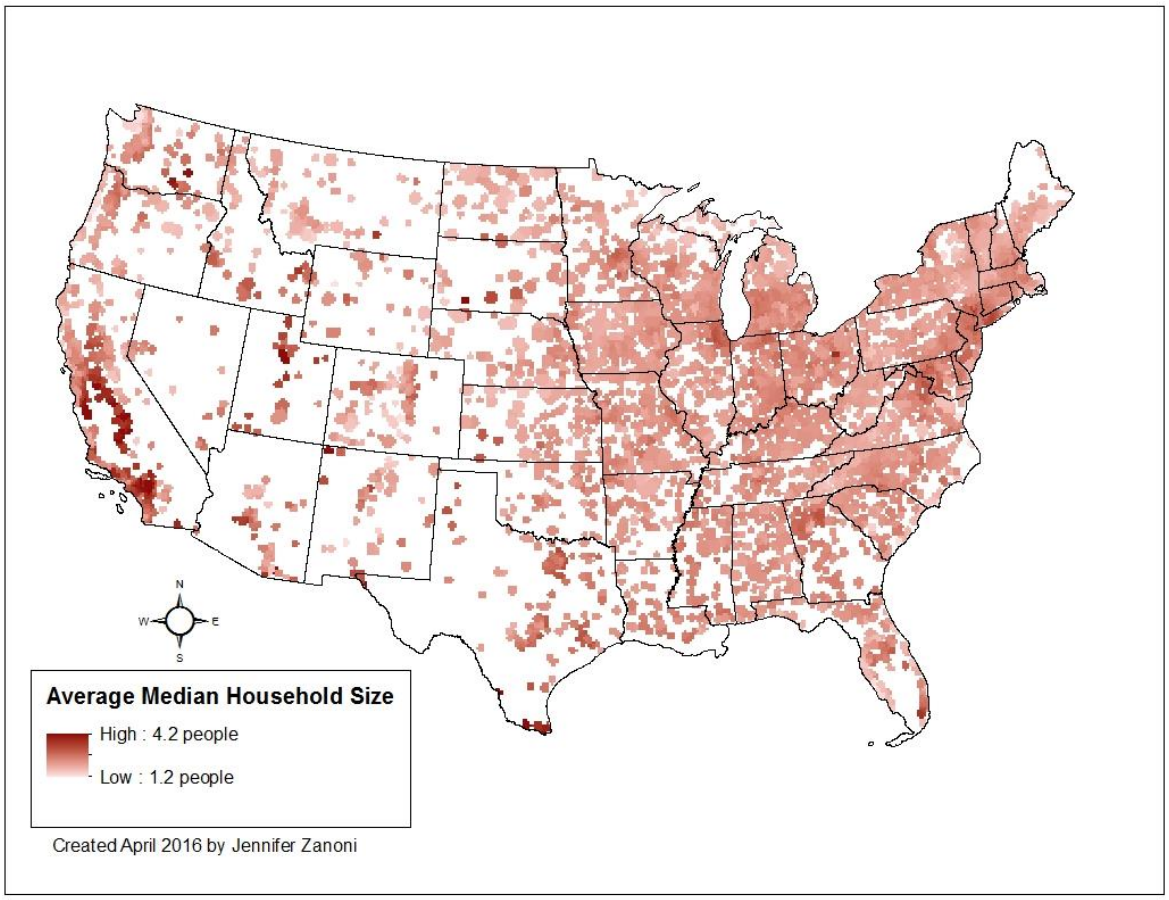

Figure 9: Population with access to a farmers' market: average household size

Median Income

The median income of the population in proximity of a farmers' market was determined in ArcGIS by averaging the median incomes of the tracts that were spatially joined to each farmers' market. When exported to Excel, the total average median income was calculated to be $56,016. Figure 10 shows the distribution of average median income.

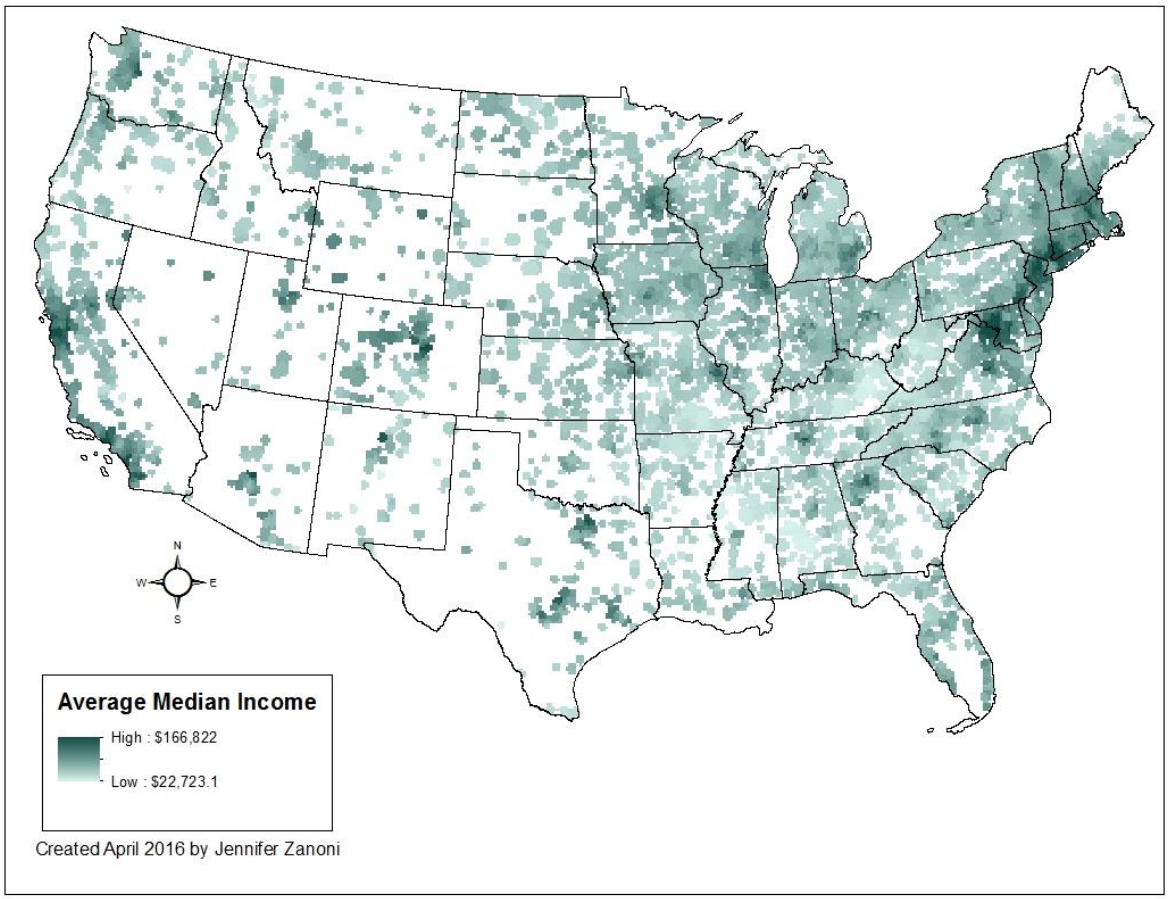

Figure 10: Population with access to a farmers' market: average median income

The following two demographic results pertain to poverty.

Poverty Level

The percent of the population living below the poverty line that is in proximity of a farmers' market was determined (Table 12). The poverty level data was obtained from the 2010 American Community Survey Data. The results show that slightly more than 1 in 10 residents near a farmers' market is living below the poverty level (Figure 11).

Table 12: Total population with access to a farmers' market: poverty level

Total Population	Below Poverty Level
282,627,969	33,102,573

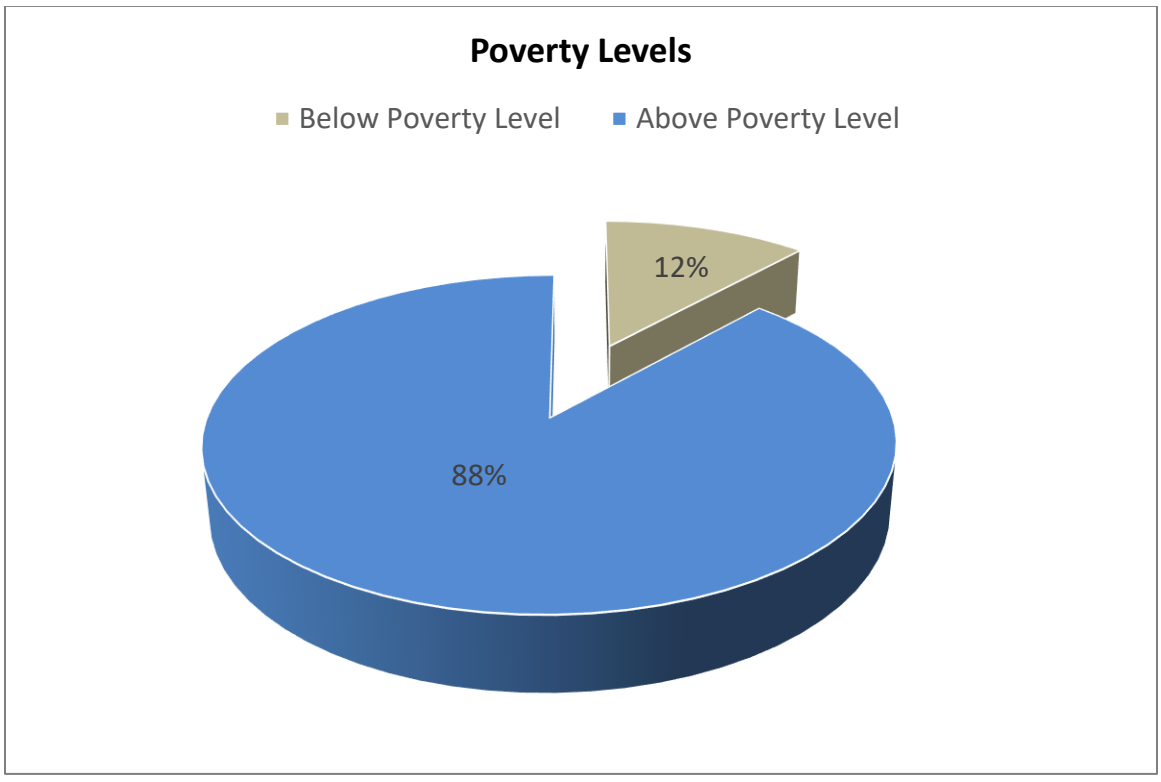

Figure 11: Population with access to a farmers' market: poverty level

SNAP Benefits

The percent of the population using SNAP benefits that is in proximity of a farmers' market was determined (Table 13). The SNAP Benefit data was obtained from the 2010 American Community Survey Data. The results show that a small percentage of the population living near a market uses snap benefits (Figure 12).

Table 13: Total population with access to a farmers' market: SNAP benefits

Total Population	Using SNAP Benefits
282,627,969	9,500,941

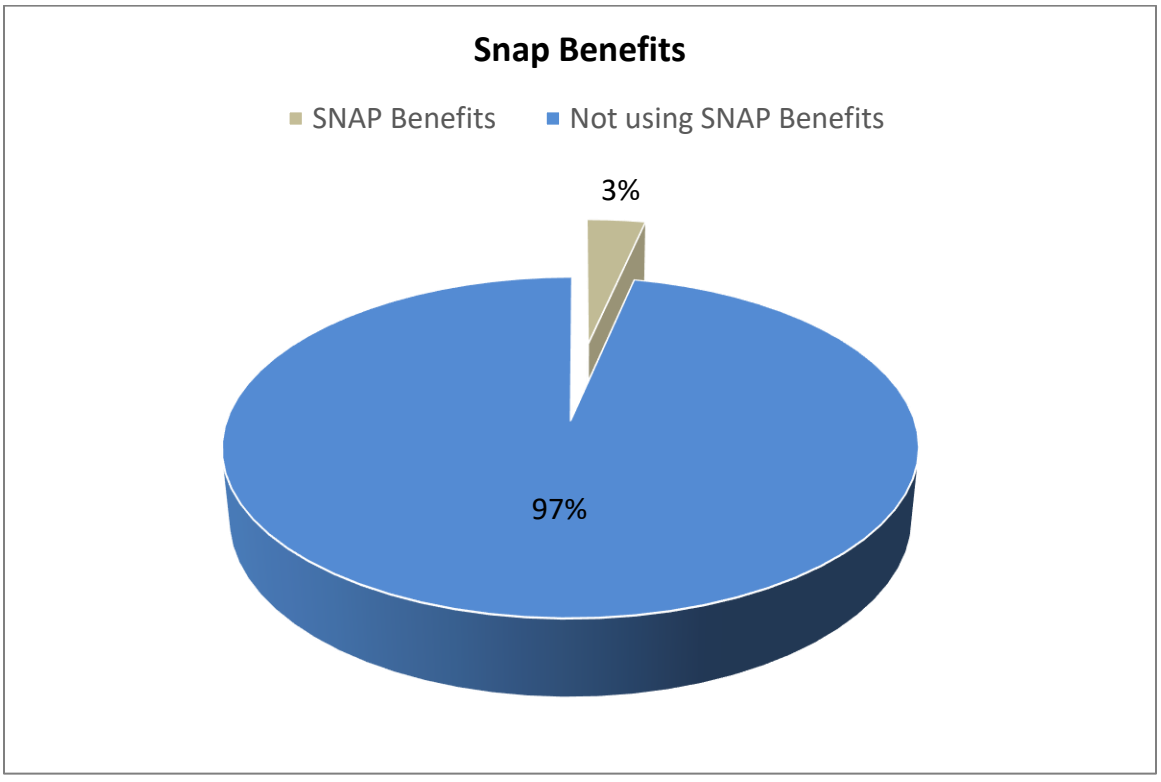

Figure 12: Population with access to a farmers' market: SNAP benefits percentages

Demographics Without Farmers' Market Access

The second question this study sought to answer is "What are the demographics of the population is not currently farmers' market accessible." The same demographics were analyzed as with the first research question.

Gender

The average gender of the population without farmers' market access was determined (Table 14). The resulting percentages show an almost even split between genders (Figure 13). These results are similar to the demographics of the population in proximity to a farmers' market.

Table 14: Total population without access to a farmers' market: gender

Total Population	Male	Female
23,684,569	11,952,932	11,731,637

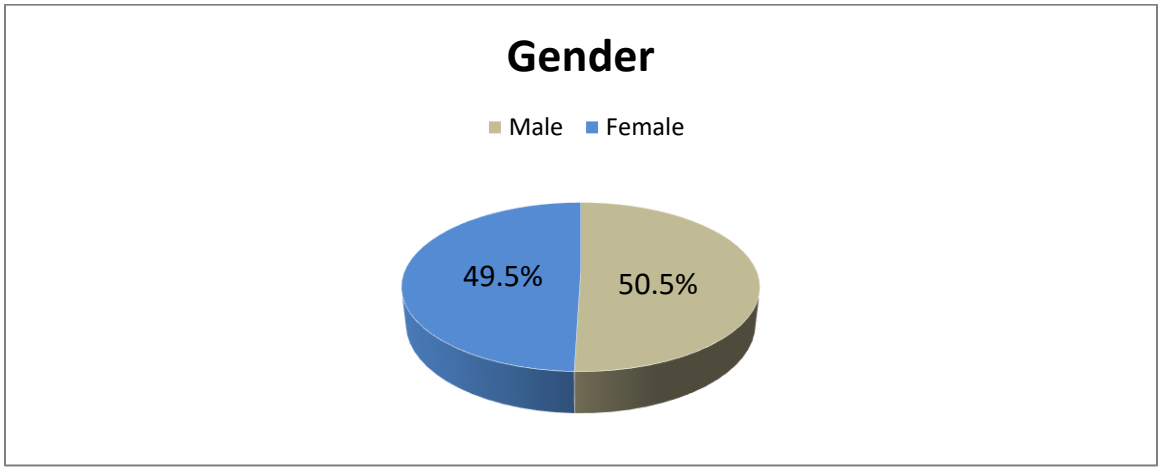

Figure 13: Population without access to a farmers' market: gender percentages

Race

The proportion of each race of the population without farmers' market access was determined (Table 15). The resulting percentages are show the majority are white, followed by black and multi-racial (Figure 14). These results indicated higher percentages of whites and American Indians that do not have access to markets.

Table 15: Total Population without access to a farmers' market: race

Total Population	White	Black	Asian
23,684,569	18,785,261	2,500,389	162,885
Multi-Racial	**American Indian**	**Hawaiian / Pacific Islander**	**Other**
496,291	617,284	16,142	3,263,102

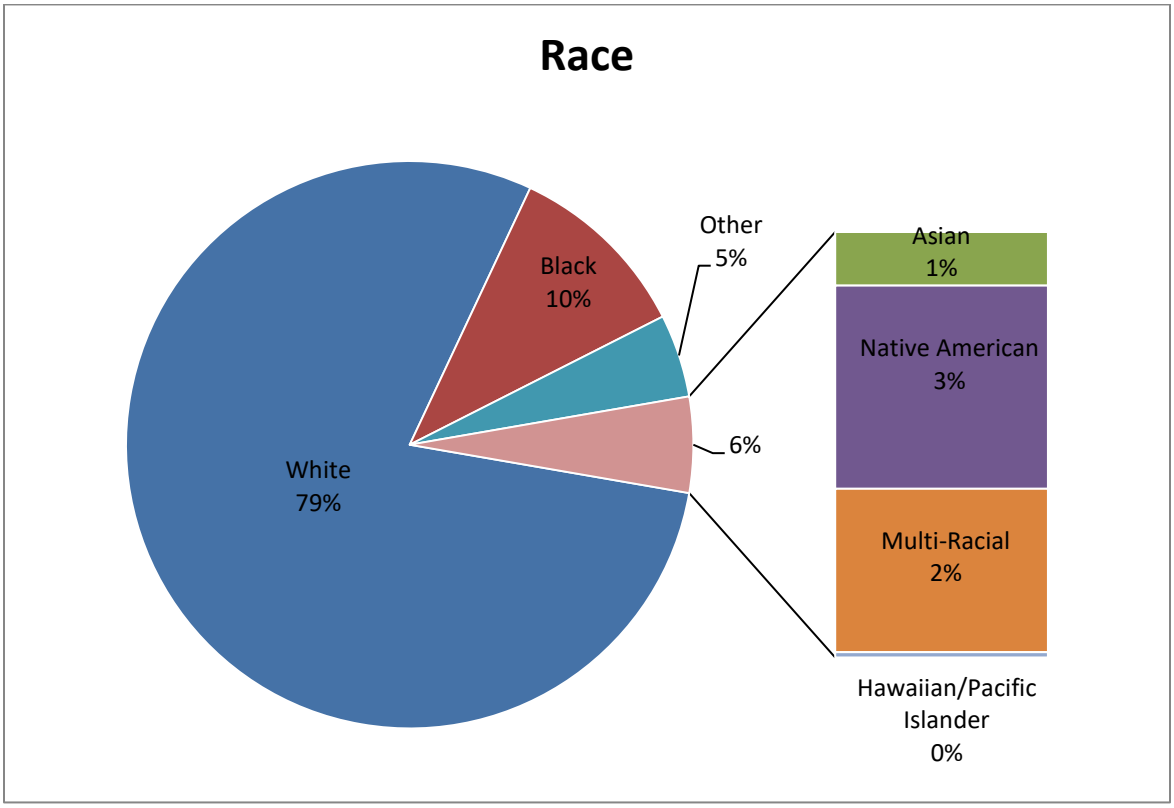

Figure 14: Population without access to a farmers' market: race percentages

Hispanic

The proportion of the population that is Hispanic and without farmers' market access was determined (Table 16). The resulting percentages are shown in Figure 14. These results are similar to the demographics of the population in proximity to a farmers' market.

Table 16: Total population without access to a farmers' market: Hispanic

Total Population	Hispanic
23,684,569	3,263,102

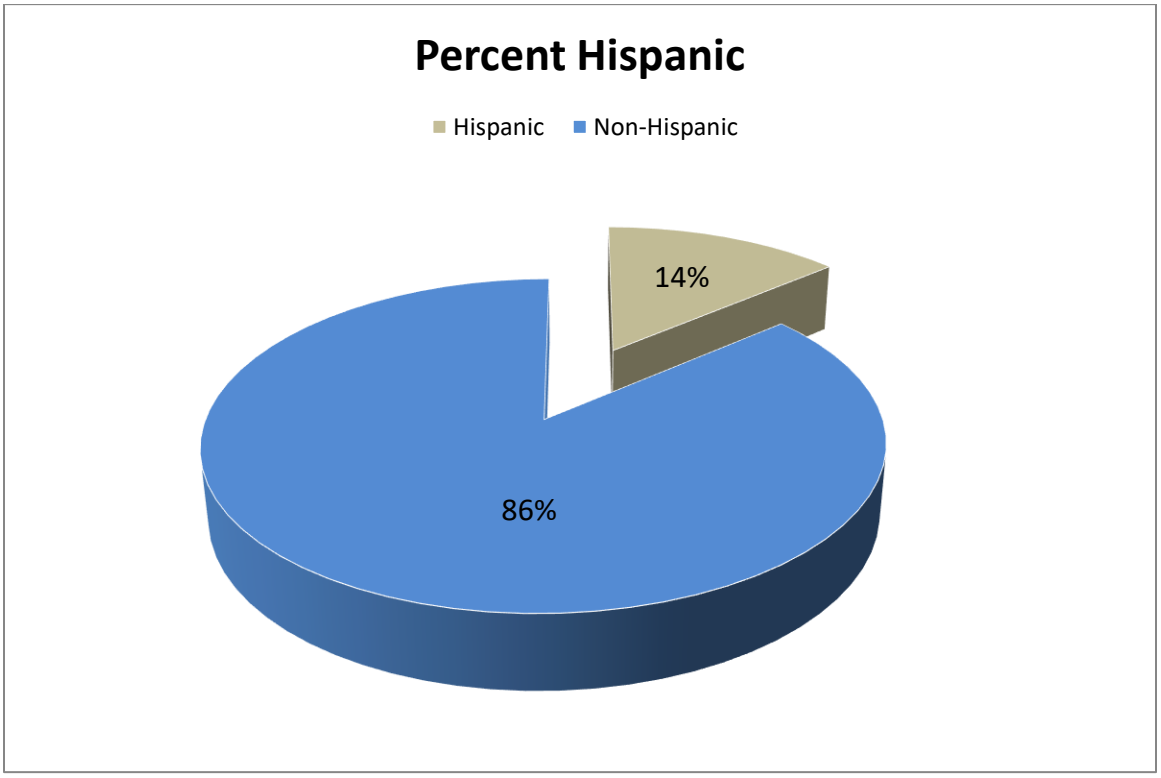

Figure 15: Population without access to a farmers' market: percent Hispanic

Occupied Housing Units

The proportion of the population without farmers' market access that lives in owner occupied or renter occupied housing units was determined (Table 17). The resulting percentages indicate that a higher percentage are owner occupied than renter compared to the population in proximity to a market.

Table 17: Total population without access to a farmers' market: total occupied units

Total Occupied Units	Owner Occupied	Renter Occupied
8,840,333	6,609,139	2,231,195

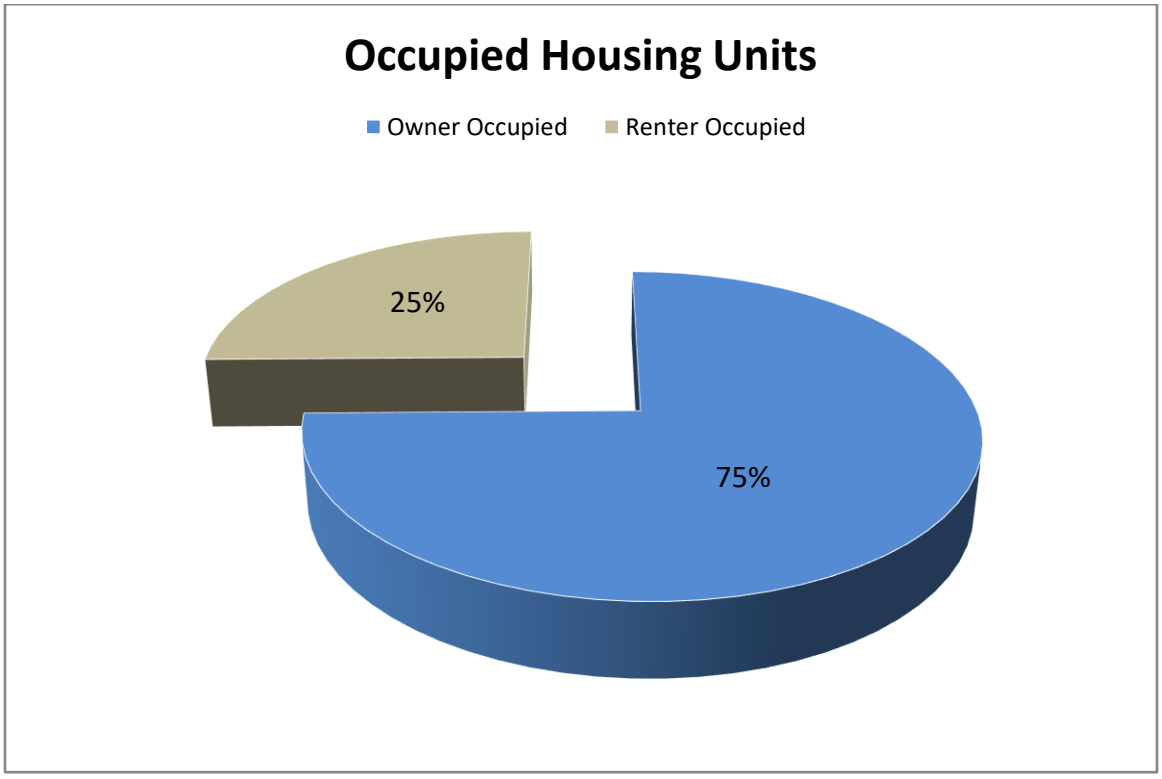

Figure 16: Population without access to a farmers' market: occupied housing

Median Age

The median age of the population without farmers' market access was determined in ArcGIS by averaging the median ages of the tracts. The average median age was calculated to be 41.0 years old, which is 2.9 years older than those in proximity of a farmers' market. Figure 17 shows the median age distribution.

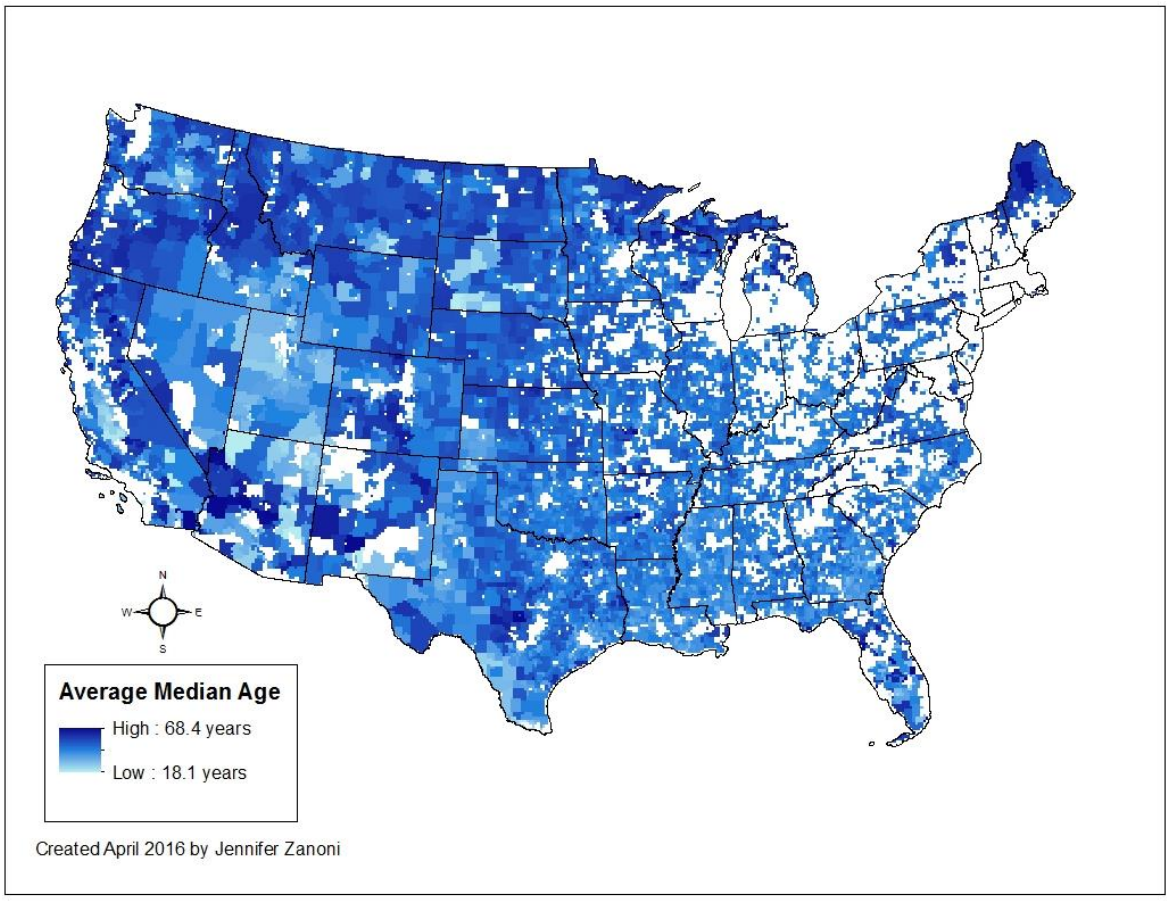

Figure 17: Population without access to a farmers' market: average median age

Household Size

The average household size of the population not in proximity of a farmers' market was determined in ArcGIS by averaging the mean household size of the tracts. The total average household size was calculated to be 2.57 people. Figure 18 shows the distribution of average household size. These results are similar to the demographics of the population in proximity to a farmers' market.

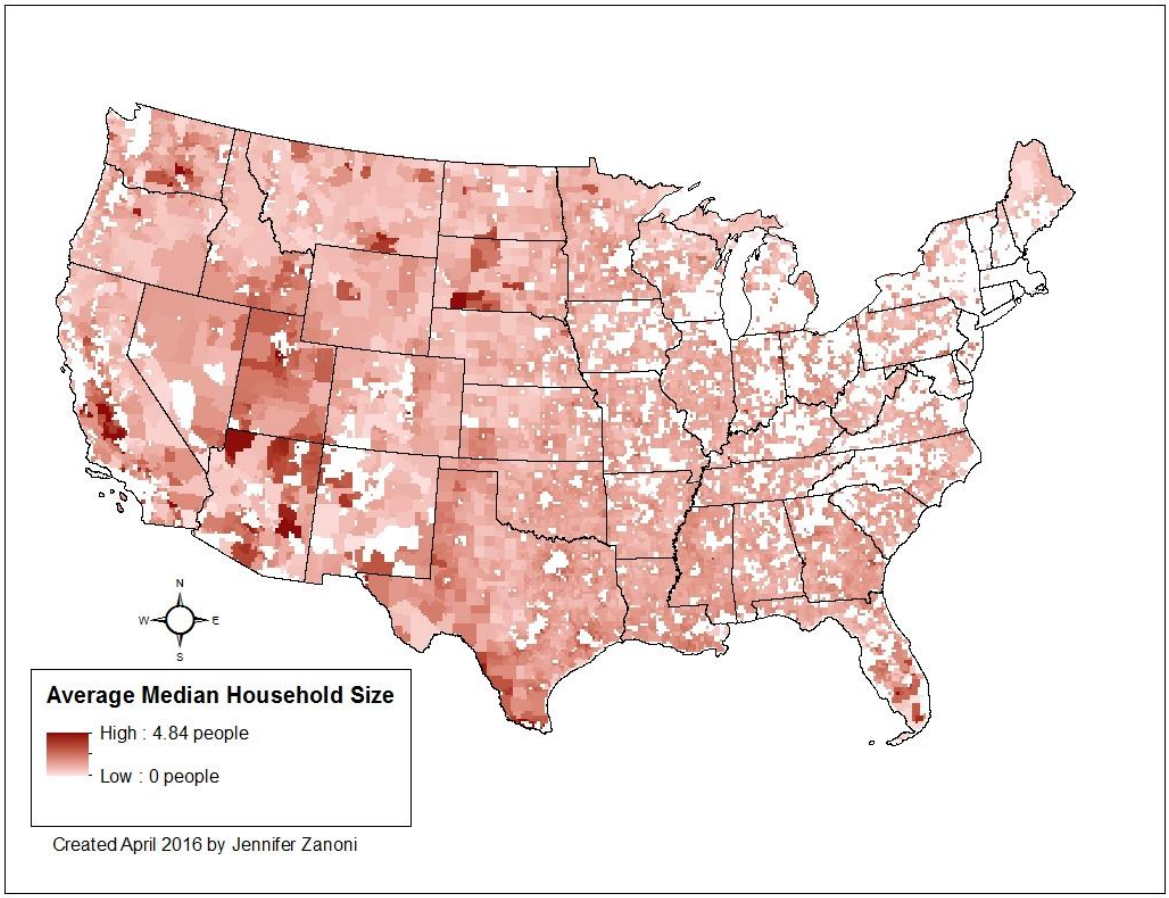

Figure 18: Population without access to a farmers' market: average household size

Median Income

The median income of the population not in proximity of a farmers' market was determined in ArcGIS by averaging the median incomes of the tracts. The total average median income was calculated to be $45,310, which is $10,706 less than the median income of the population within proximity of a market. Figure 19 shows the distribution of average median income.

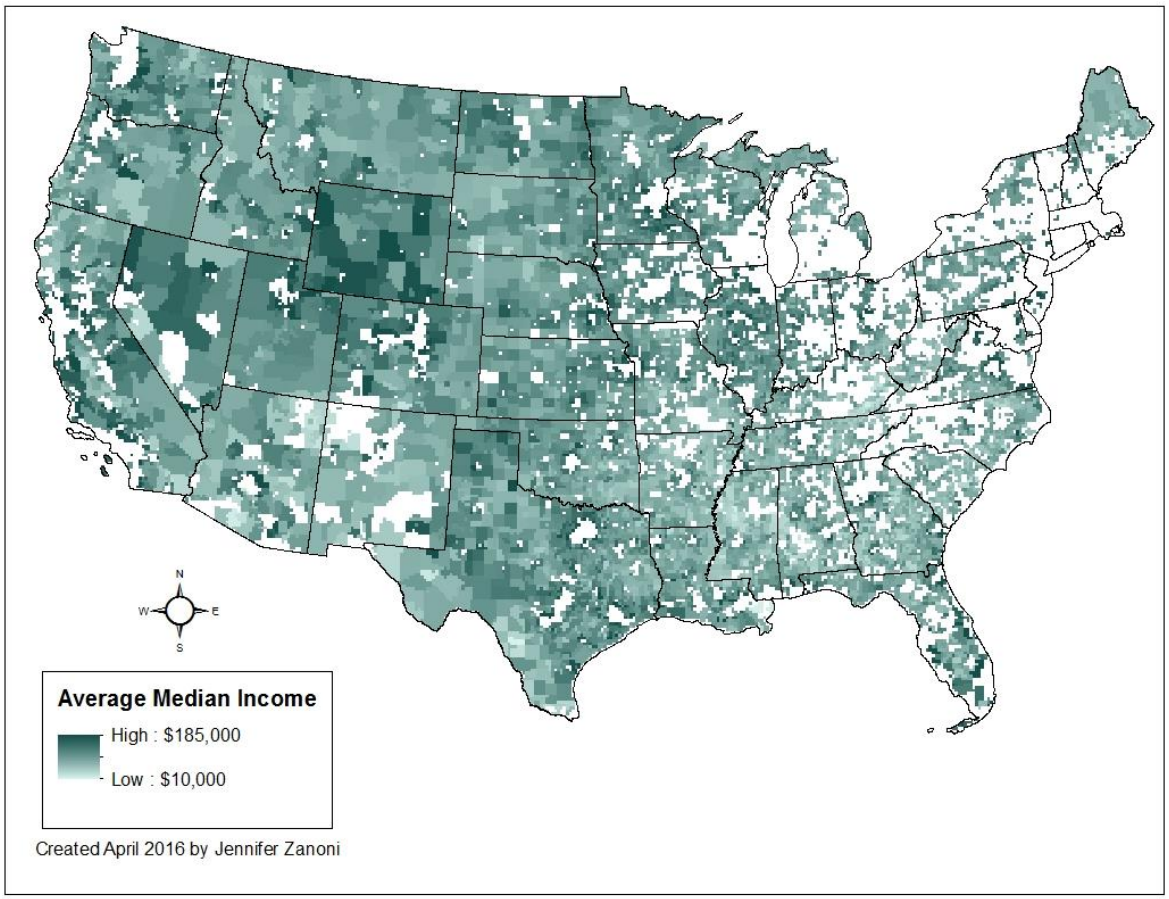

Figure 19: Population without access to a farmers' market: average median income

The following two demographic results pertain to poverty.

Poverty Level

The percent of the population living below the poverty line that is not in proximity of a farmers' market was determined (Table 18). The poverty level data was obtained from the 2010 American Community Survey Data. The resulting percentages are shown in Figure 20. These results show a slightly higher percentage are living below the poverty level than the population living in proximity to a market.

Table 18: Total population without access to a farmers' market: poverty level

Total Population	Below Poverty Level
23,684,569	3,319,484

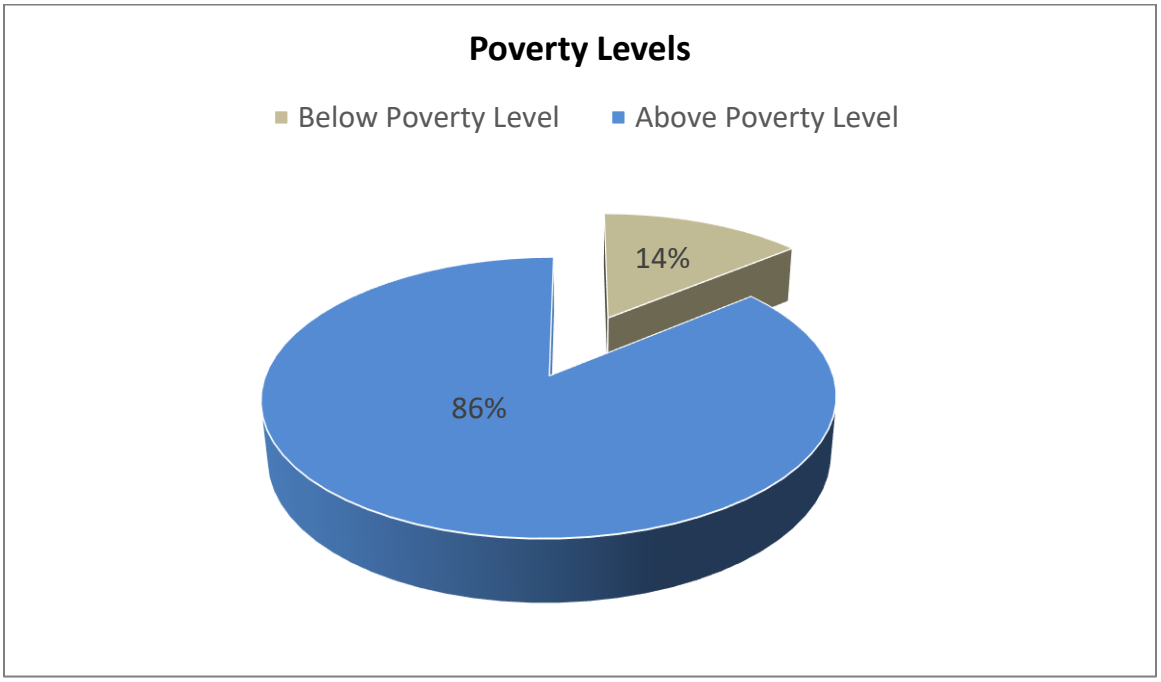

Figure 20: Population without access to a farmers' market: poverty level percentages

SNAP Benefits

The percent of the population using SNAP benefits that is not in proximity of a farmers' market was determined (Table 19). The SNAP benefit data was obtained from the 2010 American Community Survey Data. The resulting percentages are shown in Figure 21. These results indicate that a slightly higher percentage are receiving SNAP benefits than the population living in proximity to a market.

Table 19: Total population without access to a farmers' market: SNAP benefits

Total Population	Using SNAP Benefits
23,684,569	1,019,824

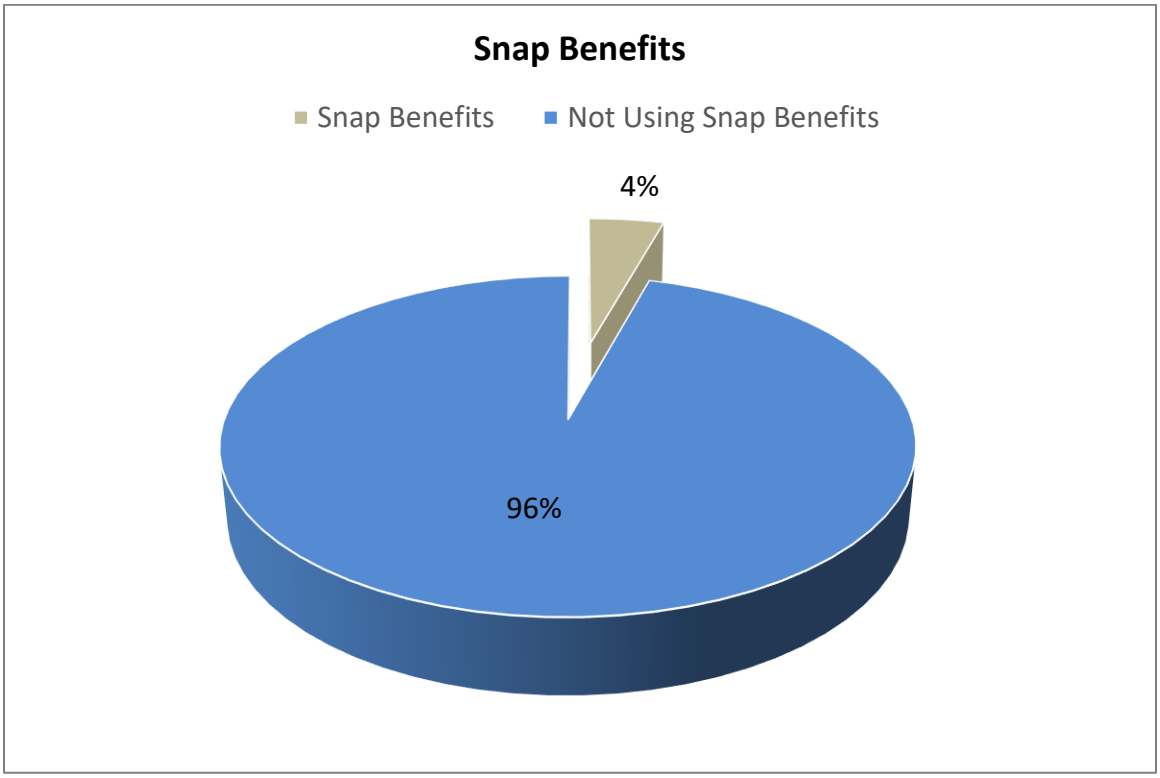

Figure 21: Population without access to a farmers' market: SNAP benefits percentages

San Luis Obispo County

To compare the dasymetric method results to the survey results of the 2005 Wolf *et al* study, the demographics of only San Luis Obispo County were analyzed. This data included age groups, gender, marital status, income levels, employment status, and education levels. As discussed previously, the income levels reported by Wolf *et al* are not bracketed in a way that correlates directly with the U.S. Census data. In the following sections, the results of this study are referred to as "Dasymetric" and the results of the Wolf *et al* study are referred to as "Survey."

Gender

The average gender of the population in proximity of San Luis Obispo County farmers' markets was determined. The resulting percentages and comparison to the Wolf *et al* study are shown in Figure 22. The dasymetric results show even gender percentages while the survey results a higher percentage of female shoppers.

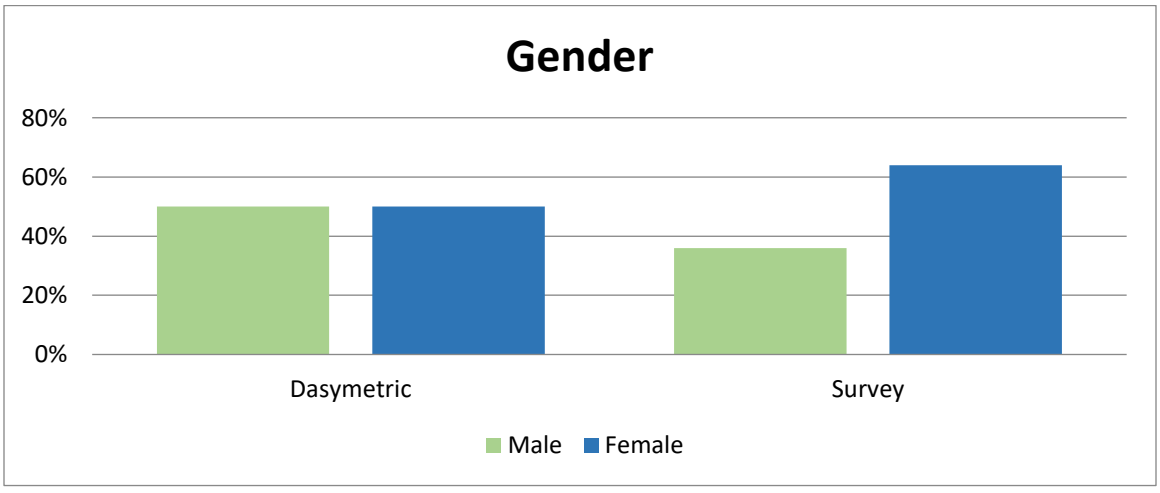

Figure 22: San Luis Obispo percentages: gender

Age

The average age group of the population in proximity of San Luis Obispo County farmers' markets was determined. The resulting percentages and comparison to the Wolf *et al* study are shown in Figure 23. The dasymetric method showed higher populations in the older age brackets, while the survey method indicated younger shoppers.

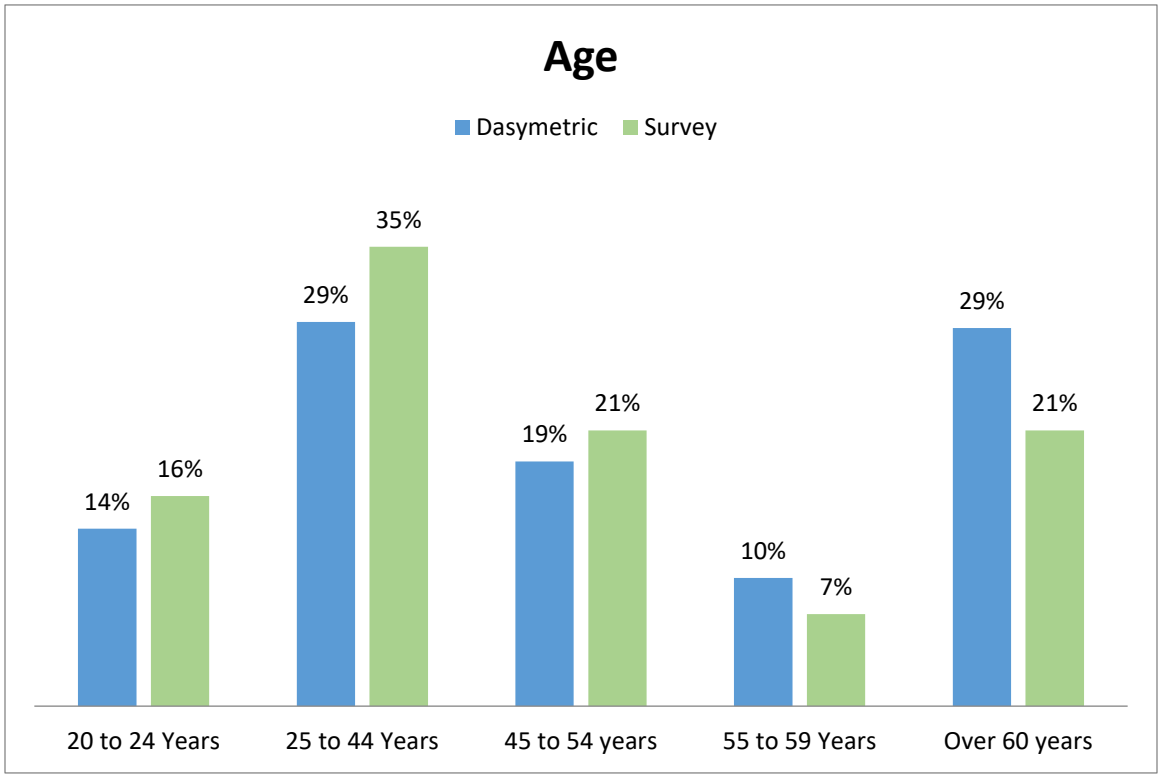

Figure 23: San Luis Obispo percentages: age

Marital Status

The marital status of the population in proximity of San Luis Obispo County farmers' markets was determined. The resulting percentages and comparison to the Wolf *et al* study are shown in Figure 24. The dasymetric method showed higher percentages of single and divorced while the survey method indicated more shoppers were married. The survey also included a "Living with a partner" category that did not align with the census data so no comparison could be made.

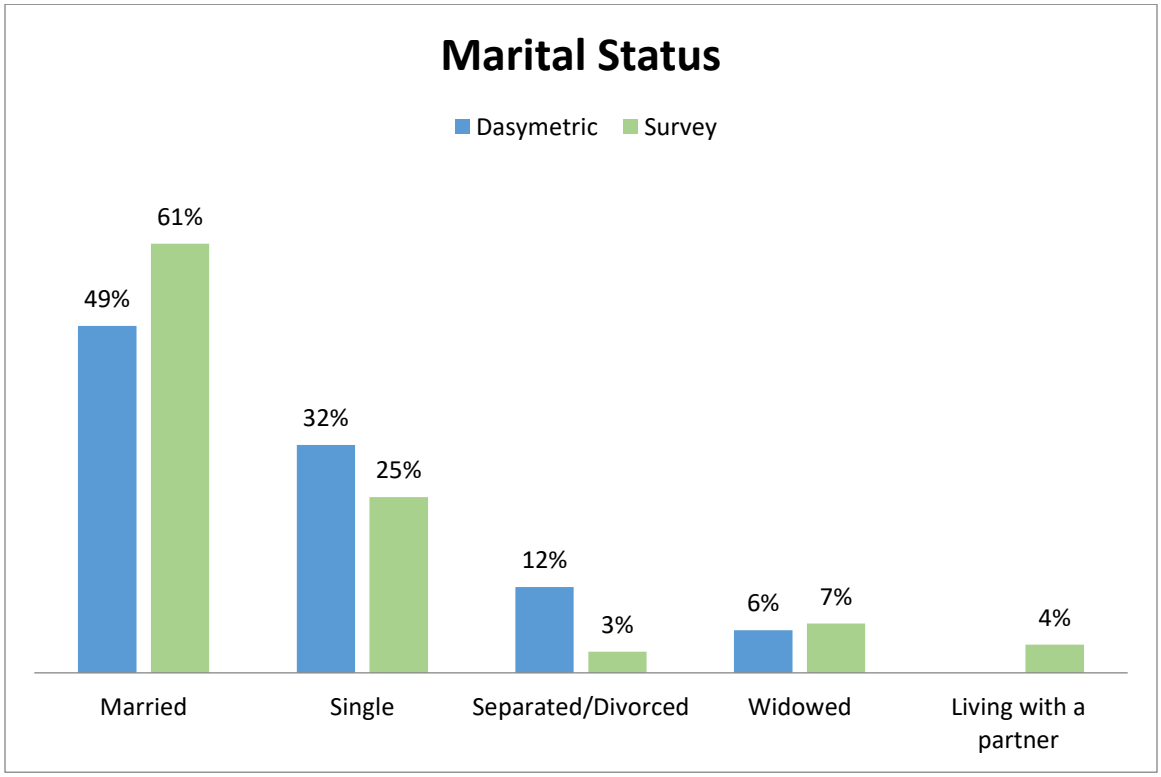

Figure 24: San Luis Obispo percentages: marital status

Education Levels

The education level of the population in proximity of San Luis Obispo County farmers' markets was determined. The resulting percentages and comparison to the Wolf *et al* study are shown in Figure 25. The results show a higher level of education with the survey than with the dasymetric method.

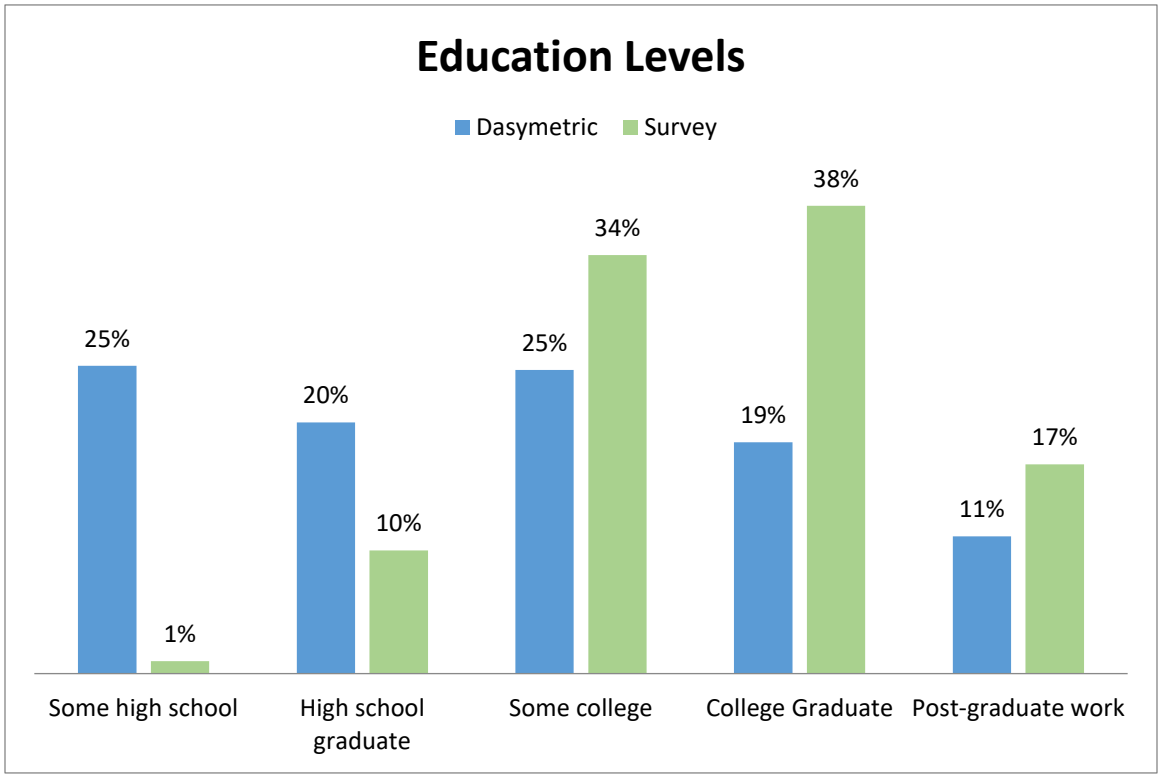

Figure 25: San Luis Obispo percentages: education levels

Employment Status

The employment status of the population in proximity of San Luis Obispo County farmers' markets was determined. The resulting percentages and comparison to the Wolf *et al* study are shown in Figure 26. While both results indicate the majority of the population is employed, the dasymetric method shows a higher percentage than the survey.

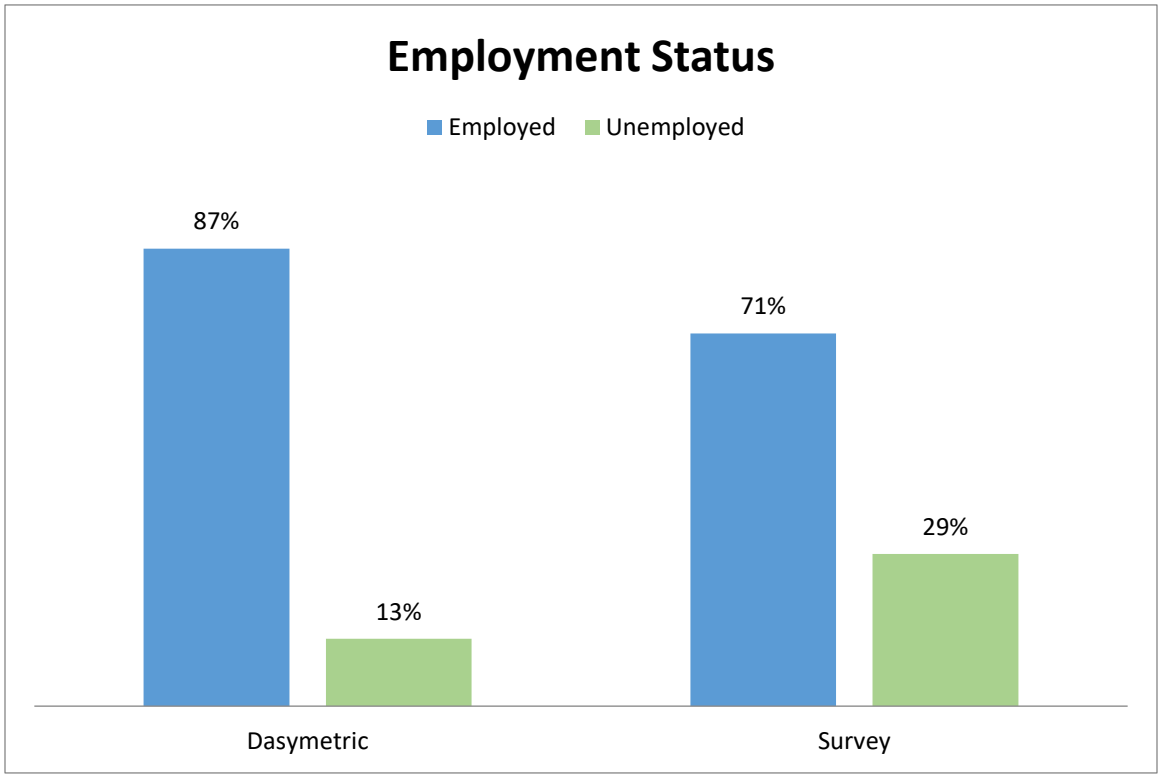

Figure 26: San Luis Obispo percentages: employment status

Income Levels

The income levels of the population in proximity of San Luis Obispo County farmers' markets was determined. The resulting percentages are shown in Figure 27.

The income levels reported by the Wolf *et al* study do not align with those reported by the U.S. Census Bureau making a side by side comparison impossible. The results of the Wolf *et al* study are shown in Figure 28.

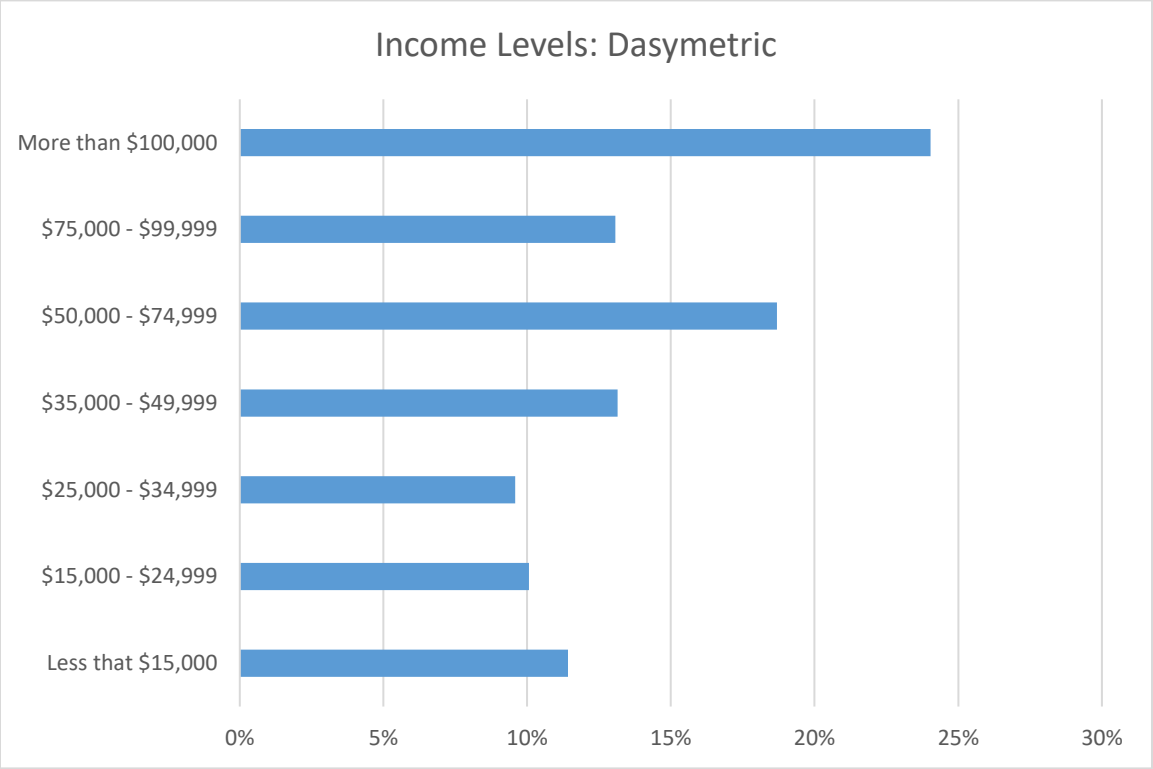

Figure 27: San Luis Obispo percentages: income levels (dasymetric)

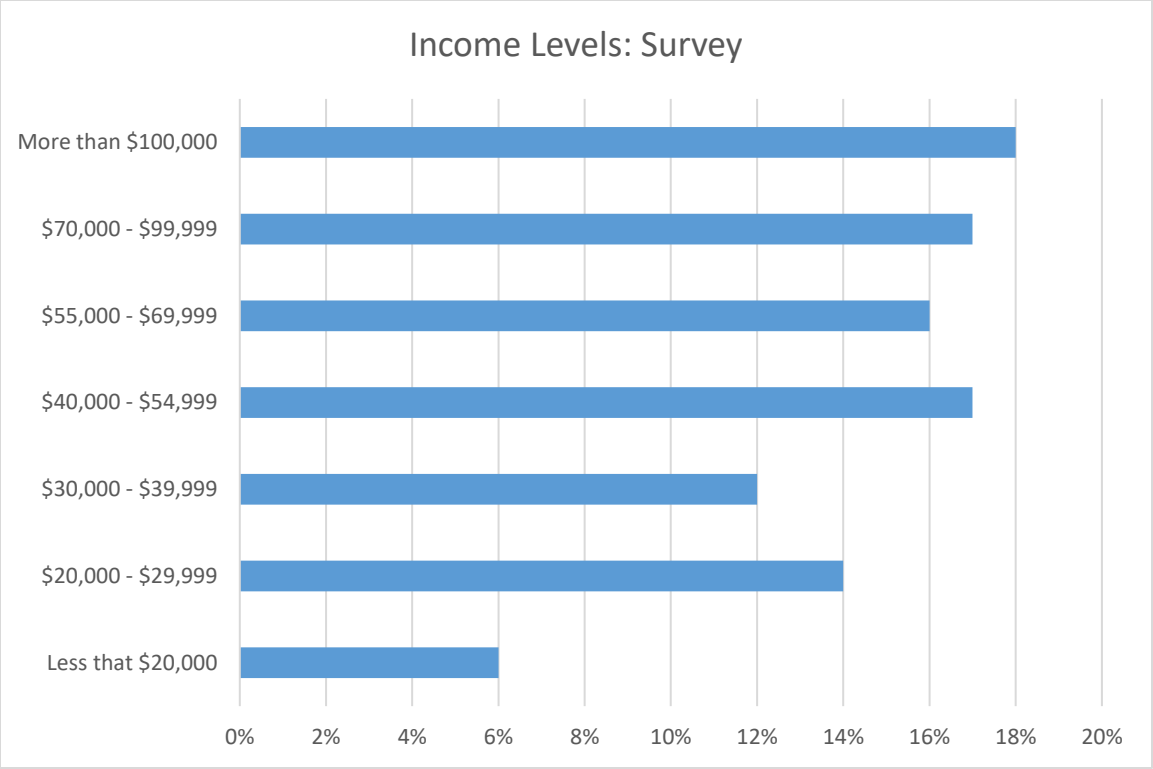

Figure 28: San Luis Obispo percentages: income levels (survey)

Chapter Five: Discussion and Conclusions

Summary of Findings

The object of this study was to determine the demographics with and without access to farmers' markets and to compare these results (using a dasymetric method) to previous research conducted by Wolf *et al* in San Luis Obispo County, California.

When evaluating the demographics with and without farmers' market access, most didn't show any differences from the national averages (Table 20). The percent of American Indians not served by a farmers' market was higher than the national average. The median income of those not served by farmers' markets was $5,834 less than the national average while those within proximity of a market had higher median incomes.

The results for SNAP benefits of those within proximity of a farmers' market and those without access both are much lower than the national average. These numbers indicate that an error was made in analysis. This error could not be identified and the reason for the low percentages is unknown.

When comparing the results of the dasymetric method in San Luis Obispo County to that of the county census averages, there weren't any major differences noticed (Table 21). The average demographic accessible to a farmers' market is almost equivalent to the average demographic of the entire county. This is likely due to the distribution of the population of within the county closely relating to the distribution of the farmers' markets.

Table 20: Results compared to national averages

	Farmers' Market	No Farmers' Market	2010 US Averages
Male	49.0%	50.5%	49.1%
Female	51.0%	49.5%	50.9%
White	65.6%	79.3%	75.0%
Black	11.6%	10.6%	12.3%
Asian	4.9%	0.7%	3.6%
Other	6.3%	4.7%	5.5%
American Indian	0.7%	2.6%	0.9%
Hawaiian / Pacific Islander	0.1%	0.1%	0.1%
Multi-Racial	10.6%	2.1%	2.4%
Hispanic	16.6%	13.8%	16.0%
Median Age	38.1	41.0	37.2
Household Size	2.6	2.6	2.58
Owner Occupied	61.0%	74.8%	65.1%
Renter Occupied	39.0%	25.2%	34.9%
Median Income	$56,016	$45,310	$51,144
Below Poverty Level	11.7%	14.0%	15.30%
SNAP Benefits	3.4%	4.3%	13%

The results of this study closely parallel the populations of urban vs rural more so than farmers' market vs. no farmers' market. This is due to the large customer travelled distances reported by the USDA. In urban areas, the buffers created around each farmers' market using these distance create overlaps of service areas. These service areas often cover entire cities even though it's unlikely that the populations in those areas all have access to a market. The east coast of the United States is one location where this problem was prevalent (Figure 29). All of Washington, DC and New York City are encompassed by the farmers' market service area. Interestingly, all but a small sliver of Delaware is also appears to be farmers' market accessible.

The question of the applicability of the dasymetric method used on national data is difficult to answer given the issues arising from the too-large service areas. Had these areas been smaller it would have been possible to assess the validity of the method but because the areas covered such large portions of the population, the demographics resulting from this method only reflected the demographics of the entirety of the country's urban areas.

Table 21: San Luis Obispo results compared to county averages

		Dasymetric	Survey	County Averages
Age	20 to 24 Years	13.5%	16.0%	13.2%
	25 to 44 Years	29.3%	35.0%	29.9%
	45 to 54 years	18.7%	21.0%	19.0%
	55 to 59 Years	9.8%	7.0%	9.7%
	Over 60 years	28.8%	21.0%	28.1%
Gender	Male	50.0%	36.0%	51.2%
	Female	50.0%	64.0%	48.8%
Marital Status	Married	49.3%	61.0%	48.6%
	Single	32.4%	25.0%	32.8%
	Separated/Divorced	12.2%	3.0%	12.6%
	Widowed	6.1%	7.0%	5.9%
	Living with a partner		4.0%	
Employment Status	Employed	87.1%	71.0%	87%
	Full Time	--------	52.0%	--------
	Part Time	--------	19.0%	--------
	Unemployed	12.9%	29.0%	12%
Education Levels	Some high school	25.0%	1.0%	25%
	High school graduate	20.4%	10.0%	21%
	Some college	24.7%	34.0%	24%
	College Graduate	18.8%	38.0%	18%
	Post-graduate work	11.1%	17.0%	10.85

Table 21 Continued

		Dasymetric	County Averages
Income Levels	Less than $15,000	11.4%	11.4%
	$15,000 - $24,999	10.1%	10.0%
	$25,000 - $34,999	9.6%	9.6%
	$35,000 - $49,999	13.1%	13.1%
	$50,000 - $74,999	18.7%	18.7%
	$75,000 - $99,999	13.1%	13.1%
	More than $100,000	24.0%	24.1%

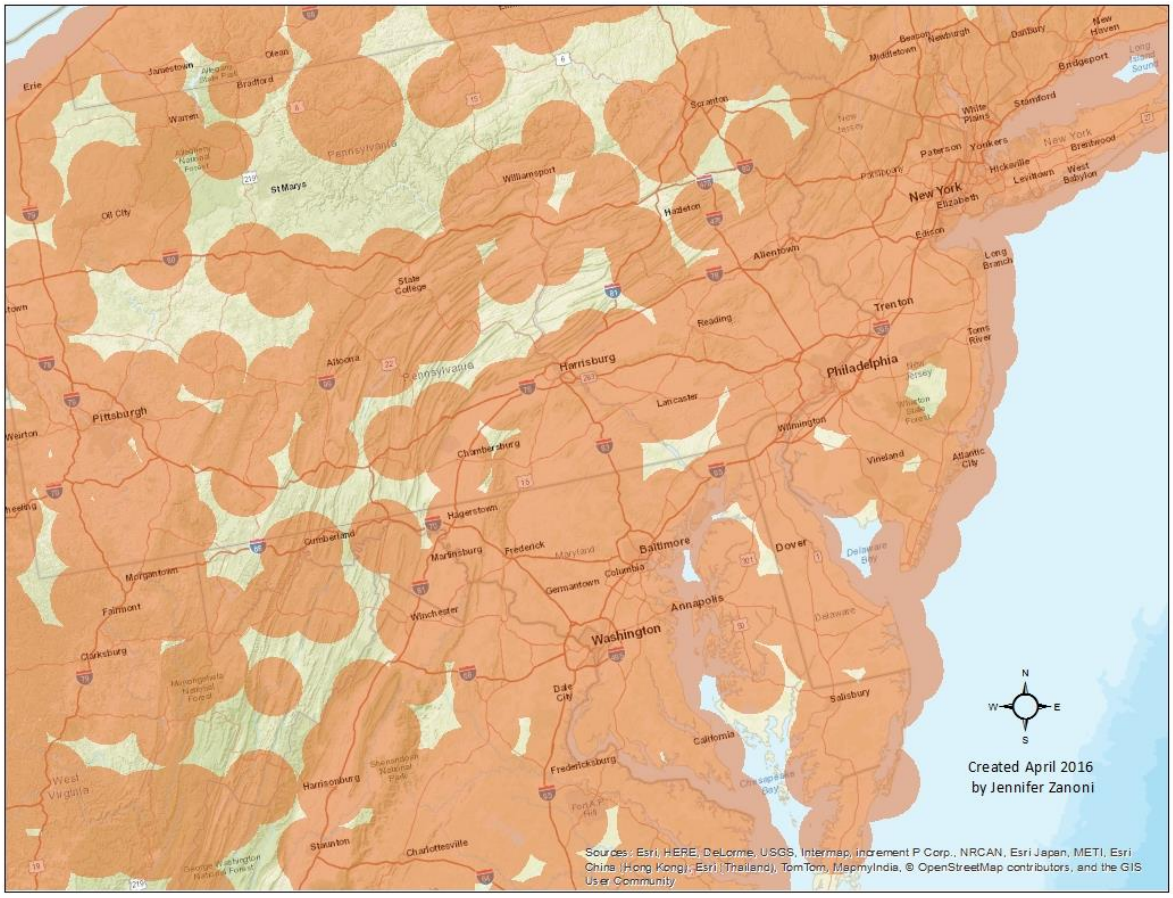

Figure 29: Farmers' market service area coverage

Limitations

This study is limited by the farmers' market data available. The USDA Farmers' Market Directory is voluntary, therefore, it is not possible to accurately know the total number of farmers' markets in the United States based on this directory. The directory information is not verified on a regular basis to assure that the markets listed are still active.

Another limitation on this study is the USDA consumer distance travelled information. This research was conducted using 2007 farmers' market data. At that point there were only 4,364 markets (Lohr 2011). As there are currently more than 8,000 markets, assumptions could be made that consumer's distance traveled has decreased. As this is the only known research at a national scale on the distance a consumer travels to a market, it is necessary for this thesis study, despite this limitation.

At a national scale, this study does not allow for an investigation into the accessibility of each farmers' market to the population within its designated service area. Access to public transportation or personal vehicles may be necessary to reach a given farmers' market. More localized studies would be able to evaluate the transportation available to specific towns and neighborhoods in order to determine the true accessibility of farmers' markets.

Future Research

While this research didn't produce significant demographic results, it does provide a framework for future research. A better determination of consumer distance travelled is necessary. In urban areas, the distances cited by the USDA create buffers that cover almost

entire cities and create significant overlaps with neighboring farmers' markets. It is the author's personal opinion that the distance travelled to a farmers' market in urban areas is much less than the USDA reported distances. Once the correct distance travelled was determined, it would be possible to use ESRI's Network Analyst to determine the true accessibility and demographics of a given farmers' market.

Another data source that could be used for a future study is ESRI's Tapestry Segmentation. This product has utilized census demographic data to create 67 segments for residential neighborhoods (ESRI n.d.-b). These segments are grouped by similar socio-economic characteristics and consumer trends (Figure 30). Utilizing this data would allow for a more in-depth analysis of demographics and consumer preferences.

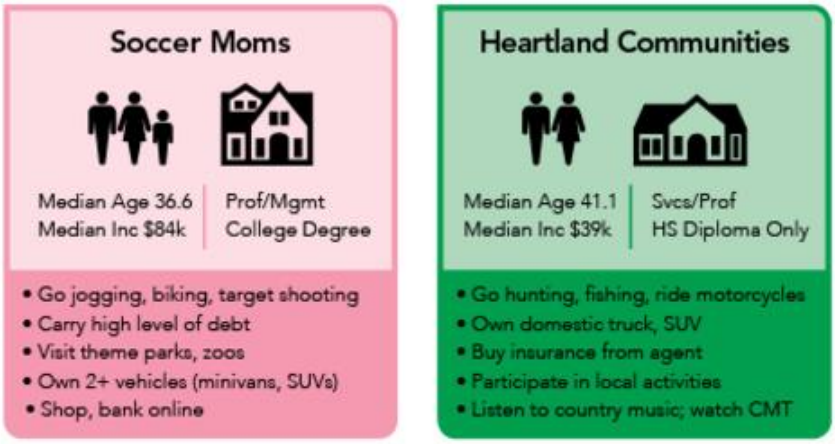

Figure 30: Tapestry segment examples (Esri n.d.-d)

Utilizing regional geography as a framework would be another possible method of future analysis. Different parts of the country have varying demographics and by focusing research on these areas it may be possible to normalize these geographic variances.

One limiting factor of farmers' market accessibility is time. Markets are offered at different times of the day or week and future analysis could look into these variables and how they affect the ability to shop at a market. Studies done using distance as opposed to travel time are unable to take into account differences in travel patterns that vary between urban and rural locations. Esri's ArcGIS Online offers a potential method of performing analysis utilizing travel time. The "enrich" tool enables a user to add demographic data to a user's dataset. A variety of demographic variables are available for enrichment and the tool offers a number of options for application. Two of the potentially most useful operations are the ability to enrich the data via "driving time" or "walking time" (Esri n.d.-a). These two functions could potentially eliminate the issue regarding farmers' market consumer distance travelled.

Previous studies have looked into spatio-temporal mapping and could provide a framework for additional research in regards to farmers' market accessibility. One study used this method to determine gender accessibility to urban opportunities (employment). Kwan (1999) sought to show that using space-time was a more accurate way of determining accessibility than locational proximity. The study utilized travel journals for 56 individuals and combined with a road network and parcel data, determined the accessibility of employment sites (based on parcel land use) via travel time. This study only included participants that owned vehicles and used them as a sole method of commuting to their

place of employment. This is a limiting factor in determining true accessibility as not all chose to or are able to utilize a personal vehicle.

Space/time methods could also be used to determine farmers' market accessibility on a localized scale. A multi-modal transportation network analysis could be used to determine travel time via pedestrian, public transportation or vehicle access. This could then be applied to different times of day or days of the week that each farmers' market was operating, thus indicating the spatio-temporal relationship of the farmers' markets and demographics.

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Appendix A: Detailed Methodology

1. Collect Data
    a. National Land Cover Database 2011 (NLCD). Available at http://www.mrlc.gov/nlcd11_data.php
    b. USDA National Farmers' Market Directory. Available at https://www.ams.usda.gov/local-food-directories/farmersmarkets
    c. U.S. Census counties and tracts (2010). Available at https://www.census.gov/geo/maps-data/data/tiger-line.html
    d. 2010 American Community Survey data. Available at https://www.census.gov/geo/maps-data/data/tiger-line.html
    e. 2013 Rural-Urban Continuum (RUC) Codes. Available at http://www.ers.usda.gov/data-products/rural-urban-continuum-codes.aspx
    f. Customer Traveled Distance data. Available at http://apps.ams.usda.gov/MarketingPublicationSearch/Reports/stelprdc5094336.pdf
2. Remove Alaska, Hawaii, and U.S. Territories from USDA National Farmers' Market Directory and counties and tracts.
3. Re-project shapefiles
    a. USA Contiguous Albers Equal Area Conic
4. Create geodatabase
    a. Load re-projected shapefiles
5. Create farmers' market Feature Class
    a. Open USDA National Farmers' Market Directory in ArcGIS
    b. Use X, Y coordinates to create feature class
    c. Re-project to USA Contiguous Albers Equal Area Conic
6. Join RUC codes to counties feature class
7. Create farmers' market buffers
    a. Spatially join farmers' markets and counties
    b. Create new field (float)
    c. Assign values to new field using Customer Traveled Distance data linked via RUC code

d. Create buffers using Customer Traveled Distance values

e. Dissolve buffers to create a farmers' market service area

8. Join 2010 American Community Survey data to tracts

9. Process NLCD

    a. Extract by value the developed areas (values 582, 583, 584)

    b. Reclassify raster to

    c. Convert raster to polygon

    d. Dissolve polygons (developed lands)

10. Areal Interpolation

    a. Clip Census tracts to developed lands polygons

    b. Calculate "Pre" area

    c. Clip Census tracts to farmers' market service areas

    d. Calculate "Post" area

    e. Recalculate demographic data

        i. Create an area multiplier (post area/pre area)

        ii. For each demographic field (except median age, average household size, and median income): area multiplier * original field value

    f. Spatially join tracts to farmer's market service areas using the merge policies in Table 7

11. Export table to Excel

    a. Calculate demographic percentages

        i. Demographic total/total population * 100