Summary

Most people picture the Northwest quadrant of Washington DC when they think of the city because of touristy attractions and tree-lined residential neighborhoods. Less attention is paid to Southeast DC where, in stark contrast, low-income and minority residents live in a geographical phenomenon called food deserts characterized by scarce access to affordable and fresh nutritional sources. DC Mayor's office wants to a simple model to identify DC's food deserts by US Census Tracts. Figure 1's identified food deserts in burnt orange all located in SE DC which only has four grocery stores serving this vast area east of the Anacostia River. Figure 2's majority of forest green food deserts are in SE DC but also a tract in the SW's Waterfront and are in the Brentwood neighborhood of NE DC. Multi-Criterion Evaluation (MCE) scheme for evaluating Figure 1 developed based on the Mayor's requirements of focusing on young and low income neighborhoods living far from a grocery store. A second model was created using custom MCE looking at neighborhood was high percentages of residents with income lower than poverty line and high percentages of residents 62 years and older and identifies the food desert in forest green color in Figure 2. The differences between the food deserts in Figures 1 and 2 can be explained by the difference in data used in the MCE. Figure 1's MCE focuses on younger residents than median age and whose income is lower than median income in the tract. Figure 2's MCE is modeled based on *percentages* of residents living below poverty and *percentages of* residents 62 years of age and older. The inset map in Figure 2 suggests three census tracts with the highest MCE east of the Anacostia River, that would most benefit of new grocery stores. Site A is census tract 98.07, site B is census tract 76.03 and Site C is census tract 109.0. The three suggested sites for grocery stores are both identified as food deserts in Figures 1 and 2.

Introduction

Washington, DC is ranked as one of the best cities to visit and to live (AFAR, n.d.). The city being America's capital makes it one of a kind; the city attracts visitors each year offering free access to high-quality museums, charming neighborhoods and a plethora of fine dining establishments. Outside NW DC there are many overlooked residential neighborhoods with residents who live below poverty levels and in food deserts. According to the USDA , food deserts are geographical areas where residents have limited access to "fresh, healthy, and affordable foods." Food deserts are defined by three main factors according to the USDA. First, neighborhood lacking healthy options or distance to the grocery store is too far to make it convenient for residents. Secondly, the model needs to take into consideration individual barriers such as being able to afford to buy food or residents have limited free time. Third, the neighborhood's lack of infrastructure where there is limited transportation options or clusters of family living with incomes below poverty level. The DC Mayor's office is looking for simple food desert model focusing on young and low-income neighborhoods, especially east of the Anacostia River, living far from grocery stores. A second model using a custom MCE looks at percentages of population living lower than poverty level and percentages of residents 62 years and older. Based on second model, suggest three locations for placing grocery stores in affected neighborhoods to address food deserts.

Methodology

For both maps, several shape files were used as a basis for analysis. The 2019 TIGER/Line® Shapefiles for DC created geographical map based on US Census tracts. In addition, Open Data DC's shapefile locating military bases, national parks, and water bodies serve as constraints for our food desert models. Grocery stores were used as the primary source of fresh, healthy and affordable foods for residents for this study. For future studies, we can consider incorporating other sources for providing healthy options such as food trucks or community gardens may be considered in future.

For the map in Figure 1 which was created using the Mayor's targeted criterion, Median Age and Median Income data was downloaded from the US Census' 2019 ACS survey for all census tracts within the District of Columbia.

In the second map (Figure 2), the percentage of population living at poverty level and percentage of population aged 62 years or higher were taken from Open Data Dc's ACS Economic Characteristics DC Census Tract data.

A Multi-Criterion Evaluation (MCE) scheme based on USDA's factors was developed to improve the accuracy of the food desert models discussed in detail below. The steps employed for creating the two maps:

1. Download shape files and socioeconomic demographic data from 2019 TIGER/Line by census tracts and Open Data DC
2. Spatial Joins to From DC shape file use the erase tool to eliminate areas that have military bases, national parks and bodies of water from analysis because they are geographical barriers and cannot serve as locations for new grocery stores
3. Change projection of DC census tract shape files and locations of grocery store to NAD 1983 (2011) StatePlane Maryland FIPS 1900 (Meters) so we can use meters for distance analysis
4. Assumption: Residents would see crossing the river as a hindrance. Within each census tract, use the Euclidian Distance tool calculate distance to nearest grocery store in meters and use water bodies as a feature barrier data.
5. To magnify the problem of distance to grocery store and make it easier to identify food deserts in the model, use the Raster Calculator and square the grocery store distances calculated in last step
6. Using a unique key of last eleven digits of the GEOID of the census tracts, join the median age and median income table data to the updated DC shape file from previous steps. After successfully joining the data, export the combined data to a new layer
7. Assumption: median age, median income and distance to grocery stores data is normally distributed. In order to compare several data points derived from different normally distributed samples, create a z-score for median age and median income. Z-scores is calculated by subtracting the mean from the observed value and dividing by the standard deviation (Mann, M., 2021).

$$zscore = \frac{X_{i-\bar{X}}}{\sigma}$$

X_i – sample data point at i
$\bar{x}$ represents the mean of X
σ – standard deviation

8. After calculating z-score for each variable, scale the values to be between 0 and 1 so it can be incorporated in MCE formula more easily using min/max formula (Mann, M., 2021)

$$(X_i - X_{min})/(X_{max} - X_{min})$$

9. Rescale income and age to give higher scores to poorer and younger census tracts

```
def Reclass(input):
    if (input < -1.5):
        return 1
    if (input > -1.5 and input <= -1):
        return 0.85
    if (input > -1 and input <= -0.5):
        return .7
    if (input > -0.5 and input <= 0.5):
        return 0.5
    if (input > 0.5 and input <= 1):
        return 0.3
    if (input > 1 and input <= 1.5):
        return 0.2
    else:
        return 0.1
```

10. For the model in figure 1, use the following MCE formula with the scaled variables: (**age_scaled * 0.15 + income_scaled * 0.30 + dist_scaled * 0.55**). By assigning heavier weights, the MCE prioritizes those factors in analyzing food deserts. Tracts with an MCE value closer to 1 would be areas most likely to be food deserts. The sum of the weights should be equal to 1. By placing the weights (85%) on low-income population and far distances to the grocery store, it is meeting the classical food desert factors set by USDA

(eg not being able to afford fresh and healthy foods and living too far from a source) whilst honoring the mayor's request to focus on young population

11. In the second food desert model for Washington DC, incorporate new variables and update the MCE. Enhance mayor's model by adding new variables into the analysis:
    - "PERCENTAGE OF FAMILIES AND PEOPLE WHOSE INCOME IN THE PAST 12 MONTHS IS BELOW THE POVERTY LEVEL: All families", ACS Economic Characteristics DC Census Tract. Metadata explained here
    - Percentage of elderly population was calculated using with the formula (b)/(a) where (a) is "SEX AND AGE: Total population" and (b) is "SEX AND AGE: Total population: 62 years and over" from Open Data DC's ACS Economic Characteristics DC Census Tract.
    - Bus stop locations downloaded from Open Data DC. Use spatial join between bus stop points to the DC census tracts shape to find the number of bus stops available in a 50 m radius within a census tract for this study. This method failed to tell us how far those bus stops are for residents so for future consideration, use Euclidian distance calculator to factor in the distance to bus stops for residents
12. Rescale to give higher scores to higher percentages of population living in poverty and higher percentages of residents older than 62 years. Refer to table below for reclassification logic in model 2.
13. In model 2, the reclass procedure of z-scores of percentages tries to place more positive scores closer to 1. Interpret a negative Z-score of percentages variables added to be population living at above poverty level and ages < 62. MCE was calculated using the formula: (**percent_elderly_scaled* 0.15 + poverty_all_scaled * 0.30 + dist_scaled * 0.40 + bus_stop_count_rescale*0.15**)

Results

Two basic models identifying food deserts are shown in Figures 1 and 2. In Figure 1, the criteria for evaluating census tracts as food desert emphasizes an almost 4:5 ratio importance to residents living below the median income and living farthest from a grocery store and to a lesser extent, young residents to satisfy the DC Mayor's requirements. Figure 2 model builds on the first model heavily weighs the percentages of population living below poverty and distance to nearest grocery store and to a lesser extent, percentage of residents older than 62 years and number of bus stops. Based on MCE weights of model 1, income weighs twice as much as age in the final MCE score.

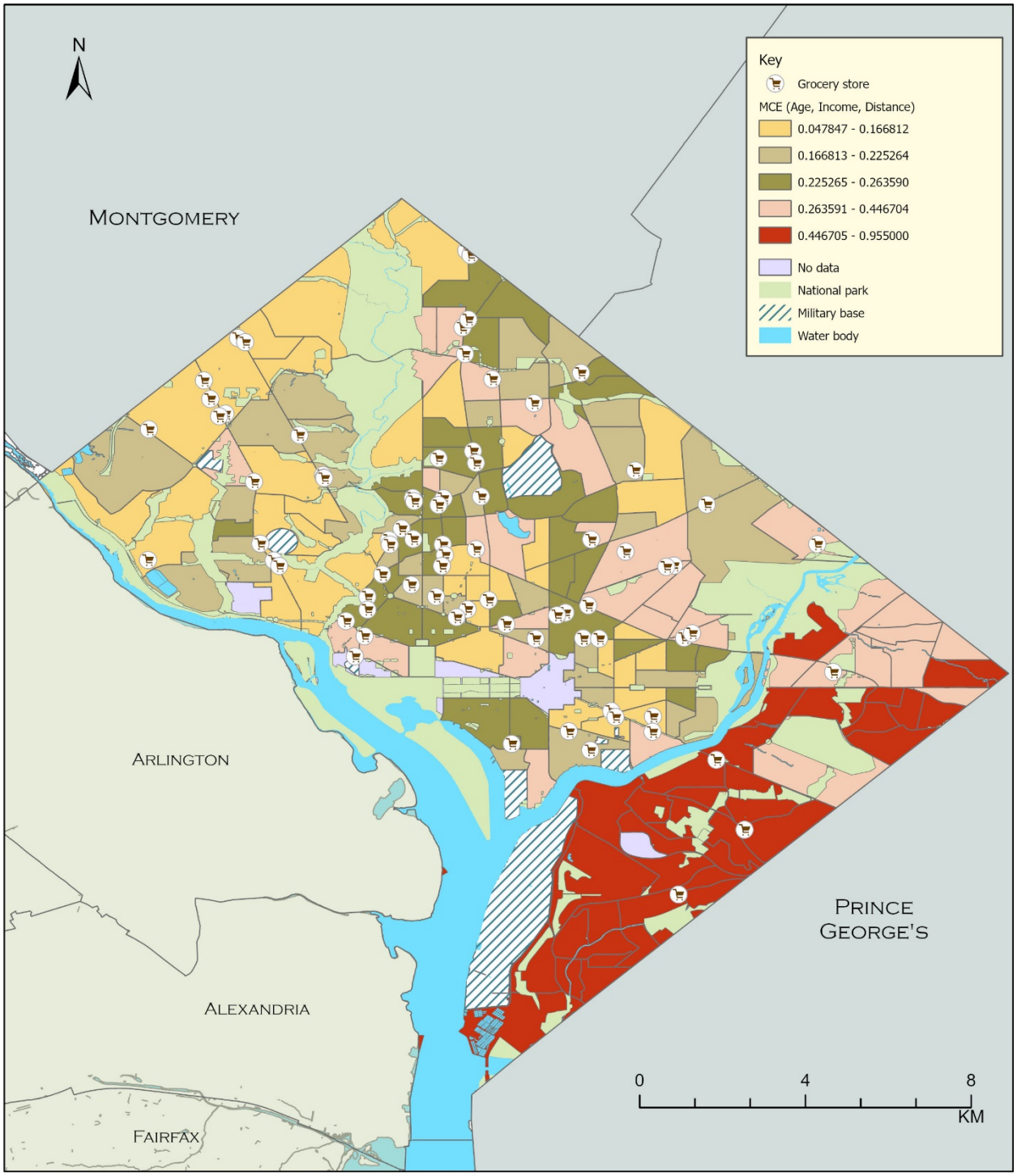
Both Figures 1 and 2 identify food deserts Southeast DC, east of the Anacostia River. Figure 1 represents food deserts as burnt orange color and Figure 2's food deserts are forest green color. A total of four grocery stores serves Southeast DC residents. The Anacostia-Bolling military base dominate the geography of Southeast but grocery stores on base only serve those who can access it. Figure 2 also identified the SW Waterfront and the Brentwood neighborhood of NE DC as food deserts housing food insecure elderly residents. Both the Waterfront/Wharf in SW DC (WashingtonDC, n.d.) and Brentwood neighborhood (WashingtonPost, Jones, Nathalie) have historically served low income and minority residents so it makes sense that model 2's custom MCD identified the neighborhood because one would expect to see see higher percentages of older residents. Figure 2 model shows a sparseness in the forest green colored food deserts in the SE compared to the burnt orange areas of Figure 1 because it looks at percentages of residents older than 62 years old. This speaks to the greater likelihood of residents 62 years and older living without young members in the house whereas the reverse of underaged residents living without an adult is unlikely and not lawful. Model 2 also assume an aging population may need to rely more heavily on public transportation so included in the MCE is the number of bus stops.

Based on MCEs in Figure 2, the inset map shows three sites (A, B, C) that would most benefit from adding grocery stores. Looking at Figure 2, Site A is census tract 98.07, is in red, had MCE score of 0.637178; site B is census tract 76.03, is in orange, with MCE score of 0.615794; site C is census tract 109.0, is in yellow, and had MCE score 0.524038. These tracts had the highest MCE's closest to 1. There was a census tract whose MCE was higher than

0.524038 but it was located west of Anacostia River, and it was assumed previously that residents would consider it a nuisance to cross the river to go to the grocery store. Both models developed using the Mayor's method and the custom method identified these three sites as food deserts and therefore would immediately benefit residents most.

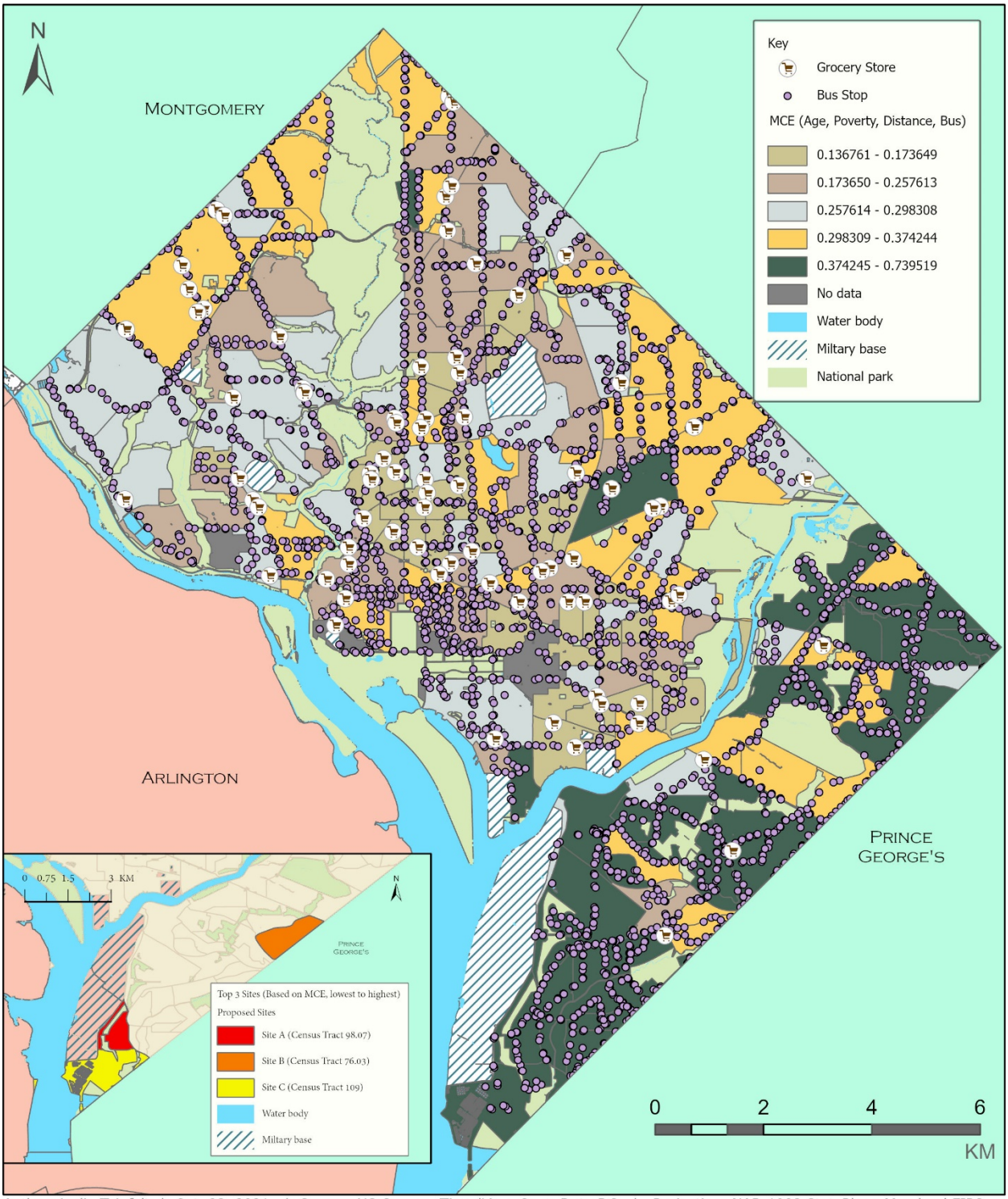
Variable Name	Scaling Method	MCE weight	MCE weight justification	Justification for Inclusion
PERCENTAGE OF FAMILIES AND PEOPLE WHOSE INCOME IN THE PAST 12 MONTHS IS BELOW THE POVERTY LEVEL: All families	*def reclass(input):* *if (input < -1.5):* *return 0.1* *if (input > -1.5 and input <= 0):* *return 0.3* *if (input > 0 and input <= 0.2):* *return 0.6* *if (input > 0.2 and input <= 0.5):* *return 0.7* *if (input > 0.5 and input <= 1.2):* *return 0.9* *if (input > 1.2):* *return 1* *else:* *return 0.1*	0.30	This meets the USDA guidelines for food desert model	This meets the USDA guidelines for food desert model. By following USDA guidelines, we rely on their expertise and experience and create a food desert model standardized across the US.
Percentage of population 62 years and older	Same reclass method as above	0.15	Half as important and not percentage of population living below poverty	Elderly residents may introduce new risk like disability and could be living alone so posing a threat of food insecurity that can be overlooked and go unchecked
Bus stop counts	Same reclass method as above	0.15		In the population 62 years old and older, may no longer able to drive safely or maintain a car so rely heavily on public transportation nearest to them, hence bus stops and not metro stops.

Figure 1: Washington DC's Food Deserts (Mayor's Method)



Author: Lydia Teinfalt | Oct. 23, 2021 | Source: US Census, Tiger/Line, Open Data DC | Projection: NAD 1983 StatePlane Maryland FIPS

Figure 2: Washington DC's Food Deserts by US Census Tract (Custom Method)



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