The George Washington University

Department of Geography and Environment

Course Title:

Intermediate Geographic Information Systems (GIS II), Fall 2023

Project Title

Mapping Urban Food Deserts in Washington, D.C.: A Multi-Criteria Evaluation Approach to Assessing Food Access and Vulnerability

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Abstract

Food deserts have emerged as a significant focus of concern for public health as well as urban planning in the past two decades. Studies have indicated that food deserts are more common in low-income and communities of color within urban environments. In this paper, we explore the food desert issue in Washington, DC, the nation's capital. We utilized a multi-criteria evaluation approach and GIS to map and identify areas in the metropolitan area that are food deserts. We utilized three variables in the MCE model, including distance to grocery stores, percent poverty, and number of elderly populations at the census tract level. The results indicate an unequal distribution of food stores and bus stops across the city, with most food deserts located in the eastern parts of the city, especially in Wards 7 and 8. The study also found that in terms of food deserts in urban areas, distance to grocery stores is not the only contributing factor; it also includes mobility and economic conditions. The study recommends that the government should have incentives that will entice private investors to site their stores in the food desert areas, as well as increase transportation and mobility options for seniors.

1.0 Introduction

Food deserts have emerged as a significant focus of concern for public health as well as urban planning in the past two decades. In 2009, as part of Michelle Obama's Let's Move! initiative, the United States Department of Agriculture's Economic Research Service began gathering data about areas of the United States with limited access to healthy food, resulting in the Food Desert Locator (USDA, Economic Research Service, 2023). The USDA defines food deserts as all census tracts that have a poverty rate of 20% or higher (or a median family income at or below 80% of the statewide or metropolitan area median family income) and in which at least 500 people, or 33% of the population, live more than 1 mile from the nearest supermarket or large grocery store (Dutko et al., 2012). This definition aligns well with the Scottish Nutrition Task Force's etymological definition of food deserts. They defined food deserts as geographic areas that lack sufficient access to grocery stores, especially in lower-income neighborhoods and communities (Karpyn et al., 2012).

Food deserts are most associated with urban areas, but rural areas face significant food access challenges as well (Dutko et al., 2012). Studies have indicated that food deserts are more common in low-income communities and communities of color (Bower et al., 2014). In the United States, an estimated 23.5 million people live in what the USDA classifies as food deserts, and more than half of them (about 13.5 million) are considered low income (USDA, 2009). The consequences of living in a food desert extend beyond mere inconvenience. Inside the food deserts, inhabitants are woefully vulnerable to increased risks of diet-associated health complications, including obesity, diabetes, and cardiovascular diseases (Morland et al., 2002). Many fast-food restaurants and convenience stores compound this health disparity by selling highly calorie-laden and nutritionally deficient foods (Larson et al., 2009).

The food deserts issue has come to be most acute in Washington, D.C. Smith (2017) found that roughly one-seventh of Washington, D.C., with an approximate area of 6.5 square miles, is in itself a food desert. According to the 2022 Survey Data of the Capital Area Food Bank, 36% of residents in Washington, D.C. Metro Areas are food insecure, with 22% categorized as "severely food insecure" (Capital Area Food Bank, 2022). The food deserts in D.C. lie predominantly to the east of the Anacostia River in Wards 7 and 8, which have historically faced economic disadvantages and the scourge of racial segregation (Smith, 2017). In urban areas such as

Washington, D.C., the persistence of food deserts is intimately tied to the broader context of poverty, racial segregation, and inadequate public transportation (Raja et al., 2008). The USDA found that 2.3 million people, which is about 2.2% of all US households, live more than a mile from a supermarket and do not have access to a vehicle, further demonstrating the intersection of food access and transportation (Ver Ploeg, 2010).

Given the complex nature of food deserts that has broad implications for public health and social justice agendas, there is a clear need for rigorous investigation that identifies robust scientific evidence for beneficial policy-making. In this research, we address this need by focusing upon Washington, D.C., and using GIS and MCE methodologies to identify and map urban food deserts. The objectives of the study are:

1. To identify and map food desert areas in Washington, DC, using a multi-criteria evaluation approach.
2. To assess the impacts of transportation and vulnerability metrics in food desert identification.

By employing advanced spatial analysis techniques and incorporating a range of socioeconomic and demographic factors, this research aims to provide a nuanced understanding of food access issues in Washington, D.C. The findings of this study have the potential to inform targeted interventions and policy decisions aimed at improving food access and reducing health disparities in urban environments.

2.0 Literature Review

The concept of food deserts has changed greatly from its beginnings in the early 1990s. Researchers and policymakers around the world have since adopted, used, and revised the concept of food deserts, which originated in Britain to describe areas of the country with limited access to healthy foods (Cummins, 2002). In the United States, the USDA definition of food deserts has become popular, and it incorporates both economic and geographic metrics (Dutko et al., 2012). Contemporary research has expanded the understanding of food deserts beyond a simple geographical distance to include food retailers. Factors such as transportation accessibility, cultural food preferences, and the quality and affordability of food items significantly influence food access (Widener & Shannon, 2014). Alkon et al. (2013) argue that the food desert concept must expand with a food justice lens to include the historical patterns of disinvestment and racially segregated neighborhoods that led to current disparities in food

access. The literature has documented the health consequences of living in a food desert. In their systematic review, Gamba et al. (2015) were able to show consistent associations between living in a food desert and higher obesity and diet-related chronic disease rates. However, the causal relationship between access to healthy food and health outcomes is anything but simple, and some studies suggest that individual and cultural factors may exert a greater influence on health than geographic access to food alone (Cummins et al., 2014).

Urban contexts have come into sharper focus on the nexus between food deserts and other social determinants of health. Shannon (2016) demonstrates that inadequate public transport systems exacerbate food access issues in cities, underscoring the need for integrated approaches to urban planning and food policies. Similarly, Freedman and Bell (2009) found that different groups may consider perceptions and objective measures of food access differently, underscoring the importance of incorporating community perspectives in food desert research. Geographic Information Systems and spatial analysis techniques have become increasingly advanced. A pioneer in research in food desert mapping, Apparicio et al. (2007) introduced measures of accessibility, which factored in diversity in food retailer characteristics and affordability. More recent studies adopt advanced statistical techniques such as geographically weighted regression to treat food access patterns as spatially heterogeneous (Chen & Clark, 2016). In Washington, D.C., research on food access issues has been ongoing. Reports by D.C. Hunger Solutions in the year 2021 found that despite the efforts to attract new grocery stores into high-poverty neighborhoods in Washington, D.C., the challenge of food deserts still existed. The grocery store pipeline for Wards 7 and 8 in 2020 remains uncompleted, with Wards 7 and 8 remaining unchanged from the previous year. It also found that the disparities between the lowest- and highest-income wards still persist (Jensen & Hall, 2021).

This study builds on available literature by using a multi-criteria evaluation (MCE) approach for food desert identification in Washington, D.C. By incorporating a set of socioeconomic and demographic variables, as well as transportation data, this study shall allow for a holistic view of food access issues in the District. This will contribute to ongoing dialogue regarding best practices in food access research.

3. 0 Data and Methods

3.1 Data

Through a careful selection and combination of data sources, this research conducted a holistic investigation into the challenge of food deserts in Washington, D.C. We obtained the demographic and socio-economic data from the American Community Survey (ACS) 5-year estimates for 2019 from the US Census Bureau, which included elderly residents and populations living below the poverty line, respectively. We also downloaded spatial data from the Open Data DC portal, which included water bodies, national parks, military bases, metro bus station locations, and grocery store locations. We projected all spatial data into the NAD 1983 (2011) StatePlane Maryland FIPS 1900 (Meters) coordinate system to maintain consistency in our spatial analysis.

3.2 Methods and Analysis

ArcGIS Pro performed the analysis in a series of steps. Data preparation involved joining the census tracts with the demographic data. We examined the quality of the spatial data and used the "Erase" geoprocessing tool to correct the geometries of the DC Census Tracts, eliminating waterways, parks, and military bases. The idea behind using this function was to make our food desert map as accurate as possible.

When investigating food deserts, understanding the accessibility of grocery stores becomes paramount. Therefore, we calculated the Euclidean distance by using the grocery stores as the input feature and the water bodies as the barrier data. The deliberate inclusion of hydrological barriers rests on assumptions that natural water bodies presented almost insuperable barriers to residents' walking or driving to food stores. By including these hydrological features as barriers when calculating distance from the tracts, we ensured the accuracy of the distance measure in reflecting real travel in the landscape.

Normalizing all data variables allowed us to compare them. We normalized the demographic data using z-scores scaling, and scaled the distance to grocery stores using min-max scaling. This was essential in ensuring standardized values for all the variables before conducting the multi-criteria evaluation. We then calculated MCE scores using a weighted sum overlay technique, assigning each variable a weight based on its relative importance to food deserts, as shown in Table 1. The resulting MCE score was a detailed representation of the likelihood of food deserts in the Washington, DC, area. Finally, we calculated mean zonal statistics to measure the distance between the census tracts and grocery stores. Figure 1 illustrates the spatial distribution of potential food desert areas within Washington, D.C. by mapping the resultant

MCE scores. The probability of classifying a location as a food desert increases when its MCE score approaches the maximum value of 1.

Table 1: Variables, Weights, and Justifications for Multi-Criteria Evaluation (MCE) Model of Food Deserts in Washington, D.C

Variable	**MCE Weight**	**MCE Weight Justification**	**Variable Inclusion Justification**
Distance to Grocery Stores	0.5	Distance is the primary consideration when assessing the presence of food deserts	Distance is a common indicator when considering food deserts
Metro Bus Stops	0.1	People can opt for other means of transport so not as important as distance to grocery stores and income	Conforms with the USDA criteria for defining food deserts
Elderly residents	0.1	In determining food deserts, age is not as significant as income and distance to grocery stores	Different age groups may have distinct mobility and nutritional needs
Population below the poverty line	0.3	Income twice as important as age as the USDA consider food deserts to be prevalent in low-income communities	Food deserts are common in low-income neighborhoods

4.0 Results and Discussion

The multi-criteria evaluation (MCE) model offers crucial insights into the spatial distribution of food deserts in Washington, D.C. The MCE model utilized variables such as the distance to the nearest grocery store, the percentage of elderly individuals, the percentage of people living in poverty, and the distance to bus stops. Figure 1 reveals a fairly substantial underlying heterogeneity in the degree of food insecurity across different census tracts. Some of the tracts appear to have relatively low levels of food access problems, while others display quite severe cases. The map indicates that food deserts are primarily located east of the Anacostia River, specifically in Wards 7 and 8. These areas exhibit high MCE scores of 0.51-0.76, indicating a higher likelihood of being classified as food deserts. This affirms findings from earlier studies that identified these wards as having limited access to grocery stores along with high levels of poverty (Jensen & Hall, 2021).

Figure 1: Washington DC Food Desert Map

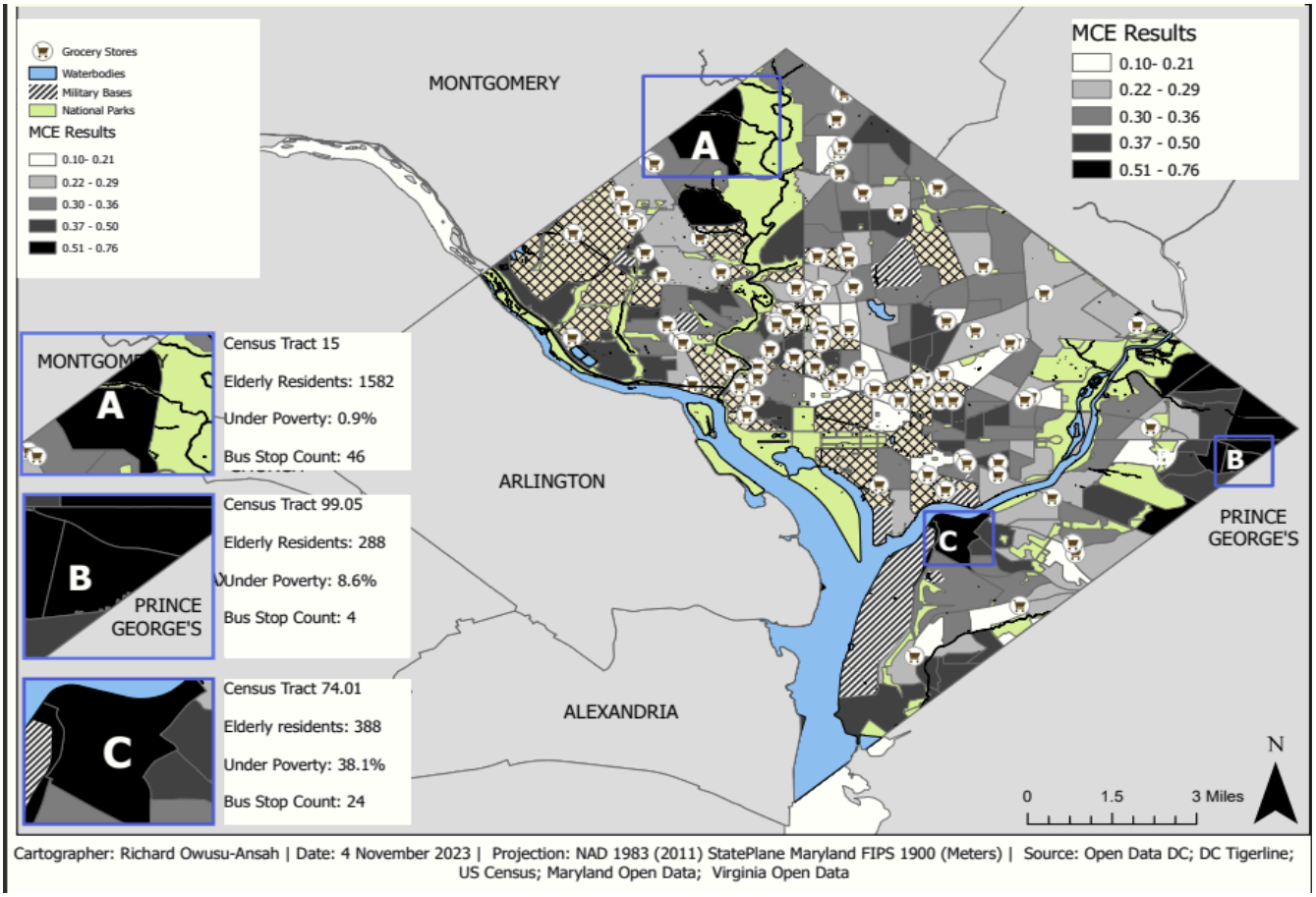
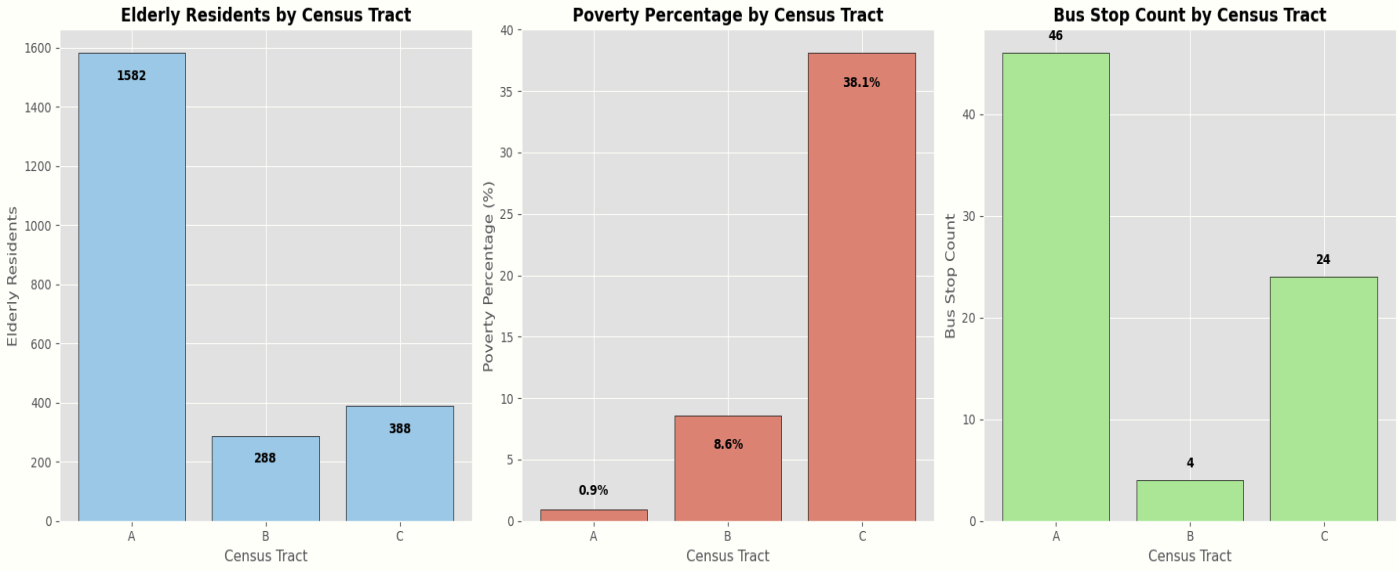


Figure 2: Demographic Information of selected Food Deserts in Washington, DC.



Source: Author

Significant demographic insights emerged from an analysis of Census tracts labeled A, B, and C. Census Tract A has fewer than 1% of its residents living below the poverty line. It also has a sizable elderly population (1,582 residents), which may partly explain its categorization as a food desert (Karpyn et al., 2012) despite the availability of many bus stops (46). It may also be observed that such a substantial concentration of elderly residents may indicate mobility issues that can exacerbate food insecurity in the region. In Census Tract B, 8.6% of the population lives below the poverty line, which is higher than Census Tract A. Furthermore, the tract has fewer bus stops (4) and a lower total population of elderly residents (288) compared to other census tracts. Although the elderly population is relatively lower compared to other tracts (288 residents), the interplay of poverty and limited transportation makes this area particularly vulnerable to food insecurity. Census Tract C, with 38.1 percent of its residents falling below the poverty line, represents one of the poorest tracts in the nation's capital. Despite the availability of more bus stops (24) in the area, the high rate of poverty and the high number of elderly residents (388) make it a food desert. These emerging vulnerabilities call for urgent intervention in this area.

The integration of public transportation data in the MCE model opened an avenue for recognizing how mobility impacts food access across Washington, D.C. Despite their geographic proximity to grocery stores, areas with fewer bus stops were more likely to qualify as food deserts. For instance, Census Tract B only has four bus stops, which significantly restricts residents' access to grocery stores, despite their relative proximity to these stores. On the other hand, Census Tract A boasts a higher number of bus stops (46), but it also has a higher proportion of elderly residents who may face mobility limitations due to their age, leading to similar challenges in accessing grocery stores.

The model highlighted the importance of economic barriers as a determinant of food insecurity in urban areas. Census tracts with higher percentages of residents living in poverty were more likely to be food deserts, no matter their close proximity to grocery stores and access to transportation. Despite having a relatively higher number of bus stops than other tracts identified as food deserts, Tract C had a higher poverty rate (38.1%). This implies that the evaluation of food insecurity in urban areas should take into account both the physical and economic availability of food.

5. 0 Conclusion

In this paper, we utilized the multi-criteria evaluation (MCE) approach to identify and map food deserts in Washington, D.C., by integrating several socioeconomic and spatial variables. The results revealed an unjust distribution of food stores across the city, with most food deserts located in the eastern parts of the Anacostia River, especially in Wards 7 and 8. The MCE model utilized variables such as distance to grocery store locations, percent poverty in each census tract, metro bus count in each census tract, and population of elderly people. Our findings revealed that a variety of social, economic, and mobility factors, which vary across urban neighborhoods, influence neighborhood food deserts in Washington, D.C., not just their proximity to food outlets. This study contributes to the ongoing conversation about access to food in urban areas and lays an important foundation for policy interventions by local, state, and federal governments to reduce food insecurity in the nation's capital.

Based on our research on food deserts in Washington, D.C., we suggest creating economic incentives to encourage private investors to establish grocery stores in the area east of the Anacostia River, which is home to the majority of food deserts. We also advocate extending public transit routes and stops to improve mobility options for persons living in these areas. These efforts should target areas with high numbers of elderly and poor populations while partnering with community organizations to maintain equal and sustainable access to food.

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