A Public Participatory Approach toward the Development of a Comprehensive Geospatial Database in Support of High-scale Food Security Analysis

Timothy Mulrooney[a] and Tysean Wooten[b]
Department of Environmental, Earth and Geospatial Sciences, North Carolina Central University,
1800 N. Fayetteville Street, Durham, NC, U.S.A.

Keywords: Geographic Information System, Geodatabase Development, Geospatial Standards, Geospatial Metadata, Geospatial Data Development, Food Desert, Food Swamp.

Abstract: While Geographic Information Systems (GIS) has slowly been integrated into the study of the food environment, little research has been performed to determine the data development needs and standards that best necessitate high-quality research at a high scale. In an era with limited resources such as personnel, bandwidth, space and time, the optimization of these resources in order to understand, visualize and facilitate interventions at an appropriate scale is critical if not necessary. In this research, subject matter experts assessed and evaluated the relative importance of various GIS data themes, attributes and facets of GIS database development in support of local-scale food security analysis. It was found that factors related to the placement of various food sources (grocery stores and farmers markets) and individualized vehicular transportation (roads) outweighed those related to land cover, utilities and zoning, as well as non-vehicular (sidewalks) and public (bus routes) means of transportation. In addition, when ranking various dimensions of data quality, subject matter experts found positional accuracy and attribute accuracy to be the most important when undertaking the development of a geospatial database of this magnitude.

1 INTRODUCTION

Patterns of negative health-related outcomes such as obesity, hypertension, and diabetes are spatial in nature and when mapped, are typically prevalent and clustered in low-income communities. While lifestyle choices and genetics contribute to individual and household vulnerability that lead to these differential health outcomes, it is possible to identify social and environmental factors, sometimes associated with geographic location, that have an effect on larger groups, and might be considered as critical indicators to address in any mitigation plan. There is, for example, a strong relationship between health and diet and it seems clear the accessibility of sources for fresh meats, fruits, and vegetables is an important factor in the overall health of a community. Even in poorer neighborhoods, Rose and Richards (2004) found food stamp recipients who live close to supermarkets ate more fresh food and vegetables. While it is safe to say that geography is not a prime determinant in explaining or even justifying health outcomes, it does have more of a role than one would think.

The United States Department of Agriculture (USDA) has popularized the term *food desert* to highlight areas within low-income communities that have limited accessibility to supermarkets. While some research has focused on rural areas (Van Hoesen, 2013; Gross and Rosenberger, 2005; Blanchard and Lyson, 2006; Morton, Ella and Oakland, 2005) much of the knowledge base on the subject has been associated with urban areas. In urban areas, this phenomenon can occur for a couple of reasons. The number of large retailers is decreasing or consolidating, but increasing in size to accommodate all shoppers, both grocery and non-grocery (Clarke et al., 2002). Combined with the fact that retailers are leaving downtowns for the suburbs

---

[a] https://orcid.org/0000-0001-9333-9641
[b] https://orcid.org/0000-0001-8355-3249

Mulrooney, T. and Wooten, T.
A Public Participatory Approach toward the Development of a Comprehensive Geospatial Database in Support of High-scale Food Security Analysis.
DOI: 10.5220/0008863900210032
In *Proceedings of the 6th International Conference on Geographical Information Systems Theory, Applications and Management (GISTAM 2020)*, pages 21-32
ISBN: 978-989-758-425-1

(Furey et al., 2001), Mamen (2007) found large retailers are tending to locate near high-volume roads that are less accessible to non-vehicular individualized transportation (i.e. walking, public transit or riding a bike). Lewis et al. (2005) reinforced this when he found unhealthy food options greatly outweighed their healthy counterparts in Los Angeles while Powell (2007) found poor and minority neighborhoods had less healthy food options than their richer and whiter counterparts. As a result, typical sources of fresh and 'healthy' foods (supermarkets, farmers' markets and other sources) are being replaced by fast food restaurants and convenience stores, which offer food options that are convenient, inexpensive but typically less healthy. While a seemingly even trade in terms of net food balance, the long-term ramifications on community health far outweigh any gains. In response to this increasing disproportion, research has explored the notion of *food swamps* which represent areas with inordinately high number of unhealthy food options compared to healthy options. Research at the local level (Cooksey-Stowers et al., 2017; Zenk et al., 2015) has shown food swamps actually better predict obesity and other negative health outcomes than food deserts.

Geospatial tools such as Geographic Information Systems (GIS) serve as a popular technology to assess and evaluate spatial dimensions of the food environment. A GIS serves as the tangible and intangible means by which information about spatially-related phenomena can be created, stored, analyzed and rendered in the digital environment. Experts in many dissimilar fields have seen the utility of GIS as a means of quantifying and expanding their research. GIS is used in disciplines such as business, sociology, justice studies, surveying and the environmental sciences. As applied to food security, GIS can be used to measure the proximity of residences to large supermarkets or supercenters or the concentration of food outlets within an enumeration unit (census tract or zip code) as a commonly used proxy for access (Morton and Blanchard, 2007; Sharkey and Horel, 2008). These areas of high access and low access can be analyzed and mapped across both space and time (Chen and Clark, 2013) as shown in Figure 1, as well as the factors that may explain this access such as spending (Figure 2). These make powerful visual products both easy to understand and disseminatable to the entire public that can have long-term policy implications.

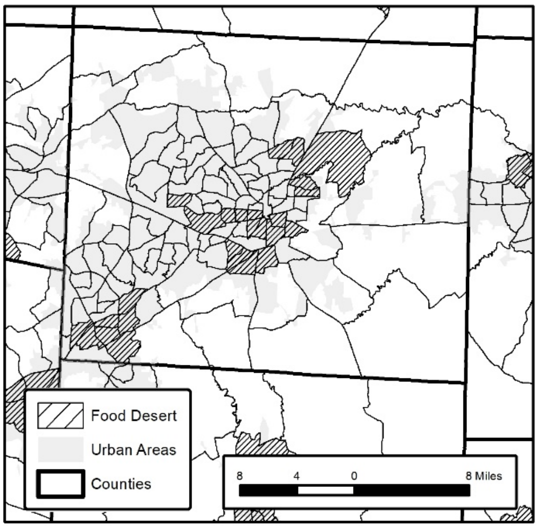


Figure 1: Map of USDA food deserts in Guilford County, North Carolina.

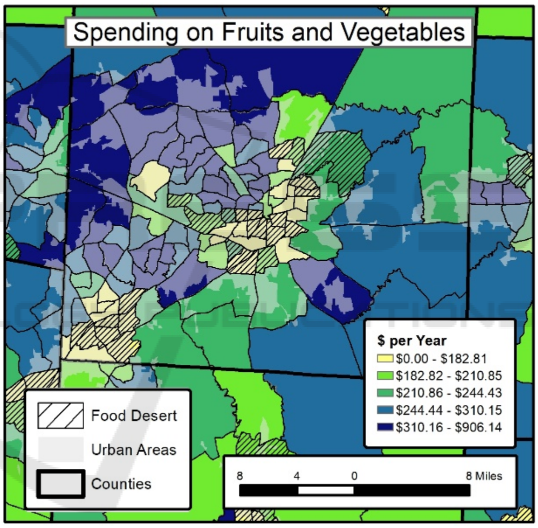


Figure 2: Map of spending patterns combined with food deserts.

While many only see the output of GIS data and analysis in the form of maps, resources must be dedicated to creating high-quality data at a local scale. This data creation takes on many different forms, ranging from the conversion of analog data and extraction from a larger database to the use of high precision equipment. This paper takes a holistic look at the types of geospatial data needed to perform high-quality analysis in support of assessing, evaluating and mapping spatial dimensions of the food environment at a local scale. These database needs are quite different than data that may be required to remediate food insecurity at the individual/household level or at a national or sub-national scale. Minimal research has been performed in this field of database development, whether for the sake of science research, decision-making or policy.

In the United States, food insecurity has been described as a "serious public health problem associated with poor cognitive and emotional development in children and with depression and poor health in adults" (Chilton and Rose, 2009, p. 1). Some have called for a rights-based approach to addressing food security in the United States given that women and children have much higher rates of food security than their male and more senior counterparts (Chilton and Rose, 2009). As a result, this research explores both technical and non-technical issues by understanding the needs and subsequently developing the database to solve this pressing and immediate problem.

2 LITERATURE REVIEW

While many operational definitions exist, food security is generally considered to be the state "when all people, at all times, have physical and economic access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life" (Food and Agriculture Organization 2009, p. 1). Contemporary literature has used terms such as *availability*, *accessibility*, *proximity, disparity, inequality, density, variety, affordability* and *quality* as well as the aforementioned *food desert* and *food swamp* to describe quantitative measures of the food environment and ultimately food security. These measures, as well as the data which describe them, can be represented at different scales. The data needs for national-level food security analysis differs than those required for community level analysis.

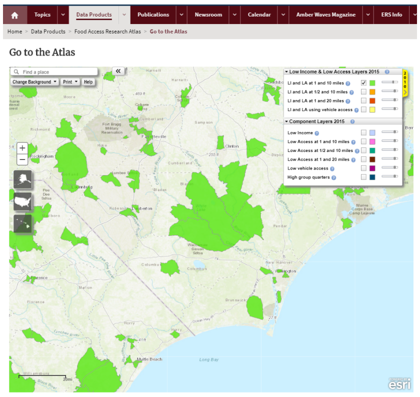
The mapping and delineation of food-insecure areas within the digital environment has been made exponentially easier with GIS technologies. While first used as an aesthetic tool to map study areas (Wrigley et. al, 2002) or display underlying explanatory variables (Guy et. al, 2004), GIS has since been used to measure distances, quantitatively express proximity and render this proximity with statistical significance using a variety of analytical, geostatistical and cartographic techniques. Among the first to do this within the realm of food desert research were Donkin et al. (1999), Lovett et al. (2002) and Pearce (2006) while more recent research (Mulrooney, 2017; Rose et al., 2009) has quantitatively calculated and mapped the spatial extent of the aforementioned food swamps at a local scale.

Within the GIS data environment, ways to express quantitative dimensions of the food environment vary from study to study. Prior research has expressed these measures as absolute linear units such as kilometers or miles (Jago, 2007), travel time in minutes (Ver Ploeg et al., 2009; Jiao et al., 2012) and densities such as the number of food options per square mile by census tract (Block et al., 2004), as well as derived metrics based on the cost to operate a car (Hallett and McDermott, 2011). More recently, relative unitless metrics (Zenk et al., 2014; Clary et al., 2015; Mason et al., 2013) have been used as alternatives to absolute measures because these absolute measures are meaningless if not placed within some context. A ten-minute drive time to the nearest fresh food source in a downtown urban area means something much different than a ten-minute drive to the nearest fresh food source in a rural area. The proper and prudent use of absolute measures requires more data, analysis and interpretation. Food swamp research using GIS has used existing metrics such as the Retail Food Environmental Index (RFEI) and the Expanded RFEI (Cooksey-Stowers et al., 2017; Luan et al., 2015) while others (Mulrooney et al., 2017; Rose et al, 2009) have derived their own metrics and subsequent interpretations to define spatial extents of food deserts and swamps using the RFEI, Expanded RFEI, Modified RFEI (mRFEI) developed by the Centers for Disease Control (2011) and Food Balance Metric (Gallagher, 2006) as guidelines.

In studies that model the supply and demand forces from farm to plate at a national scale, it is necessary to have geospatial data regarding farm locations, their arrangement, land cover, flood plains, rivers, climate and population change which support burgeoning sustainable planning, management and development efforts, especially in developing countries (Soneye, 2014; Babtunde, Omotesh and Sholatan, 2010; Obioha, 2009). At this most basic level, food security at the national scale can be thought of as a function of the socio-economic and political environment regarding factors such as macro-economy, natural resource endowment, market conditions, education, policy environment, food safety/quality and health care practices. These are not considerations in local-scale analysis where distances, drive times or derivations of these measures with respect to known food sources are calculated alongside explanatory variables to delineate food-needy regions.

While food security does exist at a variety of scales, the geospatial data required for local (community) level food is scale dependent and different in nature than data required at a coarser national or sub-national scale. These geospatial data required for this type of local research vary in scope, ranging from roads and businesses to zoning and municipal boundaries. For example, Van Hoesen et al. (2013) looked at the quality of food in conjunction with point-to-point distances along a vector road network in Vermont that is grouped within polygonal enumeration units such as towns/townships. Pioneers in the application of GIS to assess food accessibility such as Blanchard and Morton (2007), Gallagher (2006) and McEntee and Agyeman (2010) also used vector GIS data at some level (individual point, census block group, tract, etc.) to express food security. In national-scale analysis of this type, analyzing thousands to hundreds of thousand sources traveling to thousands of destinations is resource-intensive and requires large, ancillary data layers such as roads in support of this analysis as well as the abovementioned interpretation to be useful.

In the United States, guidance on the quantitative assessment of the food environment begins with the United States Department of Agriculture Food Access Atlas (https://www.ers.usda.gov/data-products/food-access-research-atlas/go-to-the-atlas/). Food access take into account both the availability or proximity of food sources to residents as well as having readily-available transportation. Information collected and mapped at the census tract level includes the aforementioned food desert metric (low income and limited access) as shown in Figure 3 as well as individual components that make up this metric and ancillary measures such as income, vehicle access and high-density housing. As shown in Figure 3, census tracts can take on varying sizes and shapes. These larger census tracts, one of which is 322 sq. miles in size, in the middle of the diagram located in Columbus, Pender and Sampson Counties in North Carolina are especially problematic because they may be too large to emphasize high-scale food security patterns necessary for community-based research. As a result, high-scale food environment analysis performed at the block group (D'Acosta, 2015; Wang, 2012; Jiao, 2012) or even pixel (Mulrooney et al., 2017) scale, which is finer than census tracts, better articulates local-level patterns and serves as a focus of this research.



Low Income & Low Access Layers 2015
LI and LA at 1 and 10 miles ☑
LI and LA at 1/2 and 10 miles ☐
LI and LA at 1 and 20 miles ☐
LI and LA using vehicle access ☐
Component Layers 2015
Low Income ☐
Low Access at 1 and 10 miles ☐
Low Access at 1/2 and 10 miles ☐
Low Access at 1 and 20 miles ☐
Low vehicle access ☐
High group quarters ☐

Figure 3: USDA Food Access Atlas of Southeastern North Carolina showing low income and low access census tracts.

Depending upon the focus and scale of analysis, the number of points used in the GIS analysis of the food environment, whether as sources or destinations, can range from the dozens (Opher, 2010; Love et al., 2013) to hundreds (Sharkey et al., 2009; McEntee & Agyeman, 2010) and even thousands (van Hoesen et al., 2013). As a basis for this research on high-scale food security in North Carolina, GIS work (Mulrooney et al., 2017; Major et al., 2018; Love et al., 2013) highlighted metrics to measure food security at some level at the block group level. A variety of disparate themes were used in these studies, ranging from roads, business locations and rivers to municipal boundaries, farmers' markets and convenience stores. Each of these layers were developed or extracted at a scale appropriate for local-scale analysis in order to facilitate decision and policy making.

While there is boundless value in performing local-scale food environment analysis using GIS, little research has been performed on the actual themes or topics that would be necessary for high-quality research at a high scale. While many end-uses only want the end-products of GIS analysis, the largest cost of any GIS project is developing the data which go into high-quality research. It goes without saying that in an era with limited resources such as personnel, space and time, database developers must be pointed and direct in the how, when and to what extent (temporal, spatial and topical) data must be developed. Attempts have been made to estimate the actual and tangible costs (Johnson et al., 2017; Janssen et al., 2012) and value (Bernknopf and Shapiro, 2015; Garcia-Rojas, 2015) of geospatial data; however, it is difficult if not impossible to place a monetary value on the data although various entities (Koutnik, 1996; Ledbetter, 1996) have tried to estimate it from a cost-savings approach in the early days of GIS in the 1990s. Nonetheless, in this day and age when GIS is omnipresent in all levels of local and state government, GIS does facilitate informed decision-making, which can be realized a number of different ways.

In particular, little work has been performed to determine how important roads are in food security research at the local level. What about elevation? In addition to the actual features, there are various questions about the individual attributes required for high-quality food desert research. Is income (at the census tract level) a necessary attribute for sub-county food desert research? What about road length? This research explores how can these themes and attributes can be prioritized when time and personnel constraints, which are a reality in the professional world, exist.

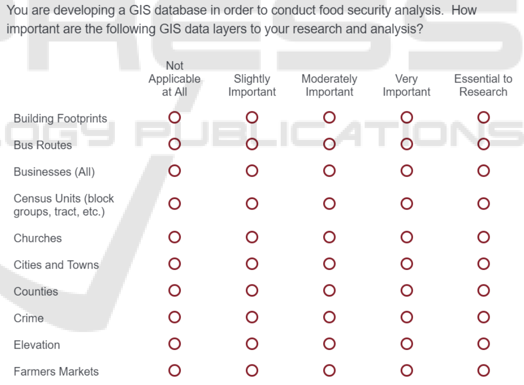
Nonetheless, the resources dedicated to data creation, especially high-quality data, are extraordinarily high. Early pioneers of GIS recognized the importance of data quality, not only from a cost efficiency standpoint, but because of the legal ramifications in publishing incorrect spatial information which may lead to accidents or the misuse of data (Epstein, 1988). Even then, they understood the compromise between accuracy, the cost of creating accurate data and the inevitability that some error will still exist. This compromise is what Bédard (1987) called *uncertainty absorption*. Given that hundreds to thousands of individual features are required for this type of GIS analysis, it is impossible to field verify every single feature used in analysis. Studies (Sharkey and Horel, 2009; Lake, 2015) have highlighted the inaccuracy of existing geospatial databases used in the study of food security using varied field techniques.

Various forms of accuracy exist, to include horizontal accuracy (distance between actual feature and GIS representation of feature), attribute accuracy (description of features matches the field) and attribute completeness (all attributes have viable values). The Federal Geographic Data Committee (FGDC) and spatial data transfer standards (SDTS) also consider vertical accuracy (error in measured vs. represented elevation), data lineage (source materials of data) and logical consistency (compliance of qualitative relationships inherent in the data structure) as part of data quality (FGDC, 1997; USGS, 2000). In some GIS circles, temporal accuracy (age of the data compared to usage date) and semantic accuracy or “the quality with which geographical objects are described in accordance with the selected model” are also considered elements of data quality (Salge, 1995) as well as metadata, the formal cataloguing of GIS data. In addition to better understanding to what extent different data layers are required for research, this study will also address these facets of data quality.

3 PROCEDURES

In order to prioritize data layers, attributes and facets of data quality, a survey was developed and distributed to the GIS community that focuses on local-scale food security research. It is composed of twelve questions that not only ask about users' GIS experience, but also asks users Likert-type questions about their preferences for particular GIS data layers (Figure 4) and the attributes attached to those layers (Figure 5).

As shown in these figures, respondents were asked to scale responses to these questions on a 5-point Likert-type scale, representing “Not Applicable at All” through “Essential to Research”. The Likert scale uses ordered responses on a bipolar measurement scale to assess the level of agreement or disagreement with a statement. Some scales do have an even number of responses (4, for example), which force respondents to choose one side of the mean or the other.



You are developing a GIS database in order to conduct food security analysis. How important are the following GIS data layers to your research and analysis?

	Not Applicable at All	Slightly Important	Moderately Important	Very Important	Essential to Research
Building Footprints	○	○	○	○	○
Bus Routes	○	○	○	○	○
Businesses (All)	○	○	○	○	○
Census Units (block groups, tract, etc.)	○	○	○	○	○
Churches	○	○	○	○	○
Cities and Towns	○	○	○	○	○
Counties	○	○	○	○	○
Crime	○	○	○	○	○
Elevation	○	○	○	○	○
Farmers Markets	○	○	○	○	○

Figure 4: Likert-type assessment used to rate importance of GIS data themes for use in food desert research. 23 layers were used in this assessment.

Table 1: Respondents were asked the question *“You are developing a GIS database in order to conduct local-scale food security analysis. How important are the following GIS data layers to your research and analysis?”* regarding GIS data layers (street network, for example). The following scale assigned point values to their answers.

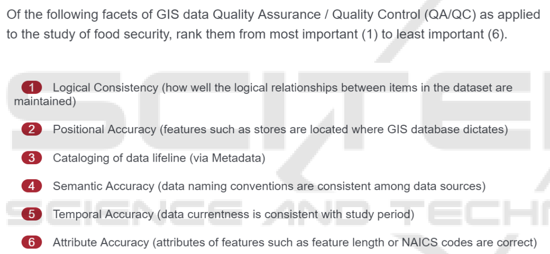
Response	Point Value
Not Applicable at All	1
Slightly Important	2
Moderately Important	3
Very Important	4
Essential to Research	5

You are developing a GIS database in order to conduct food security research. How important are the following categorical or numerical attributes to your research?

	Not Applicable at All	Slightly Important	Moderately important	Very Important	Essential to Research
Average Household Size	○	○	○	○	○
Building Size	○	○	○	○	○
Distance to Nearest Resource	○	○	○	○	○
Education Attainment	○	○	○	○	○
Housing Status (Owner-Occupied / Rental / Vacant)	○	○	○	○	○
Income	○	○	○	○	○
Median Age	○	○	○	○	○
Median Rent Paid	○	○	○	○	○
North American Industry Classification Standard (NAICS) Code	○	○	○	○	○

Figure 5: Likert-type assessment used to rate importance of attributes for use in local-level food desert research. 18 attributes were used in this assessment.

As applied to rating the various dimensions of data quality, respondents were given a survey rating six facets of data quality. An example of this survey and explanations of these facets are highlighted below in Figure 6.



Of the following facets of GIS data Quality Assurance / Quality Control (QA/QC) as applied to the study of food security, rank them from most important (1) to least important (6).

1. Logical Consistency (how well the logical relationships between items in the dataset are maintained)
2. Positional Accuracy (features such as stores are located where GIS database dictates)
3. Cataloging of data lifeline (via Metadata)
4. Semantic Accuracy (data naming conventions are consistent among data sources)
5. Temporal Accuracy (data currentness is consistent with study period)
6. Attribute Accuracy (attributes of features such as feature length or NAICS codes are correct)

Figure 6: Dimensions of spatial data quality that respondents were asked to rate using online assessment tool.

This survey was created and distributed to the food desert community via message boards, e-mails and online forums in the Fall of 2017 and Spring 2018. 32 respondents answered the survey.

4 RESULTS

4.1 Prioritization of Data Layers

Respondents were asked to rate data layers on 5-point Likert-type scale ranging from "Not Applicable at All" to "Essential to Research" where each response as assigned a point value as highlighted in Table 1.

For each layer, an average based on responses was computed from the values and Table 1 and ranked according to all 23 data layers in the survey. For example, for the Counties data layer, there were two responses for "Not Applicable at All", two for "Slightly Important", six for "Moderately Important", twelve for "Very Important" and the remaining ten responded with "Essential to Research". This would compute to a value of 3.94 and this value would be ranked among the other 22 data layers selected for this survey. In this case, the Counties layer ranked 8th amongst the 23 data layers in the questionnaire. Unsurprisingly the "Grocery Stores" data layer ranked with the highest with a score of 4.25, followed closely by "Roads", "Farmers' Markets" and "Urban Areas". These are highlighted in Table 2.

Table 2: Rank of Layers/Themes as Voted by GIS User Community.

Rank	Layer
1	Grocery Stores
2	Roads
3	Farmers Markets
4	Urban Areas
5	Census Units (block groups, tract, etc.)
6	Cities and Towns
7	Fast-Food Restaurants
8	Counties
9	Bus Routes
10	Businesses (All)
11	Non-census sub-county units (boroughs, townships, etc.)
12	Schools
13	Zoning
14	Sidewalks
15	Land Cover
16	States
17	Churches
18	Walking / Jogging Trails
19	Building Footprints
20	Crime
21	Utilities (Electrical / Gas / Cable / Phone)
22	Elevation
23	Golf Courses

In addition, users were asked to name themes not mentioned in the above list. Themes that were mentioned include: Community Gardens, Parks, Greenhouses, Arable Land, Irrigation Pathways, Rivers, Access to Water, Food Banks, Food

Assistance Organizations, Non-Profit Businesses, Health Agencies, Corner Stores, Partial Markets (Walgreens, for example), Liquor Stores, Bus Stops and County Agencies.

4.2 Prioritization of Attributes

The same conventions and number scales were applied to attributes that may be used to describe data layers from Table 1. After averaging values marked by uses, the "Distance to Resource" attribute was ranked highest, followed by "Income" and "Race /Ethnicity (by enumeration unit)". These results are highlighted in Table 3.

Table 3: Rank of Attributes to Layers/Themes as Voted by GIS User Community.

Rank	Attribute
1	Distance to Nearest Resource
2	Income
3	Race / Ethnicity (by enumeration unit)
4	Population Density
5	Average Household Size
6	Population
7	Education Attainment
8	Housing Status (Owner-Occupied / Rental / Vacant)
9	Transportation (# of vehicles by enumeration unit)
10	Median Age
11	Median Rent Paid
12	Spending Patterns (by enumeration unit)
13	Zoning Type
14	North American Industry Classification Standard (NAICS) Code
15	Road Length
16	Building Size
17	Number of Employees by Business
18	Speed Limit

4.3 Dimensions of Data Quality

Users were asked to rate six different dimensions of data quality from 1 (most important) to 6 (least important). These data dimensions speak to how the data are created, described and catalogued as part of the data development process. Scores for each facet were averaged and ranked. These rankings are highlighted in Table 4.

Table 4: Rank of Dimensions of Data Quality.

Rank	Facet of Data Quality
1	Positional Accuracy (features such as stores are located where GIS database dictates)
2	Attribute Accuracy (attributes of features such as feature length or NAICS codes are correct)
3	Temporal Accuracy (data currentness is consistent with study period)
4	Logical Consistency (how well the logical relationships between items in the dataset are maintained)
5	Semantic Accuracy (data naming conventions are consistent among data sources)
6	Cataloging of data lifeline (via Metadata)

5 STANDARDS-BASED APPROACH TO DATABASE DEVELOPMENT

Data standards such as the Spatial Data Standards for Facilities Infrastructure and Environment (SDSFIE) are used by the Department of Defense (DoD) to maximize interoperability across installations and branches by dictating naming conventions, attributes and domain values for spatial data layers. The name *road_centerline* is denoted as "the center of the roadway as measured from the edge of the paved surface" and is consistent across all DoD installations instead of using layer names such as *street*, *streets* or *roads*. The *road_centerline* feature class contains 55 attributes. The FGDC has defined data standards for landmarks, addressing, thoroughfares and parcels (FGDC, 2011) in order to standardize attributes so features can geocoded, described and represented fully and completely. While the development of a database dedicated solely to food security is still being realized, point and polygonal features representing municipal and census-based units such as zip codes, towns, census tracts and census block groups should have attributes which rank highly in this study such as distance to the nearest resource and access to transportation, as well as socio-economic indicators such as income, race/ethnicity, education attainment, population and population density. The calculation of these attributes may require further processing or the import of data from various spatial databases such as the 2010 Census, Esri Demographic Database, Esri Spending Patterns and American Community Survey.

In order to catalog both data for this specific purpose and the processing performed to develop the database, it is necessary to describe administrative, structural and descriptive information about the geospatial data. Metadata serves as an organized means to describe a dataset, and provides the formal framework for providing information about a dataset's lineage, age and creators using both qualitative and quantitative entries. In the GIS community, the FGDC-endorsed Content Standard for Digital Geospatial Metadata (CSDGM) is slowly giving way to an International Standards Organization (ISO)-based metadata standard that accounts for evolving technologies such as remotely sensed imagery, online services and ontologies that did not exist when the CSDGM (formally known as *FGDC-STD-001-1998*) was first published.

While more than 400 individual elements comprise a complete metadata record, the state of North Carolina has developed a State and Local Government Profile, based on the ISO 19115, 19115-1 and 19119 standards that streamlines these 400 elements into about 75 elements that best capture the necessary information about a data layer which enable content consistency and improves the search and discoverability of data through online data repositories such as NCOneMap. This standard, as well as guidance for its use, is provided by the North Carolina Geographic Information Coordinating Council (NCGICC) through the NCOneMap online portal (North Carolina Geographic Information Coordinating Council, 2019).

Using the State and Local Government Profile as a guideline, data layers developed in support of high-scale food security research should be cognizant of the following entries that already exist within this profile which speak explicitly to data quality and data discoverability:

1) Process Description: A repeatable element that provides a description of how the data were created and indicate the data source, where applicable. This process description should include any geoprocessing and/or field calculations used to derive spatial and attribute data derived for the sole purpose of food security research. This process description should also contain the source scale denominator and publication date of source information, where available to clarify positional and temporal accuracy respectively.
2) Topic Category: A theme keyword that adheres to at least one of the ISO Topic Categories.
3) Feature Catalogue: Entity and Attribute Descriptions and Citations referenced to ISO 19110, where possible.

In addition, the following Data Quality elements not explicitly addressed in this profile should be completed to catalog attempts to maintain the highest possible accuracies given this scale of analysis. While not required, this cataloguing should strive to achieve popular positional (horizontal and vertical) accuracy standards such as the National Mapping Accuracy Standards (NMAS) for paper maps (United States Bureau of the Budget, 1947) and more recent National Standard for Spatial Data Accuracy (NSSDA) used for digital data (Federal Geographic Data Committee, 1998)

1) Attribute Accuracy Report: an explanation of the accuracy of the identification of the entities and assignments of values in the data set and a description of the tests used. This may be useful if food sources and/or destinations have been field checked for attribute errors.
2) Quantitative Attribute Accuracy Assessment: a value assigned to summarize the accuracy of the identification of the entities and assignments of values in the data set and the identification of the test that yielded the value.
3) Attribute Accuracy Value: an estimate of the accuracy of the identification of the entities and assignments of attribute values in the data set.
4) Logical Consistency Report: an explanation of the fidelity of relationships in the data set and tests used. This may be applicable if data used in the same analysis or derivation of attributes come from multiple data sources and/or at different scales.
5) Completeness Report: information about omissions, selection criteria, generalization, definitions used, and other rules used to derive the data set. Useful for both spatial data and attribute completion.
6) Horizontal Positional Accuracy Report: an explanation of the accuracy of the horizontal coordinate measurements and a description of the tests used. This may be useful when field checking the locations of food sources and/or destinations.
7) Horizontal Positional Accuracy Value: an estimate of accuracy of the horizontal positions of the spatial objects.

8) Horizontal Positional Accuracy Explanation: the identification of the test that yielded the Horizontal Positional Accuracy Value.
9) Vertical Positional Accuracy Report (where applicable): an explanation of the accuracy of the vertical coordinate measurements and a description of the tests used (FGDC 2000).

6 CONCLUSIONS

Food security entails the ability, whether it be at the individual, community or national scale, to procure nutritious and affordable food. While GIS has increasingly become a powerful tool to map spatial dimensions of food security and the factors that help explain it, little research has been performed to determine what themes are useful in local-level food security research. Given that data and the people that develop it are the most expensive component of any GIS project, this is especially important when limited resources exist. This data development can take on many forms, ranging from the downloading of existing data, extraction from currently existing databases, the creation of brand-new spatial data via digitization, geocoding or the use of remotely sensed imagery, either purchased, procured or captured using a UAS (Unmanned Aircraft System). Regardless of the method, time and personnel resources must be utilized in order to derive the attributes that facilitate food security research while cataloguing these people, processes and resources.

The database requirements for food security analysis in the digital environmental at a local scale are much different than those needs at the national/sub-national scale. National scale and sub-national (state) studies in food security explore the economics of food production and links between this food and those who need it using data such as land cover, soil type, low-scale transportation networks (both road and railroad), state and county outlines using coarse and general data. High-scale analysis at the block group and even pixel scale requires more specialized data, analysis, attribution and cataloguing than data grouped at tracts, the standard for a lot of research, including the United States Department of Agriculture Food Access Atlas, as well as more coarse zip codes and counties. From a data development standpoint, the realization of a database in support of local-scale food security research requires a reconciliation between developing the correct data layers while developing them at an appropriate scale that allows for local-level (sub county) scale analysis.

In a survey of 32 GIS professionals who utilize GIS data in support of food security research, questions were asked about their opinions of various themes and their relative importance in food security research. Themes directly related to the food environment and food accessibility such as grocery stores, roads and farmers' markets were ranked highest by these GIS professionals. In addition, sub-county census units such as census tracts and block groups were ranked higher than counties, highlighting the need for higher-scale data compared to the coarser county-level data.

In addition, attributes used to describe these themes were prioritized in this survey. Information related to distance (more specifically distance from resources) and socio-demographic indicators such as income, race/ethnicity and household size ranked amongst the highest in the GIS community. This ties in directly with food desert research and specifically the USDA definition of a food desert, which utilize both distance and poverty components. Lastly, various dimensions of data quality exist and users were asked to rank them in their order of importance. Positional accuracy and attribute accuracy ranked the highest while the cataloguing of data in the form of data was ranked the lowest.

The specific focus of this work has been on the collection, integration, analysis, assessment and description of geospatial data that is of a type and level of detail to be of practical value in the development, implementation and evaluation of interventions addressing food security. While the results of this work can be used as pure research in and of itself, it is anticipated that results can be used in helping to facilitate decision-making and formulate policy at directly addressing and remediating the phenomenon of food deserts. Furthermore, it addresses the technical aspects of geospatial database development such as attribution, naming conventions and metadata according to existing standards such as the ISO-based North Carolina State and Local Government Metadata Profile. While some minor questions still remain unanswered such as the potential for cross-validation or the use of qualitative data given that food desert research has been trending towards a mixed-methods approach combining qualitative and quantitative data, it is our hope to further explore cost-effective methods for needs assessment that take into account both causal complexity and programmatic challenges imposed by the combination of limited resources and increased demand. Integrating GIS technologies with intervention planning has the potential to be a cost-effective means for organizations to conduct effective planning aimed at improving food and nutritional security at multiple spaital and temporal scales. Prudent database development serves as the cornerstone of this effective planing and implementation.

ACKNOWLEDGEMENTS

The project was supported by the Agricultural and Food Research Initiative Competitive Program of the USDA National Institute of Food and Agriculture (NIFA), grant number 2016-67023-24904.

This material is also based upon work supported by the National Science Foundation under Grant No. 1824949. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Science Foundation.

REFERENCES

Apparicio P., Cloutier M.S. and Shearmur, R. 2007. The case of Montreal's missing food deserts: evaluation of accessibility to food supermarkets. *International Journal of Health Geographics* 6:4: 1-13.

Babatunde R.O., Omotesho O.A. and Sholatan, O.S. 2010. Factors influencing food security status of rural farmers in North Central Nigeria. *Agricultural Journal* 2(3): 351-357.

Bedard, Y. 1987. Uncertainties in land information systems databases. *Proceedings of the 8th International Symposium on Computer Assisted Cartography (Auto Carto 8)*, (pp. 175-184). Baltimore, MD.

Bernknopf, R. and Shapiro, C. 2015. Economic assessment of the use value of geospatial information. *ISPRS International Journal of Geo-Information* 4: 1142–1165. doi: 10.3390/ijgi4031142

Blanchard, T. & Lyson, T. 2006. Access to low cost groceries in nonmetropolitan counties: Large retailers and the creation of food deserts. Paper presented at the Measuring Rural Diversity Conference, Washington, DC [online]. Retrieved from: http://srdc.msstate.edu/trainings/presentations_archive/2002/2002_blanchard.pdf

Block J.P., Scribner R.A. and DeSalvo K.B. 2004. Fast food, race/ethnicity, and income: a geographic analysis. *American Journal of Preventative Medicine* 27: 211–217.

Both, A., Wauer, M., Garcia-Rojas, A, Hladky, D and Lehmann, J. 2015. GeoKnow Generator Workbench – An integrated tool supporting the linked data lifecycle for enterprise usage. *Proceedings of the 11th International Conference on Semantic Systems Posters and Demos*, *of SEM '15*. 92-92.

Burns, C. and Inglis, A. 2007. Measuring food access in Melbourne: access to healthy and fast foods by car, bus and foot in an urban municipality in Melbourne. *Health Place* 13: 877–885.

California Center for Public Health Advocacy. 2007. *Searching for Healthy Food: The Food Landscape in California Cities and Counties* [online]. Retrieved from http://www.publichealthadvocacy.org/RFEI/expanded percent20methods.pdf

Centers for Disease Control and Prevention. 2011. *Children's Food Environment State Indicator Report, 2011* [online]. Retrieved from http://www.cdc.gov/obesity/downloads/ChildrensFoodEnvironment.pdf

Chen, X. and Clark, J. 2013. Interactive three-dimensional geovisualization of space–time access to food. *Applied Geography* 43: 81–86.

Chilton, M. and Rose, D. 2009. A Rights-Based Approach to Food Insecurity in the United States American Journal of Public Health 99: 1203_1211, https://doi.org/10.2105/AJPH.2007.130229

Clarke, G., Heather E., and Guy, C. 2002. Deriving Indicators of Access to Food Retail Provision in British Cities: Studies of Cardiff, Leeds and Bradford. *Urban Studies* 39(11): 2041-2060.

Clary C.M., Ramos Y., Shareck, M., and Kestens, Y. 2015. Should we use absolute or relative measures when assessing foodscape exposure in relation to fruit and vegetable intake? Evidence from a wide-scale Canadian study. *Preventative Medicine (Baltimore)* 71: 83–87.

Cooksey-Stowers, K, Schwartz, M. and Brownell, K. 2017. Food Swamps Predict Obesity Rates Better than Food Deserts in the United States. *International Journal of Environmental Research and Public Health* 14: 1366.

D'Acosta, J. 2015. Finding food deserts: a study of food access measures in the phoenix-mesa urban area (Master's Thesis). University of Southern California. Los Angeles, CA.

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

Epstein, E. F. 1988. Litigation over information: The use and misuse of maps. *Proceedings, IGIS: The Research Agenda* 1 (pp. 177-184). Washington, D.C.: NASA.

Food and Agriculture Organization of the United Nations. 2009. *Declaration of the World Summit on Food Security* [online]. Retrieved from ftp://ftp.fao.org/docrep/fao/Meeting/018/k6050e.pdf

Federal Geographic Data Committee (FGDC). 1998. *Geospatial Positioning Accuracy Standards Part 3: National Standard for Spatial Data Accuracy.* FGDC-STD-007.3-1998.

Federal Geographic Data Committee (FGDC). 2000. *Content Standard for Digital Geosp atial Metadata Workbook.* Washington D.C.: Federal Geographic Data Committee.

Federal Geographic Data Committee (FGDC). 2011. *United States Thoroughfare, Landmark and Postal Address Data Standard.* Washington D.C.: Federal Geographic Data Committee.

Furey, S., Strugnell, C. and McIlveen, H. 2001. An Investigation of the Potential Existence of "Food Deserts" in Rural and Urban Areas of Northern Ireland. *Agriculture and Human Values* 18: 447–457.

Gallagher M. 2006. *Examining the impact of food deserts on public health in Chicago. Mari Gallagher Research and Consulting Group* [online]. Retrieved from http://www.marigallagher.com/site_media/dynamic/project_files/1_ChicagoFoodDesertReport-Full_.pdf

Gross, J. and Rosenberger, N. 2005. *Food Insecurity in Rural Benton County: An Ethnographic Study*. Working Paper No. 05-02, Rural Studies Program, Oregon State University, Corvallis, OR.

Guy, C. M., Clarke, G., & Eyre, H. 2004. Food retail change and the growth of food deserts: a case study of Cardiff. *International Journal of Retail & Distribution Management*, 32: 72–88.

Hallett, L. and McDermott, D., 2011. Quantifying the extent and cost of food deserts in Lawrence, Kansas, USA. *Applied Geography* 31: 1210–1215.

Jago R., Baranowski T., Baranowski J.C. 2007. Distance to food stores and adolescent male fruit and vegetable consumption: mediation effects. *International Journal of Behavioral, Nutritional and Physical Activity* 4:35.

Janssen, M., Charalabidis, Y. and A. Zuiderwijk. 2012. Benefits, adoption barriers and myths of open data and open government. *Information Systems Management* 29(4): 258 – 268.

Jiao, J., Moudon, A., Ulmer, J., Hurvitz, P. and Drewnowski, J. 2012. How to identify food deserts: Measuring physical and economic access to supermarkets in King County, Washington. *American Journal of Public Health* 102(10): 32–39.

Johnson, P. A., Sieber, R., Scassa, T., Stephens, M. and Robinson, P. 2017. The Cost (s) of Geospatial Open Data. *Transactions in GIS* 21: 434–445,

Koutnik, Mike. 1996. *The Benefits of GIS in Local Government: Examples from ESRI's User Community*. Environmental Systems Research Institute, Inc. (Unpublished).

Ledbetter, M., Carder Hunt and Don Anderson. 1997. Blueprints for a Citywide GIS: Scottsdale's Award-Winning System Provides a Profitable Example. *GIS World*, November, 62-64.

Lewis, L.B., D.C.Sloane, L.M. Nascimento, A.L. Diamant, J.J. Guinyard, A.K. Yancey, G. Flynn. 2005. "African Americans' Access to Healthy Food Options in South Los Angeles Restaurants." *American Journal of Public Health* 95(4): 668-73.

Love, G., Mulrooney, T., and Brown, L. 2012. Using GIS to address food availability in Durham, North Carolina. *The North Carolina Geographer* 19: 34-52.

Lovett, A., Haynes, R., Sunnenberg, G., & Gale, S. 2002. Car travel time and accessibility by bus to general practitioner services: a study using patient registers and GIS. *Social Science & Medicine*. 55(1): 97–111.

Major E., Delmelle E., Delmelle E. 2018 SNAPScapes: Using geodemographic segmentation to classify the food access landscape. *Urban Science* 2:71. doi: 10.3390/urbansci2030071.

Mamen, Katy. 2007. "Facing Goliath: Challenging the Impacts of Supermarket Consolidation on our Local Economies, Communities, and Food Security." *Policy Brief, The Oakland Institute* 1(3): 1-8.

McEntee, J., and Agyeman, J. 2010. Towards the development of a GIS method for identifying rural food deserts: Geographic access in Vermont, USA. *Applied Geography* 30(1): 165–176.

Morton, L., Bitto, E. and Oakland, M. 2005. Solving the Problems of Iowa Food Deserts: Food Insecurity and Civic Structure. *Rural Sociology* 70(1): 94–112.

Morton, L., and Blanchard, T. C. 2007. Starved for access: Life in Rural America's food deserts. *Rural Realities* 1(4):1–10.

Mulangu, F. and Clark, J. 2012. Identifying and measuring food deserts in rural Ohio. *Journal of Extension*, 50(3): 3FEA6. Retrieved from: http://www.joe.org/joe/2012june/a6.php.

Mulrooney, T., McGinn, C., Branch, B., Madumere, C. and Ifediora, B. 2017. A New Raster-Based Metric to Measure Relative Food Availability in Rural Areas: A Case Study in Southeastern North Carolina. *Southeastern Geographer* 57(2): 151 - 178.

North Carolina Geographic Information Coordinating Council (NCGICC). 2018. *North Carolina State and Local Government Metadata Profile for Geospatial Data and Services* [online]. Retrieved from http://www.nconemap.gov/DiscoverGetData/Metadata.aspx#iso.

Obioha, E.E. 2009. Climate Variability, Environment Change and Food Security Nexus in Nigeria. *Journal of Human Ecology* 26(2): 107-121.

Opfer, P. 2010. *Using GIS technology to identify and analyze 'food deserts' on the southern Oregon coast*. Oregon State University Archives 1–52.

Pearce, J., Witten, K., & Bartie, P. 2006. Neighbourhoods and health: a GIS approach to measuring community resource accessibility. *Journal of Epidemiology and Community Health* 60(5): 389–395.

Powell, L. M., Slater, S., Mirtcheva, D. Bao, Y. and Chaloupka, F. 2007. Food Store Availability and Neighborhood Characteristics in the United States. *Preventive Medicine* 44:198-95.

Rose, D. and Richards, R. 2004. Food Store Access and Household Fruit and Vegetable Use Among Participants in the US Food Stamp Program. *Public Health Nutrition* 7(8):1081-8.

Rose D., Bodor J.N., Swalm C.M., Rice J.C., Farley T.A., Hutchinson P.L. 2009. *Deserts in New Orleans? Illustrations of urban food access and implications for policy*. Paper presented at: University of Michigan National Poverty Center/USDA Research Conference on Understanding the Economic Concepts and Characteristics of Food Access; February 2009; Washington, DC [online]: Retrieved from: http://www.npc.umich.edu/news/events/food-access/rose_et_al.pdf.

Salgé, F. 1995. *Semantic accuracy*. In S.C. Guptill and J.L. Morrison *(*Eds.), Elements of Spatial Data Quality *(*pp. 139-152). New York: Elsevier Science Ltd.

Sharkey, J. R., and Horel, S., 2008. Neighborhood socioeconomic deprivation and minority composition are associated with better potential spatial access to the ground-truthed food environment in a large rural area. *Journal of Nutrition* 30(5): 620–627.

Soneye, Alabi. 2014. Farm Holdings in Northern Nigeria and Implication for Food Security: A Remote Sensing and GIS Assessment. *African Journal of Food and Agriculture, Nutrition and Development* 14(2): 1-15.

United States Bureau of the Budget, 1947, United States National Map Accuracy Standards: U.S. Bureau of the Budget, Washington, D.C.

United States Geological Survey (USGS). 1997. *Spatial Data Transfer Standard (SDTS): Logical specifications*. Reston, Virginia: United States Geologic Survey.

Van Hoesen, J., Bunkley, B. & Currier, C. 2013. A GIS-based methodology toward refining the concept of rural food deserts: a case study from Rutland County, Vermont. *Journal of Agriculture, Food Systems and Community Development* 3(2): 61-76.

Ver Ploeg, M., Breneman, V., Farrigan, T., Hamrick, K., Hopkins, D., et al. 2009. *Access to affordable and nutritious food–measuring and understanding food deserts and their consequences*: Report to congress. Washington, D.C.: United States Department of Agriculture, Economic Research Service.

Wang, Z. 2012. Socio-demographic and economic determinants of food deserts (Master's Thesis). University of Arkansas. Fayetteville, AR.

Wrigley, N. 2002. 'Food Deserts' in British cities: policy context and research priorities. *Urban Studies* 39(11): 2029–2040.

Zenk S.N., Powell, L.M., Rimkus, L., Isgor, Z. and Barker, D.C. 2014. Relative and absolute availability of healthier food and beverage alternatives across communities in the United States. *American Journal of Public Health* 104: 2170–2179.