Understanding Accessibility to Snap-Accepting Food Store Locations: Disentangling the Roles of Transportation and Socioeconomic Status

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Abstract Research suggests that spatial inaccessibility to food stores adversely affects the health status of individuals living in predominantly low income or racial minority geographic areas. Previous studies examining geographic accessibility to food stores have focused on defining 'food deserts' using a variety of methods to map and quantify inaccessibility. However, the ability to afford and purchase healthy food must also be considered, and a scan of recent research reveals few studies that have accounted for the role of government assistance programs and how this might impact people's accessibility. In this paper, we analyze specific at-risk populations' accessibility to Supplemental Nutrition Assistance Program (SNAP) accepting locations using GIS-based estimates of specific personal transportation costs. In the U.S., the SNAP program attempts to alleviate food insecurity among low-income groups who qualify for assistance. We focus on understanding the relative accessibility of potentially vulnerable demographic populations as captured at the Census block group level and their potential ability to reach SNAP accepting food store locations. A mid-sized city in Florida is used as a test case. Network-based approaches are employed using GIS to gauge accessibility in terms of walking, automobile, and public transit modes. Ultimately, we seek to better understand possible differences in accessibility across socioeconomic groups, emphasizing characteristics such as vehicle ownership, race, and income, while recognizing the importance of the SNAP program. Findings suggest that higher income, high vehicle access, and white populations are more accessible to food opportunities than lower income, low vehicle access, and African American populations and potential policy implications of this work include whether certain transportation costs should be subsidized for individuals receiving SNAP benefits.

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Introduction

Food environment research has increasingly shown that access to food stores affects individual purchases, food intake, and health status (Chang 2006; Pathania 2009; Walker et al. 2010). Much of this research involves identifying 'food deserts', where studies seek to define areas or neighborhoods that have inequitable access to food retail locations with healthy and nutritious food choices (Gatrell et al. 2011; White 2007). Geographical analyses of food availability may have a significant effect in reversing the rising trend of obesity seen in poor and minority populations who often tend to reside in food deserts (Cummins and Macintyre 2002; Rose et al. 2009). This is because food availability is often discussed in terms of *accessibility* where the distance or costs required to visit food stores is quantified in order to identify possible inequities across populations (Larsen and Gilliland 2008) .

Despite the acknowledged importance of food accessibility research, there still remain critical gaps in our understanding between the associations of food insecurity, population characteristics, and inequitable neighborhood access. Overwhelmingly, studies have shown that lower income groups incur greater costs due to inequitable geographic access (Rigby et al. 2012; Rose et al. 2009; Walker et al. 2010). These costs can include longer distances and times required to visit food retail stores due to the physical locations of the stores or a lack of sufficient transportation alternatives available (Rose and Richards 2004).

The Supplemental Nutrition Program (SNAP) seeks to eliminate or minimize food insecurity by providing access to nutritious food in the form of financial benefits (Andrews et al. 1999). Here, food insecurity is described as the unavailability of nutritious food (Andrews et al. 1999). Unfortunately, researchers have found that food insecurity often does not decrease for households enrolled in the SNAP program (Nord et al. 2009). One reason households receiving SNAP benefits do not experience the optimal benefits of this program may be due to spatial or geographic inaccessibility to SNAP accepting retail locations (Rigby et al. 2012). While SNAP benefits assist household nutrition status by covering the cost of nutritious food, they do not account for the transportation costs (i.e., time and distance) incurred when traveling to SNAP retail locations to make purchases.

To this point, few studies have analyzed people's accessibility to SNAP accepting food stores (Rigby et al. 2012; Rose et al. 2009). Even fewer studies examine access to the various categories of stores where food is sold (Rigby et al. 2012). Food stores differ across categories and carry vastly different food products at different prices. Using geographic information systems (GIS) based methods, this paper examines potentially vulnerable population's accessibility to SNAP accepting stores by automobile, transit, and walking in Leon County, Florida, a smaller Metro area. Ultimately, the goal of this paper is to understand possible inequities in terms of access to different categories of SNAP accepting stores across different socioeconomic groups, including controlling for vehicle ownership, race, and income.

Background and Literature Review

SNAP and Food Deserts

Since 1969, the U.S. government has attempted to combat nutritional inequalities among low-income households and effectively tried to correct disparities with monetary benefits known as food stamps. In 2008 the Food stamp program became the Supplemental Nutrition Assistance Program (SNAP) and is the largest federal food assistance program in the United States (Bonanno and Ghosh 2010). The U.S. Department of Agriculture (USDA) estimates how much it would cost to buy food in order to prepare nutritious, affordable meals, and these estimates determine the amount of food assistance benefits a family or individual receives. These benefits are not provided in the form of cash but instead are distributed on an electronic card where recipients can use it as they would use a bankcard(United State Department of Agriculture (USDA 2012). Benefits are only distributed to "households." For example, individuals who purchase and prepare their food together are considered one household for food assistance purposes and their eligibility to receive benefits is determined as a group. In order to receive benefits the Food Assistance Program counts most types in order to assess whether a household is eligible for benefits or not. The total monthly gross income of a household is compared to a percentage of the federal poverty level (United State Department of Agriculture (USDA 2012). Households are able to use their benefits in order to purchase breads and cereals, fruits and vegetables, meats, fish, and poultry, dairy products, and seeds and plants to grow and produce food for the household to eat (Andrews et al. 1999).

Despite efforts by the USDA and SNAP to relieve these conditions there is evidence to suggest that insecurity does not decrease once a household has enrolled in the program (Nord et al. 2009; Rigby et al. 2012). In 1999, the USDA commissioned a comprehensive survey attempting to understand Food Stamp participants' access to food retailers. It found that approximately one third of SNAP recipients do not shop within their immediate vicinity because grocery prices tended to be higher and there was an absence of SNAP accepting retail locations (Ohls and Ponza 1999). The study also acknowledged other factors that may prevent a SNAP recipient from being able to access a retail store with a variety of nutritious foods. These factors may include lack of a personal vehicle, inaccessibility to public transportation, and absence of SNAP accepting retail locations within a recipient's neighborhood (Ohls and Ponza 1999; Rigby et al. 2012; Rose and Richards 2004). The most common reason cited for SNAP households to shop outside of their neighborhoods is a lack of nearby stores and higher prices at neighborhood stores (United State Department of Agriculture (USDA 2012).

It has been hypothesized that vulnerable populations, such as those who redeem SNAP benefits, may suffer from spatial barriers to accessing food stores. Here it is argued that a broader range of methods should be brought to bear on measuring food accessibility in the SNAP context. This would allow new insights into questions such as whether the subsidization of travel costs to and from food stores, specifically for households already receiving SNAP benefits is warranted (Apparicio et al. 2007; Gatrell et al. 2011). The subsidization of travel costs could come in the form of financial reimbursements for the time and distance it takes for SNAP recipients to reach food stores.

Measuring Accessibility

Accessibility is a fundamental concept for researchers in fields such as urban planning, engineering, and geography. It captures the ease with which a site or service may be reached or obtained, either from the perspective of people making the trip or the locations to be visited (Handy and Niemeier 1997; Kwan 1998; Mcallister 1976; Miller 2007; Morrill and Symons 1977). There have been many approaches developed to conceptualize accessibility, which have evolved during the last few decades (Handy and Niemeier 1997; Kwan 1998; Nicholls 2001; O'Kelly and Horner 2003). For the purpose of measuring accessibility to food stores, a place-based perspective is most appropriate. These measures are readily quantifiable, summarized, and easily mapped, which enables one to better understand the spatial distribution of the population and the time necessary to reach SNAP accepting locations. Place-based measures are derived from the original Hansen framework which is as follows (Horner and Mefford 2005):

$$A_i = \sum\nolimits_{j=1,\ i \neq j}^{m} O_j f\left(C_{ij}\right) \qquad (1)$$

Where:

A_i is the accessibility at origin i
O_j is the opportunities at destination j
$f\left(C_{ij}\right)$ is a function of the generalized travel cost from i to j.

The basic equation above serves as a starting point for our analysis. It may be implemented in various ways according to constraints, needs, etc. in a GIS environment and has been utilized in numerous studies, including those that have focused on accessibility to food stores (Apparicio et al. 2007; Cervero et al. 1999; Horner and Mefford 2005; Larsen and Gilliland 2008; Pearce et al. 2006; Talen and Anselin 1998). In Eq. (1), accessibility scores at a given location, (A_i), are positively affected by greater opportunities (O_j) and diminished by rising travel costs (C_{ij}).

Besides implementations of the accessibility model in (1), researchers interested in assessing food store accessibility have used other techniques. For those exploring food store availability, one can estimate the overall distribution of stores within a neighborhood, where census tracts or other geographical units are typically used as a proxy for boundaries (Rigby et al. 2012; Smith et al. 2010; Walker et al. 2010; Zenk et al. 2005). This approach assumes that if there is a certain number of food stores within the boundaries of a given geography then people in the neighborhood have access. However, this view is problematic because it does not take into account the distance or costs between people and stores. Buffering approaches represent another class of GIS-based methods that are often utilized to measure food store accessibility. Here, a buffer is a predefined unit area constructed around census spatial units, where specific features (e.g., retail food stores) are identified within the buffer area boundary (Larsen and Gilliland 2008; Walker et al. 2010).

Generally speaking, metrics that utilize network analysis techniques are considered most preferable, whereby roadways, routes, and paths are modeled within a GIS and used to determine the distance and time an individual may travel between origins and desired destinations (Apparicio et al. 2007; Larsen and Gilliland 2008). Larsen and Gilliland (2008) have explored accessibility through network analysis by bus, walking,

and automobile from a census tract as the origin and to supermarkets as the destination in their study concerned with identifying food deserts in London, Ontario. Researchers have noted that not all individuals choose to travel to places within their immediate vicinity, sometimes traveling directly outside of their neighborhoods(Kent 2014; Rose et al. 2009). While shortest path distance and time are not the only variables associated with travel costs, they serve as a starting point for understanding the basic movements associated with travel decisions.

There have been some papers looking at the link between the spatial distribution of retail stores that supply healthy foods and SNAP recipients (Rigby et al. 2012; Rose et al. 2009). For example, Rigby et al. attempted to examine whether neighborhood characteristics of race, income, and rurality were related to the distribution of SNAP accepting retail stores in Leon County, FL. Another study conducted by Rose et al. (2009) in New Orleans, explores the potential for subsidizing travel expenditures for SNAP recipients by estimating travel costs to the nearest supermarket. However, none of these studies have looked at different forms of transportation when accessing SNAP accepting stores.

In conclusion, food accessibility research has gained considerable momentum in recent years due to the increasing interest in food deserts research (Walker et al. 2010). Policy makers and researchers have made efforts in order to identify possible interventions to poor health outcomes revolving around food insecurity (USDA 2012). The majority of neighborhood food access studies have found that vulnerable population groups tend to reside in food deserts (Walker et al. 2010). Since many of the characteristics of the populations residing in food deserts are similar to the demographics of individuals relying on SNAP benefits it is possible that food insecurity persists among SNAP recipients due to inaccessibility to food stores that provide healthy foods. Our study explores the relative accessibility to four different categories of SNAP accepting stores at the block group level for specific demographic groups of interest. It differs from past studies by examining accessibility by walking, transit, and driving at the census block group population level. This analysis also differs by disaggregating SNAP accepting food stores according to their selection of healthy foods. Methods and data for our analysis will be discussed in the following section.

Data and Methods

Geographic and Demographic Data

This study is conducted in Leon County, Florida, which encompasses Florida's state capital, Tallahassee, and some rural areas. According to the US Census Bureau the total population of Leon County in 2010 was 283,769. All road linkages and 169 census block groups contained within the borders of Leon County are used in the accessibility analysis. Population subgroups at the block group level are the basis for SNAP accepting food stores demand. These particular subgroups, race, income, and vehicle ownership, were chosen based on attributes that have been associated with food desert populations. Census block groups and associated demographic data were retrieved from Nielsen Claritas P-Census estimates ("PCensus 9.1 for ArcView," 2009). These estimates are for the year 2009 and are based on demographic data from the 2000 U.S.

census. Road network data for Leon County, Florida were taken from Census TIGER line files, which include all highway, interstate, and local streets necessary for the analysis.

SNAP Accepting Retail Stores Data

Baker and Schootman (2006) and Rigby, et al. (2012) used the USDA's guidelines to determine stores, which accept SNAP benefits and also have sufficient healthy food for sale. This paper uses similar methods for determining whether a SNAP accepting retail store allows individuals to access the foods that enable healthy eating. The USDA (2012) and Florida Department of Agriculture and Consumer services (FDAC) (2009) groups SNAP accepting stores into multiple categories based on the availability of fruits and vegetables, square footage, annual sales, and the number of checkout lanes. A complete listing of 227 SNAP accepting stores and their corresponding addresses within Leon County was obtained from the USDA's SNAP retail locator (United State Department of Agriculture (USDA). Food and Nutrition Service. 2013). Store locations were geocoded into a GIS environment using the addresses provided by the retail locator. Each of the 227 SNAP accepting stores within Leon County have been examined and grouped into their respective category in Table 1.

Other stores and supermarkets tend to provide a larger variety of fresh fruits and vegetables compared to the grocery stores, specialty stores, and convenience stores (Walker et al. 2010). These foods also tend to be less expensive at these larger stores. Ideally, SNAP recipients would want adequate access to stores that have the least

Table 1 Description of SNAP accepting store types and number of stores in each category

Type	Number of Stores (% of total Stores)	Description
Description	227	
Other (Supercenters and Warehouse Club Stores)	10 (4.4 %)	Large retail chain stores that include groceries but food is not their main retail item. Examples include Wal-Mart, Target, and Costco.
Super markets	20 (8.8 %)	Large retail food stores that carry predominantly food and have a wide variety of fruits and vegetables. Have a larger square footage and reported over 2 million dollars in sales annually.
Grocery stores and specialty stores	26 (11.5 %)	Small retail food stores that carry predominantly food. These stores have a smaller selection and limited variety of food. Also, have a smaller square footage and less than 2 million dollars in sales annually. Examples include butchers, fish markets, and bakeries.
Convenience stores	171 (75.3 %)	Small retail stores known as gas stations, drug stores, or convenience stores. Do not usually carry fresh fruits or vegetables and have limited food items.

expensive and largest variety of healthy foods. We look at accessibility to each of these categories of SNAP accepting food stores separately in order to ascertain how each population is served by particular types of SNAP accepting retail outlets.

Leon County Demographic Classifications

This study classifies block groups according to their demographic characteristics associated with race, income, and vehicle ownership. In determining the racial classification of a single census block group the proportion of African Americans determines the classification of a block group as African American, Mixed, or White. This classification approach was originally used in Rigby, et al.'s (2012) investigation of the distribution of SNAP accepting stores across census tracts in Leon County and they are replicated here for comparability. In this system, mixed block groups have between 20 and 80 % African American residents, white block groups had less than 20 % African American residents, and African American block groups had more than 80 % African American residents. Income classification was determined according to the population living under the federal poverty level and it too was based on the same divisions used in Rigby, et al.'s study conducted on Leon County. High-income census block groups consisted of a higher proportion of the population (>9.25 %) living above the poverty level and low-income census block groups had a higher proportion of the population (<9.25 %) living below the poverty level. For the purposes of comparing populations with high vehicle access, we based vehicle ownership on the proportion of households that do not own a vehicle where low vehicle ownership consisted of census block groups who had 15 % or more of the population with no vehicle, and the high vehicle ownership classification was assigned to census block groups with 15 % or more of the population with vehicle access.

Automobile and Walking Accessibility Measures

Accessibility to SNAP accepting retail stores will be conducted using methodologies that rely on well-defined accessibility measures (based on Eq. 1) estimated within a GIS environment. Time is adopted as a cost metric because it represents the most realistic assessments of making journeys to SNAP accepting stores. Trips are assumed to begin from the centroids of their respective census block group. Accessibility will be analyzed using three different modes: walking, automobile, and transit. Accessibility to each of the four different categories of SNAP accepting stores will be measured separately in order to understand access to SNAP accepting stores that offer the most variety in terms of nutritious food. The first measure, time from the block group to the closest SNAP accepting store in each category, will be assessed to determine the immediate proximal opportunity. The second measure adapts Eq. (1) to determine the cumulative opportunities available to a given census block group within some time budget or threshold (O'Kelly and Horner 2003).

The number of SNAP accepting stores within 10 and 20 min by walking, 10 and 20 min by automobile, and 10 and 20 min by transit of spatial units will be evaluated. This will determine the diversity and variety of SNAP accepting stores within the immediate neighborhood vicinity. These thresholds were chosen based on similar

values found in the literature (Jiao, Moudon, Ulmer, Hurvitz, and Drewnowski 2012; Larsen and Gilliland 2008).

A network based GIS accessibility measure was used to define the census block groups within Leon County that do not have sufficient access to the FDA's recommended dietary foods. Geometric centroids were created for each census block group within Leon County. This geographic point is assumed to be the origin for residents residing within each census block group. For measuring accessibility to SNAP accepting stores by automobile, the GIS software TransCAD was used with a local street network developed from U.S. Census TIGER centerline files. Road speeds were estimated for each line segment using Census Feature Class Codes (CFCC). For each category of SNAP accepting stores a cost matrix was created for the estimated time and distance it takes to travel from each SNAP location to each census block group centroid. Accessibility by walking was also estimated assuming a maximum speed of three miles per hour.

Transit Accessibility Measures

For the public transit accessibility analysis, data on individual stop locations, schedules, and segment times were not readily available and a transit network model could not be constructed. As a substitution, a pre-computed travel time matrix was obtained from Star Metro (2,013). Star metro is the transit operating system for the City of Tallahassee. This matrix contains the travel costs or time in minutes at the Traffic Analysis Zone (TAZ) level from and to each origin and destination TAZ. The transit matrix contains data on the time it takes to travel from all TAZ centroids to all other TAZ centroids by bus within Leon County. The corresponding GIS shapefile consists of 548 TAZs– substantially more units than the 169 census block groups. In order to attain transit times from SNAP accepting stores and Census block group centroids, aggregation of the TAZ data was a necessary step. On the origin side, each census block group centroid was assigned to its closest TAZ centroid while on the destination side each SNAP accepting store location was assigned to its closest TAZ centroid. As such, transit travel costs should be considered less representative when compared with the estimates of the walking and automobile travel costs.

Results

Demographic Characteristics of Categorized Census Block Groups

Table 2 shows demographic characteristics for census block groups categorized according to low and high income, low and high vehicle access, and the level of African American, mixed, and White populations. Block groups classified as 'African American' have the highest proportion of residents in poverty (31.3 %), the highest proportion of residents without a vehicle (26.1 %), and the lowest proportion of residents with a Bachelor's Degree over age 25 (10.1 %). The demographic characteristics of low income, African American, and low vehicle ownership block groups highlight many of the inequities people living there face when compared with residents residing in white, high vehicle ownership, and high income block groups. These groups

Table 2 Demographic characteristics for low and high income, African American, mixed, and white, and low vehicle ownership and high vehicle ownership census block group categories

	Total (s=169)	African American (s=17)	Mixed (s=83)	White (s=69)	Low income (s=84)	High income (s=85)	Low vehicle ownership (s=33)	High vehicle ownership (s=136)
Land area	701.794	6.123	204.049	491.622	364.387	337.407	44.346	657.448
Total population	271,708	17,189	135,401	119,118	118,157	153,550	34,244	237,464
Total households	113,378	6,215	60,852	46,311	50,757	62,621	14,102	99,276
Total families	63,790	3,513	27,889	32,388	21,283	42,507	5,566	58,224
White	170,796	819 (4.8 %)	69,133 (51.1 %)	100,844 (84.7 %)	55,376 (46.9 %)	115,420 (75.2 %)	12,471 (36.4 %)	158,325 (66.7 %)
African American	84,716	15,936 (92.7 %)	56,888 (42.0 %)	11,892 (10 %)	55,030 (46.6 %)	29,686 (19.3 %)	19,784 (57.8 %)	64,932 (27.3 %)
Female	140,381	9,116 (53.0 %)	69,870 (51.6 %)	61,395 (51.5 %)	60,739 (51.4 %)	79,642 (51.9 %)	17,980 (52.5 %)	122,401 (51.5 %)
No vehicle	7,955	1,623 (26.1 %)	4,775 (7.8 %)	1,557 (3.4 %)	57,10 (11.2 %)	2,254 (3.6 %)	3,539 (25.1 %)	4,416 (4.4 %)
Below poverty	6,157	1,098 (31.3 %)	4,079 (14.6 %)	980 (3.0 %)	4,921 (23.1 %)	1,236 (2.9 %)	1,741 (31.3 %)	4,416 (7.6 %)
Above poverty	57,634	2,415 (68.7 %)	23,810 (85.4%)	31,409 (97.0%)	16,363 (76.9 %)	41,271 (97.1 %)	3,826 (68.7 %)	53,808 (92.4 %)
Per capita income	$23,541	$12,085	$19,729	$36,571	$15,418	$33,279	$12,085	$26,365
Median income	$43,103	$21,692	$34,545	$71,316	$28,644	$66,401	$19,208	$49,877
High school diploma only over age 25	30,459	2,471 (28.3 %)	15,775 (19.9 %)	12,213 (15.8 %)	13,679 (22.2 %)	16,780 (16.2 %)	3,692 (22.1 %)	26,767 (18.0 %)
Bachelor's degree only over age 25	40,545	882 (10.1 %)	17,116 (21.6 %)	22,456 (29.1 %)	11,691 (19.0 %)	28,763 (27.8 %)	2,542 (15.2 %)	37,912 (25.5 %)
Average median value of owner occupied housing units	$153,409	$96,500	$125,000	$223,786	$102,193	$195,543	$90,909	$163,870
Population over age 25	165,198	8,723	79,294	77,181	61,608	103,590	16,671	148,527

tend to have a lower proportion of households that own a vehicle, a higher proportion of families living below poverty, and their median income is almost half that of their counterparts. In the context of this study, not having access to a vehicle would make it harder for residents to travel to and from a retail food store, and having a higher proportion of residents living below the poverty level indicates that a higher chance that these residents would need to rely on SNAP benefits in order to supplement their already low incomes.

Accessibility to SNAP Accepting Stores by Walking

Overall, accessibility to other stores, or supercenters and warehouse stores, across income, race, and vehicle ownership was very low (Table 3). Less than 5 % of the population of all block groups could walk to a supercenter or warehouse store under 20 min. Block groups that were deemed primarily African American could reach no supercenter or warehouse store in less than 20 min, while only 6.6 % of mixed block groups and 4.3 % of white block groups could reach 70 and 20 % of "other" stores respectively. Generally, "other" stores are located in suburban areas that are more car accessible, so retailers typically do not take into account whether people are in walking distance when they select a retail location. Like accessibility by walking to "other" stores, access to supermarkets is also very low across all census block group categories with only 2.4 % of all block groups and 1.9 % of the population of all block groups able to walk to 20 % of all SNAP accepting supermarkets in less than 10 min. African American and low vehicle ownership block groups were not able to reach any supermarkets by walking in under 10 min. Generally, the highest proportion of census blocks and their population can reach convenience stores, where 62.7 % of all census blocks and 56.2 % of the population of all census blocks can reach 75.8 % of all convenience stores in less than 20 min by foot.

Accessibility to SNAP Accepting Stores by Automobile

Results for access to SNAP accepting stores by automobile can be referenced to in Table 4. On the whole 78.7 % of all census block groups and 79.2 % of the population of all census block groups can reach "other" stores in less than 10 min, and 87 % (94.2 % of population) can access their nearest "other store" in less than 20 min. Every block group can reach 100 % of SNAP accepting "other" stores within 20 min by automobile. Overall, SNAP accepting supermarkets are easily accessible to the general population of Leon County. Within a driving distance of 10 min, 92.3 % of all block groups and 89.0 % of the population can reach 100 % of supermarkets. Even though access perhaps appears to be marginally better for the lower socioeconomic categories, the nearest SNAP accepting supermarkets can be reached by the majority of block groups, which perhaps infers supermarket access by automobile is not an issue in Leon County.

Grocery store access, like supermarket access, is also relatively high with 87.6 % of all block groups and 82.8 % of the population of all block groups being able to reach their nearest grocery or specialty store within 10 min, and 98.8 % of all block groups and 99.3 % of the population of all block groups being able to reach a grocery store in less than 20 min. Nearly every category of block group could reach 100 % of SNAP

Table 3 Accessibility to SNAP accepting stores by walking

Characteristics	Total census block groups (s=169)		African American (s=17)		Mixed (s=83)		White (s=69)		High income (s=85)		Low income (s=84)		Low vehicle access (s=33)		High vehicle access (s=136)	
	>10	>20	>10	>20	>10	>20	>10	>20	>10	>20	>10	>20	>10	>20	>10	>20
Population of census block groups within walking distance																
Threshold (Minutes)	>10	>20	>10	>20	>10	>20	>10	>20	>10	>20	>10	>20	>10	>20	>10	>20
Other (n=10)	0.7 %	4.4 %	0.0 %	0.0 %	1.3 %	6.6 %	0.0 %	2.6 %	1.2 %	5.0 %	0.0 %	6.0 %	0.0 %	3.0 %	0.8 %	5.1 %
Supermarkets (n=20)	1.9 %	18.4 %	0.0 %	29.9 %	2.9 %	27.1 %	1.1 %	7.0 %	1.7 %	12.3 %	2.2 %	15.5 %	0.0 %	18.2 %	2.2 %	19.1 %
Grocery stores (n=26)	6.2 %	16.8 %	20.7 %	83.5 %	5.0 %	15.1 %	5.5 %	9.1 %	3.1 %	8.6 %	10.2 %	13.1 %	20.4 %	57.6 %	4.2 %	14.7 %
Convenience stores (n=171)	23.6 %	55.7 %	70.8 %	100.0 %	28.0 %	70.7 %	11.7 %	32.3 %	11.8 %	37.9 %	38.9 %	45.2 %	63.9 %	87.9 %	17.7 %	55.9 %
Total (n=227)	25.6 %	56.2 %	76.2 %	100.0 %	29.4 %	71.7 %	14.0 %	32.3 %	13.6 %	38.8 %	41.3 %	46.4 %	66.6 %	87.9 %	19.7 %	56.6 %
SNAP accepting stores that can be reached by walking																
Threshold (Minutes)	>10	>20	>10	>20	>10	>20	>10	>20	>10	>20	>10	>20	>10	>20	>10	>20
Other (n=10)	10.0 %	80.0 %	0.0 %	0.0 %	10.0 %	70.0 %	0.0 %	20.0 %	10.0 %	50.0 %	0.0 %	40.0 %	0.0 %	10.0 %	10.0 %	80.0 %
Supermarkets (n=20)	20.0 %	75.0 %	0.0 %	10.0 %	10.0 %	50.0 %	10.0 %	30.0 %	10.0 %	45.0 %	10.0 %	55.0 %	0.0 %	20.0 %	20.0 %	75.0 %
Grocery stores (n=26)	20.0 %	69.2 %	15.4 %	34.6 %	15.4 %	50.0 %	11.5 %	19.2 %	11.5 %	38.5 %	30.8 %	57.7 %	23.1 %	30.8 %	19.2 %	61.5 %
Convenience stores (n=171)	20.0 %	76.6 %	9.9 %	22.2 %	17.5 %	57.3 %	12.3 %	33.9 %	9.9 %	39.2 %	28.1 %	59.1 %	17.0 %	33.3 %	23.4 %	71.3 %
Total (n=227)	20.0 %	75.8 %	9.3 %	21.6 %	16.3 %	56.4 %	11.5 %	31.3 %	10.1 %	40.1 %	25.6 %	57.7 %	15.4 %	30.8 %	22.0 %	70.9 %

Table 4 Accessibility to SNAP accepting stores by Automobile

Characteristics	Total census block groups (s 169)		African American (s 17)		Mixed (s 83)		White (s 69)		High income (s 85)		Low income (s 84)		Low vehicle access (s 33)		High vehicle access (s 136)	
Threshold (Minutes)	>10	>20	>10	>20	>10	>20	>10	>20	>10	>20	>10	>20	>10	>20	>10	>20
Population of census block groups within walking distance																
Other (n 10)	79.2 %	94.2 %	84.2 %	100.0 %	81.2 %	95.2 %	76.2 %	92.1 %	78.2 %	93.8 %	80.4 %	94.0 %	88.6 %	97.0 %	77.8 %	84.6 %
Supermarkets (n 20)	89.0 %	97.5 %	100.0 %	100.0 %	93.8 %	100.0 %	82.0 %	94.2 %	88.1 %	97.3 %	90.2 %	97.6 %	97.2 %	97.0 %	87.8 %	97.1 %
Grocery stores (n 26)	82.8 %	99.3 %	100.0 %	100.0 %	96.0 %	100.0 %	65.3 %	98.3 %	74.5 %	98.9 %	93.5 %	98.8 %	97.2 %	100.0 %	80.7 %	98.5 %
Convenience stores (n 171)	97.8 %	100.0 %	100.0 %	100.0 %	100.0 %	100.0 %	95.0 %	100.0 %	97.9 %	100.0 %	97.6 %	100.0 %	100.0 %	100.0 %	97.5 %	100.0 %
Total (n 227)	97.8 %	100.0 %	100.0 %	100.0 %	100.0 %	100.0 %	95.0 %	100.0 %	97.9 %	100.0 %	97.6 %	100.0 %	100.0 %	100.0 %	97.5 %	100.0 %
SNAP accepting stores that can be reached by walking																
Threshold (Minutes)	>10	>20	>10	>20	>10	>20	>10	>20	>10	>20	>10	>20	>10	>20	>10	>20
Other (n 10)	100.0 %	100.0 %	80.0 %	100.0 %	90.0 %	100.0 %	100.0 %	100.0 %	100.0 %	100.0 %	100.0 %	100.0 %	90.0 %	100.0 %	100.0 %	100.0 %
Supermarkets (n 20)	100.0 %	100.0 %	85.0 %	100.0 %	90.0 %	100.0 %	95.0 %	100.0 %	100.0 %	100.0 %	95.0 %	100.0 %	90.0 %	100.0 %	100.0 %	100.0 %
Grocery stores (n 26)	100.0 %	100.0 %	80.8 %	96.2 %	100.0 %	100.0 %	92.3 %	100.0 %	88.5 %	100.0 %	96.2 %	100.0 %	88.5 %	100.0 %	100.0 %	100.0 %
Convenience stores (n 171)	100.0 %	100.0 %	81.3 %	97.7 %	99.5 %	99.4 %	93.0 %	100.0 %	97.1 %	99.4 %	95.3 %	100.0 %	90.6 %	98.2 %	100.0 %	100.0 %
Total (n 227)	100.0 %	100.0 %	81.5 %	97.8 %	98.2 %	99.6 %	93.4 %	100.0 %	96.5 %	99.6 %%	95.6 %	100.0 %	90.3 %	98.7 %	100.0 %	100.0 %

accepting stores in fewer than 20 min by automobile. Conclusively, the majority of census block groups appear to have access to multiple grocery stores within 10 min, which illustrates that access to SNAP accepting grocery stores by automobile is not problematic in Leon County.

Accessibility to SNAP Accepting Stores by Transit

Access to SNAP accepting stores by transit yielded some interesting results (Table 5). Unsurprisingly, census block groups in Leon County do not have as convenient access to "other" stores or supercenters and warehouse stores by transit as they do by automobile. Only 1.8 % of all block groups and 1.4 % of the population can reach an "other" store in less than 10 min, and only 23.1 % of all block groups and 25.6 % of the population can reach these stores in less than 20 min. Compared with white and mixed block groups, African American block groups have the worst access to "other" stores because they can reach no stores in less than 20 min, while 15.7 % of mixed (13.9 % of population) and 37.7 % of white block groups (42.5 % of population) can reach at least three stores in less than 20 min. Additionally, both low income and low vehicle access block groups can reach no stores in less than 10 min while their counterparts can reach at least one store in under the same time. African American block groups have no access to any supermarkets in less than 10 min by transit, and only 5.9 % of African American block groups and 3.6 % of their population can reach a supermarket in less than 20 min. Overall, it appears that accessibility to SNAP accepting stores by transit has some inequitable distributions across race and vehicle ownership categories.

Taken all together, 10.1 % of all block groups and 7.3 % of their population were able to reach 19.2 % of all SNAP accepting grocery stores in less than 10 min, and 29.6 % of all block groups and 36.3 % of their population were able to reach 34.6 % of their nearest grocery stores in less than 20 min. African American and low vehicle ownership block groups were not able to reach any SNAP accepting grocery stores within the 10 min threshold, but 5.9 % (7.0 % of population) and 9.1 % (8.1 % of population) were able to reach 3.8 and 15.4 % of stores, respectively, under the 20 min threshold. Notably, 34.6 % of high vehicle ownership block groups (40.4 % of population), 44.7 % of high income block groups (40.3 % of population), and 44.9 % of white block groups (42.5 % of population) could reach at least 30 % of SNAP accepting grocery stores within 20 min. In contrast, less than 16 % of the population of low income, low vehicle ownership, and African American block groups can reach their nearest grocery store under the 20 min threshold. This may illustrate an example of inequitable access to grocery stores within the transit system of Leon County.

A key finding is that African American block groups cannot reach any SNAP accepting convenience stores in less than 10 min by transit, while comparatively, 24.6 % of white block groups and 17.9 % of their population can reach their nearest convenience store. Effectively, there are no SNAP accepting stores that African American block groups can reach in less than 10 min, and only 19.8 % of their population can reach 2.2 % of all SNAP accepting stores in less than 20 min.

Table 5 Accessibility to SNAP accepting stores by Transit

Characteristics	Total census block groups (s=169)		African American (s=17)		Mixed (s=83)		White (s=69)		High income (s=85)		Low income (s=84)		Low vehicle access (s=33)		High vehicle access (s=136)	
	>10	>20	>10	>20	>10	>20	>10	>20	>10	>20	>10	>20	>10	>20	>10	>20
Population of census block groups within walking distance																
Threshold (Minutes)	>10	>20	>10	>20	>10	>20	>10	>20	>10	>20	>10	>20	>10	>20	>10	>20
Other (n=10)	31.4 %	25.6 %	0.0 %	0.0 %	0.8 %	13.9 %	2.3 %	42.5 %	2.5 %	40.3 %	0.0 %	6.5 %	0.0 %	5.3 %	1.6 %	28.5 %
Supermarkets (n=20)	3.9 %	29.1 %	0.0 %	3.6 %	2.1 %	15.5 %	6.5 %	48.3 %	5.8 %	43.7 %%	1.5 %	10.1 %	0.0 %	8.6 %	4.5 %	32.0 %
Grocery stores (n=26)	7.3 %	36.3 %	0.0 %	7.0 %	1.9 %	23.2 %	14.5 %	55.4 %	12.9 %	52.5 %	1.6 %	15.2 %	0.0 %	8.1 %	9.1 %	40.4 %
Convenience stores (n=171)	11.4 %	48.2 %	0.0 %	16.1 %	7.1 %	32.5 %	17.9 %	70.7 %	15.6 %	66.6 %	6.0 %	24.3 %	4.2 %	20.5 %	12.5 %	52.2 %
Total (n=227)	13.2 %	50.5 %	0.0 %	19.8 %	7.1 %	35.7 %	22.1 %	71.7 %	18.8 %	68.1 %	6.0 %	27.6 %	4.2 %	22.3 %	14.5 %	54.5 %
SNAP accepting stores that can be reached by walking																
Threshold (Minutes)	>10	>20	>10	>20	>10	>20	>10	>20	>10	>20	>10	>20	>10	>20	>10	>20
Other (n=10)	10.0 %	30.0 %	0.0 %	0.0 %	10.0 %	30.0 %	10.0 %	30.0 %	10.0 %	30.0 %	0.0 %	30.0 %	0.0 %	20.0 %	10.0 %	30.0 %
Supermarkets (n=20)	20.0 %	40.0 %	0.0 %	5.0 %	15.0 %	35.0 %	15.0 %	35.0 %	20.0 %	35.0 %	10.0 %	30.0 %	0.0 %	25.0 %	20.0 %	40.0 %
Grocery stores (n=26)	19.2 %	34.6 %	0.0 %	3.8 %	7.7 %	23.1 %	19.2 %	30.8 %	19.2 %	34.6 %	3.8 %	23.1 %	0.0 %	15.4 %	19.2 %	34.6 %
Convenience stores (n=171)	14.0 %	40.9 %	0.0 %	1.8 %	9.9 %	34.5 %	11.1 %	36.3 %	11.1 %	38.0 %	8.2 %	31.6 %%	4.1 %	22.8 %	11.1 %	40.9 %
Total (n=227)	15.0 %	39.6 %	0.0 %	2.2 %	4.8 %	33.0 %	12.3 %	35.2 %	12.8 %	37.0 %	7.5 %	30.4 %	3.1 %	22.5 %	12.8 %	39.6 %

Discussion

To this point reasonably little attention has been paid to accessibility to SNAP accepting stores and food store typologies in the context of food environments, with the exception of work done by Rigby et al. (2012) and Rose et al. (2009). Originally, Rigby et al. (2012) evaluates access to SNAP accepting stores by examining their distribution census tracts as a proxy for neighborhoods. That study concluded African American groups had the least access to food stores within a given census tract. While these results are valuable, they only look at the number of stores within census tract boundaries in order to determine whether a particular population group has access or not. This method is somewhat limited in that the analysis does not assess the role of the transportation system in allowing people to reach SNAP accepting stores. Another issue is that census tracts in rural areas are sometimes larger than census tracts in more urban areas, covering larger land areas, which makes it difficult to compare distribution of stores across dissimilar census tracts. In this way, we build upon previous work by estimating the time and distance it may take individuals to reach their destinations, at a more disaggregate spatial scale. There has also been limited exploration of accessibility to different typologies of food stores. This paper analyzes access to stores across a variety of categories based on cost and variety of foods offered.

Access Across Modes

More broadly, this paper has also explored definitions of automobile, transit and walking access, and findings support the idea that studies should embrace a diversity of measures in determining accessibility to food stores. For example, if only walking to SNAP accepting stores was considered in this analysis one would have reached the conclusion that because vulnerable populations are essentially closer to their nearest SNAP accepting store they have better access than their counterparts. However, after incorporating additional dimensions in terms of automobile and transit modalities, results showed that all populations have adequate accessibility by automobile and poor access by walking, while vulnerable populations have poor access by transit.

Surprisingly, when examining the walking mode to the nearest SNAP accepting store, the lower socio-economic areas had a greater proportion of block groups that could reach a supermarket or "other" store within 20 min. This can be visualized in Fig. 1 when one observes the locations of SNAP accepting stores compared with African American block groups. Most opportunities tend to be concentrated towards the center of the city/county, and this is also the case for low income block groups and low vehicle ownership block groups. Therefore, while the more vulnerable socioeconomic categorized block groups tend to be located nearer SNAP accepting opportunities when measured by automobile, the higher socioeconomic categorized block groups are more spread out throughout the county thus suggesting that people in higher socioeconomic categories have less accessibility. At the same time, the demographic characteristics associated with the African American, low income, and low vehicle ownership block groups demonstrate that these areas are more likely to have residents that do not own a vehicle, have a lower income, and are more likely to live in poverty. We might surmise that even though these block groups may be closer to food
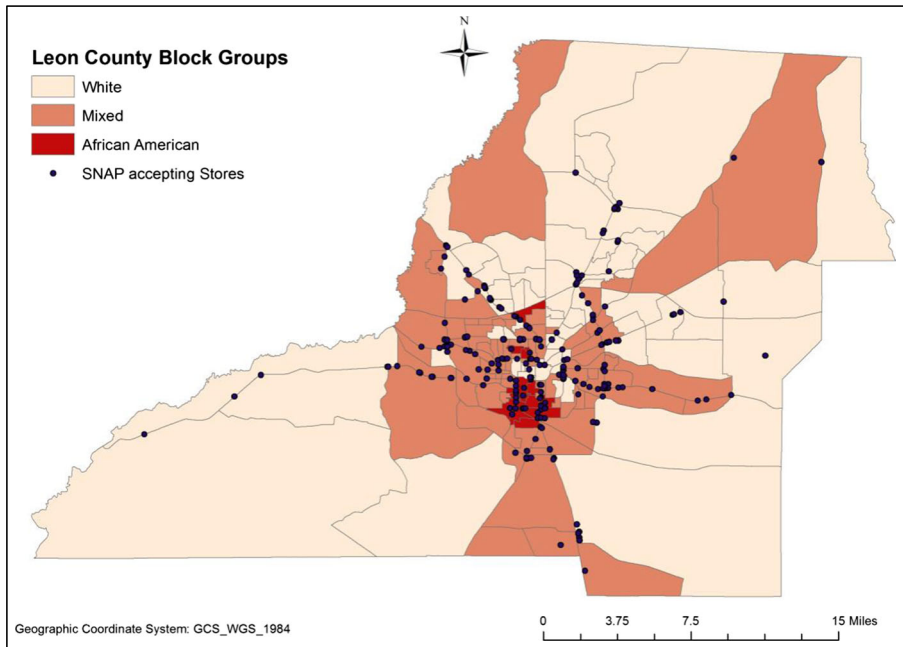
Fig. 1 Racial categories with location of SNAP accepting stores

opportunities some residents may not have access to a vehicle or lack sufficient funds to maintain and operate a vehicle. Consequently, some of these residents would have to rely on walking or the transit system in order to access SNAP accepting stores. In short, these results demonstrate that the measurement of accessibility to food stores is context sensitive, suggesting that multiple measures are needed to understand the full extent of access. While all populations have poor access by walking, it is less likely that households that own a vehicle will choose to walk to their nearest SNAP accepting store, thus the households without vehicles ultimately will have higher travel costs if they must walk or use the transit system.

Access Across Store Types

Through exploring accessibility to SNAP accepting stores in Leon County, it was found that the transit system provides inequitable access to supermarkets and "other" stores, which are where nearly 84 % of SNAP benefits are redeemed. The quality of food carried at each retailer differs enough to have a substantial impact on whether or not SNAP recipients have adequate choices in healthy foods across retailers. Supermarkets and "other" stores carry the widest variety of inexpensive fruits and vegetables compared to grocery stores, specialty stores, and convenience stores. It must also be noted that convenience stores are the most accessible SNAP accepting stores across all modes and population groups. Convenience stores carry an abundance of processed and calorie dense foods and a shortage of fresh fruits and vegetables. They also tend to have higher prices than their SNAP accepting store counterparts. For those individuals who do not own a personal vehicle, redeeming their benefits at a convenience store may be the most logical choice if they are short on time or unable to reach a

supermarket due to transportation constraints. Examining the different food store types is important when evaluating the food environment so that an assessment can be made about the difference in cost and availability of foods conducive to a healthy diet.

In summary, this paper supports the majority of research conducted on food accessibility citing that vulnerable populations have inequitable access to supermarkets. Again, supermarkets carry the widest variety of healthy foods at lower prices compared to the other retail SNAP accepting stores. So it must be emphasized here that not having access to supermarkets could mean that SNAP recipients do not have the best choices in the quality and prices of food that they can buy. Currently the USDA does not offer subsidization of travel costs to SNAP accepting recipients, past research has suggested that doing so may relieve some economic hardships on those receiving SNAP benefits (Rose et al. 2009). This paper augments previous research in the areas of food deserts, food environments, and accessibility and provides those interested in policy decisions with an effective exploration of the accessibility to SNAP accepting locations for vulnerable populations.

Conclusion

The idea that measuring food store access is complex and that quantitative, GIS-based analyses must include multiple measures of accessibility is supported by our work. Many researchers have argued that a mixed methods approach to investigating food environments which incorporates qualitative analysis should be integrated into food access studies (Rose et al. 2009; Short et al. 2007). Here, we did not attempt to explore SNAP recipient's individualized grocery shopping behaviors or habits in Leon County. Ideally, in future work, qualitative methods, such as in-depth interviews or surveys, would also be incorporated in order to explore lived experiences of the travel costs accumulated by individuals in households receiving SNAP benefits, including looking at the time available people had for shopping.

There are some limitations to this work that should be noted. The paper focuses on the SNAP accepting stores in Leon County and uses the county boundary as the delineation. Thus, opportunities outside the boundary are not considered. Second, it should also be noted that there is some aggregation bias at the block group level as some of these represent fairly large areas spatially. Additionally, the store typologies were not confirmed individually as matching their corresponding description, so there may be some discrepancies in whether or not a store is classified accurately. There is also the issue of shortest path travel times being the only cost associated with food store decisions. While this study extends past work by looking at the different categories of food stores, other factors may influence food store choices that are not associated with travel times. Our study also omits the concept of trip chaining, where we have assumed that the only trips occurring are to and from food stores. This does not allow for an exploration of access to food stores when individuals have multiple stops during an outing, and future analyses should incorporate this notion. Lastly, as previously mentioned, the transit data were aggregated from the TAZ level to the census block group level. Additionally, the error associated with the actual travel time versus the TAZ to TAZ travel times are also unknown and were unavailable. As such, this must be acknowledged as a further limitation to the transit travel time estimations. Future

analyses would take advantage of a full transit network model in GIS that allowed for more complete estimates of possible travel and wait times.

Despite our study's use of aggregate data and related limitations, the accessibility analyses described in this paper add new insights into SNAP recipient's access food stores. Multiple measures of accessibility as well as demographic data that are more disaggregate (census block groups) than that of previous studies (census tracts) were utilized (Rigby et al. 2012). In sum, this paper offers a framework providing interested researchers and policy experts a means of analyzing inequitable accessibility to SNAP accepting stores via multiple types of transportation systems.

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