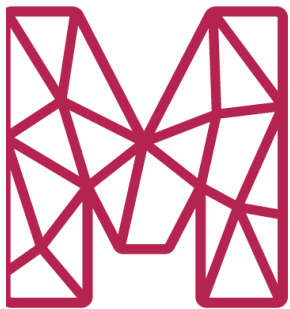


# A Systems Thinking Approach to Food Systems and Security



**Metabolic**  
Institute



**Utrecht  
University**

**Minor Research Project**

**Tom Szabo-Hemmings**

**8670331**

**MSc. Bio Inspired Innovation**

**Supervisor - Antoine Coudard**

**Second Examiner - Jaco Appelman**

## Scientific Abstract

Food systems are essential for both global environmental sustainability and food security. However, they are major contributors to anthropogenic greenhouse gas emissions and are the primary driver of biodiversity loss. This research examines the regional food system of the Charlotte Metropolitan Area (CMA) specifically focusing on the role of small farms in the regional food system. In addition, the study assesses food insecurity in Mecklenburg County and develops new methodologies for locating Low-income, Low-access (LILA) areas. Using a mixed-methods approach, the study identified 494 small farms in the CMA region and 4,387 food selling establishments in Mecklenburg County. Data was collected from farmers markets vendor list, Google Maps Places API, and a nutritional tracking study involving local residents using the MyFoodRepo app. The findings indicate that while small farms are a potential source of fresh, nutritious produce, food insecurity persists. Inadequate access to affordable, healthy food disproportionately affects low-income communities, particularly in LILA areas. The study also highlights the limitations of existing methodologies for identifying LILAs and proposes a more granular approach to accurately locate food-insecure households. These insights underscore the need for policy interventions that support small farms, improve food access, and promote the distribution of affordable, nutritious food throughout the region.

## Layman Summary

Our food systems are responsible for a large amount of greenhouse gas emissions, a key driver of climate change, and are the main cause of biodiversity loss. This research looks at the food system in the Charlotte Metropolitan Area (CMA) in North Carolina, with a special focus on small farms and how they fit into the larger picture of food security and sustainability in the region. The study also explores food insecurity in Mecklenburg County, which is a serious issue affecting many residents, especially low-income families.

Food insecurity is when some people don't have reliable access to enough affordable, healthy food. This problem can be even worse in areas known as "Low-income, Low-access" (LILA) zones, where residents are both limited by income and access to places that sell nutritious food. One goal of this research was to develop better ways to find these areas so that help can be directed where it's needed most.

To understand the food landscape in the CMA, we used several approaches. First, we identified 494 small farms in the region by looking at farmers market vendor lists and using data from Google Maps. Small farms are important because often they sustainably grow fresh, nutritious food, like fruits, vegetables, and meat, that local communities need. However, despite the presence of these farms, food insecurity remains a significant issue in Mecklenburg County.

We also mapped out 4,387 food-selling establishments in Mecklenburg County, including grocery stores, convenience stores, and restaurants. In addition, we used an app called MyFoodRepo to conduct a small

study with local residents tracking what they ate over a week. This helped us understand not only what kinds of food are available but also what people are actually eating. The data showed that while fresh produce is available, it is not always accessible or affordable for everyone, especially in poorer communities. Fast food and convenience stores that sell less healthy options are often easier to access, which means that people may not be eating the fresh nutritious food they need for a balanced diet.

The study also looked at the current methods used to find LILA areas, which don't always give a full picture of the problem. We proposed a more detailed way of identifying these areas, taking into account not just distance to healthy food retailers but also the affordability of these retailers. A grocery store might be nearby, but if the food there is too expensive, it's just as inaccessible as a store that's far away.

In conclusion, small farms have the potential to play a bigger role in improving local food security by providing fresh, healthy food. However, there are still many barriers to accessing this food, especially in low-income communities. To address this, policymakers should create programs that support small farms, improve food access for all residents, and ensure that nutritious, affordable food is available in all parts of Mecklenburg County.

# Introduction

Food systems are a major driver of climate change, accounting for approximately 34% of all anthropogenic greenhouse gas emissions (Crippa et al., 2021). Simultaneously, food systems are the primary driver of global biodiversity loss (Benton et al., 2021). These consequences are the result of a greater human demand causing increased pressure on production systems (Benton et al., 2021). Despite the industrialization and intensification of food production over the past century, food and nutrition security remain critical challenges, exacerbated by a rapidly growing population on a planet with finite resources (Cole et al., 2018). Nutrition inequality and food insecurity are becoming increasingly evident, with socioeconomically disadvantaged groups disproportionately affected by nutrition-related conditions, such as obesity and malnutrition (Hayes et al., 2019; Van de Poel et al., 2008). Climate change and the increasing frequency of extreme weather events are expected to make crop yields more unpredictable, exacerbating food insecurity, especially in communities already grappling with high levels of hunger and scarcity (Wheeler et al., 2013). As climate change intensifies, the gap in nutrition inequality is likely to widen (Salm et al., 2021). The interconnectedness of the food system, environment, health, and socioeconomics underscores the need for a systems-thinking approach to address these challenges. To create a food system that benefits humanity, nature, and the environment holistically, significant and systematic changes are essential.

Mecklenburg County is a county located in North Carolina, USA. It contains the city of Charlotte, the most populous city in the state (U.S. Census Bureau, 2023). Being North Carolina's largest city, it is a hub for food production, distribution, retail and consumption. In 2022 it was reported that in North Carolina alone there were over 42,000 farms (USDA 2022). In the Charlotte metropolitan area (CMA)<sup>1</sup>, there are over 7,660 farms, with a combined coverage of around 1.2million acres (USDA, 2022; USDA, 2022). In 2022, the total market value of agricultural products sold in CMA was over \$2.3billion (USDA, 2022; USDA, 2022), which displays the significance of the food production industry in this region. However, 90% of what is harvested in CMA is attributed to 4 crops (hay, corn, soy and wheat) which are grown for animal feed and therefore not directly cultivated for human consumption (USDA, 2022). In the CMA, there is a huge disparity between different farms with regards to size, practice, and output. They range from small urban farms of under an acre to animal feeding operations (AFOs) which can hold up to a few thousand of animals indoors for large durations of time and contribute significantly to local pollution (EPA, 2023). Information about large farms is well documented by the USDA but the same is not true for smaller farms, especially those under 10 acres in size. Small farms are noted for preserving local customs and traditions as well as promoting sustainability in the region (Žmija, et al., 2019). Through increasing local employment and cultivating food for residents, small farms have been suggested as key to revitalising rural economies and increasing regional food security (McDonagh et al., 2017). In recent years, the impacts of the COVID-10 pandemic and the war in Ukraine have resulted in global food price rises and increases of food insecurity, further highlighting the importance of sustainable local food

---

<sup>1</sup> CMA is made up of 10 counties in North Carolina (Alexander, Anson, Cabarrus, Catawba, Gaston, Iredell, Lincoln, Mecklenburg, Rowan, Union) and 4 counties in South Carolina (Chester, Chesterfield, Lancaster, York).

production (Lin et al., 2023). Therefore, small local farms are an essential part of any food system and understanding and collecting information on them is vital for understanding a food system as a whole.

Despite the significant economic contribution and vast swathes of land dedicated to feed production for livestock in this region, food insecurity is still a significant issue in Mecklenburg. The goal for any municipality, with regards to food systems, is to create food security for their residents. The issue of food insecurity in the USA is worsening with 12.8% of households in 2023 being food insecure, a 2.3% rise from 2020 (Rabbitt et al., 2023). This issue is especially prevalent in Mecklenburg County with it being reported that 15% of its residents are food insecure (McFadden, 2020). The county is already introducing numerous initiatives to combat this issue including a Refrigerator Programme, providing infrastructure to corner stores in the area allowing them to provide fresh produce for local residents, as well as the Healthy Corner Store initiative which provides fresh produce to food insecure locations (Mecklenburg County, 2024). Despite these efforts, the problem of food insecurity persists. In a food-secure environment, nutritious and healthy food is available, affordable and accessible (Simelane and Worth, 2020). Food insecurity is a systemic failing and cannot be solved by simply opening more stores. Transit deserts, areas with large transport requirements while lacking transport infrastructure, can also heavily contribute to food insecurity (Aman and Smith-Colin, 2020). Furthermore, in areas enduring economic hardship, the availability of nutritious food is not enough to combat food insecurity if it is not affordable for local residents (Crowe et al., 2018). To determine the extent at which Mecklenburg County is a food secure environment we need to create an inventory of all food selling establishments as well as the socioeconomic data of the residents living in Mecklenburg. When looking at food security, it is important to take a multifaceted approach ensuring that the availability, affordability and accessibility of healthy food is researched to fully understand why food insecurity exists in the region.

The USDA defines food deserts as low-income areas which have little to no access to affordable nutritious food, in urban environments, low access is categorised as living further than 1 mile away from a fully functional grocery store (Dutko et al., 2012). The current methodologies used for locating food deserts lack granularity and do not take affordability of grocery stores into consideration, despite expensive stores being inaccessible to low-income residents (Dutko et al., 2012). New methodologies should be devised to more accurately locate those households living in food deserts to ensure they are not excluded from analysis. Furthermore, new terminologies are emerging in the field as it has been suggested that the term 'food desert' naturalises a very human-made problem, and instead the term Low-income and Low-access (LILA) should be used (USDA, 2024).

Understanding food systems and their complexity is essential for addressing issues related to public health, food security and sustainability. The analysis identifies gaps in sustainability and productivity and identifies opportunities for innovations to fill these gaps. This report attempts to comprehensively investigate CMAs regional small farms, analyse food and nutrition insecurity, and discover what the people of Mecklenburg are eating.

## **Research Question**

Is Mecklenburg County a food secure region for all its human inhabitants and to what extent do small farms play a role in the wider CMA food system?

To help answer this research question I have formulated the following sub-questions.

- To what extent can small farms contribute to the local food system?
- Can the diet of Mecklenburg residents be classified as balanced and nutritious?
- To what extent is there equal access to nutritious and affordable food in Mecklenburg County?
- Are the current methods for locating LILA areas sufficient?

# Methods

## Identifying CMAs Small Farms

To identify regional small farms, I first located 26 farmers markets in Mecklenburg County using the *'North Carolina Food Infrastructure Map'* (PTRC, 2024). From this list of farmers markets, I would investigate the websites of each farmers market and locate their vendor lists when available. From the information present in the vendor lists I attempted to locate the vendors and determine their farm location as well as what they cultivate and produce on their farm. I also established which farms were still in operation and which had gone out of business.

In an attempt to locate additional farms not on farmers market vendor lists a Google Maps Places API was conducted using the term *'farm'* for the entire CMA region (Google, 2024). This information had to be carefully reviewed as many businesses located were not sites of agricultural activity, but for example new housing developments containing the word *'farm'* in their name, such as "Sycamore Farms, Union County" or various other businesses using the word *'farm'*. When it was confirmed that a business was not actually a farm engaging in agricultural activities they were removed from the dataset.

Once all the information of the farms had been collected they were mapped using GIS.

## My Food Repo Study

Understanding what residents are eating can reveal gaps in the food system. Collaborating with volunteers at Davidson College, NC, we recruited 10 Mecklenburg residents to take part in a 7 day study looking at their food consumption. Using the mobile app *'MyFoodRepo'* developed by the Digital Epidemiology Lab of the Swiss Federal Institute of Technology Lausanne (EPFL) participants were able to log their meals for the duration of the study (MyFoodRepo, 2024). MyFoodRepo is an AI assisted application that is developed for research into nutrition tracking (MyFoodRepo, 2024).


Participants were encouraged to upload photos of the food and drinks they consumed, throughout the study period, alongside annotation.. From this image the MyFoodRepo AI predicted the food type and the amount (Figure 1). The AI's prediction was then checked and altered if necessary. If the AI was unable to make a prediction, then using the images and description the food consumed would be manually logged into the app (Figure 2). On these occasions, the website <https://www.caloriefriend.com/en> was used to allow us to make an accurate estimation of food weights from the participant images alone.

Dish Foods

1. ■ Greek Salad, no dressing

Total: 400g | 0ml

[+ Add a dishfood](#)



Dish Food 01

● Greek Salad, no dressing (US - 20452)

Present amount ⓘ

400 g

Eaten unit      Eaten amount ⓘ

g    %      400    g

Skip energy validation

Dish Food 01 Segment 01

**Figure 1 - MyFoodRepo correctly analysing meal type and amount of food.**

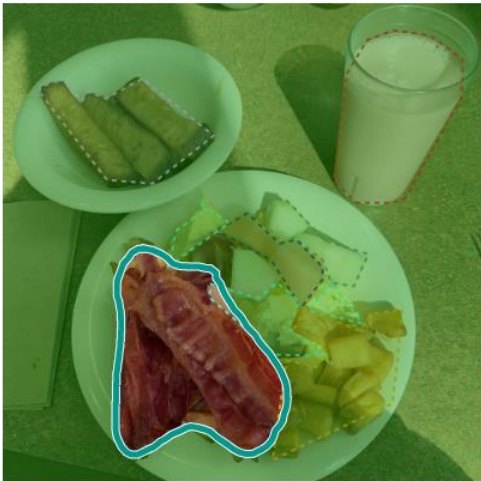
## Segmentation

Dish Foods

1. ■ Bacon, NS as to type of meat, cooked
2. ■ French toast sticks, NFS
3. ■ Potato, home fries, NFS
4. ■ Honeydew melon, raw
5. ■ Cantaloupe, raw
6. ■ Egg omelet or scrambled egg, no added fat

Total: 510g | 236ml

[+ Add a dishfood](#)



Dish Food 01

● Bacon, NS as to type of meat, cooked (US - 24339)

Present amount ⓘ

40 g

Eaten unit      Eaten amount ⓘ

g    %      40    g

Skip energy validation

Dish Food 01 Segment 01

**Figure 2 - MyFoodRepo entry which had to be manually imputed due to inability from the MyFoodRepo AI.**

Once the study had elapsed, MyFoodRepo calculated an array of different nutrition data for all participants as well as the entire cohort.



## Creating a Mecklenburg Food Database

To gain an understanding of Mecklenburg food environment we had to compile a database of all food selling establishments from **food retailers** (such as grocery stores, supermarkets and ethnic stores) to establishments where prepared food is purchased or eaten away from home (such as restaurants and takeaways) which for the remainder of this report will be referred to as **food away from home (FAFH)**. To compile all the information needed for this database a Google Places API was used (Google, 2024). The Google Places API provided us with information on name, location, affordability and type of business. Place request and text query were used to locate the food selling establishments.

### **Place Request**

All establishments in Mecklenburg area which google maps categorised under the following place types were collected (Google, 2024):

- bakery
- bar
- cafe
- drugstore
- convenience store
- gas\_station
- meal\_delivery
- meal\_takeaway
- restaurant
- supermarket

### **Text Query**

To find additional food establishments which had not been categorised within one of the previously mentioned categories, the following text queries were used:

- "supermarket or grocery store"
- "department store with food"
- "pharmacy with food"
- "ethnic store"
- "gas station with food"
- "restaurant"
- "fast food restaurant"
- "bakery"
- "cafe or coffee shop"

Once all the data had been collected for all food selling establishments it then had to be cleaned to remove all locations which were permanently closed, inactive, or duplications.

## Availability of Nutritious Food

In order to determine the availability of nutritious food in Mecklenburg County we had to categorise each food selling establishment with regards to the availability of healthy and nutritious food at their location.

### Food Retail

The modified Retail Food Environment Index (mRFI) is a commonly used method by the Center for Disease Control to classify retailers as “healthy” or “unhealthy” (CDC, 2012). Stores which have very little or no fresh fruits, vegetables, proteins and whole grain products, such as convenience and dollar stores, are classified as unhealthy. Whereas, full-service stores providing a whole range of fresh and nutritious products are classified as healthy. However, this methodology does not take into consideration all food retailers, such as farmers markets, ethnic stores and corner stores selling nutritious options (such as those taking part in the Mecklenburg 2024 Refrigerator Program (Mecklenburg County, 2024)). Therefore, the methodology was amended for this study to include these retailers. Retailers were given a Dietary Risk categorisation based on their business type (Table 1).

**Table 1 - Retailers and their dietary risk categorisation.**

Food retailer classification by dietary risk		
Food retailer	Dietary risk	Rationale
Grocery store chains	Healthy	Grocery stores carry a full range of fresh vegetables, fresh meat, dairy and whole grain products.
Other independent grocery stores	Healthy	Grocery stores carry a full range of fresh vegetables, fresh meat, dairy and whole grain products.
Ethnic grocery store	Healthy	Ethnic grocery stores, whilst often small, are known to carry a wide variety of healthy food options (Emond et al., 2012).
Supercenter	Healthy	Supercenters carry a full range of fresh vegetables, fresh meat, dairy and whole grain products.
Convenience store chains	Unhealthy	Convenience stores primarily sell a limited assortment of goods. While they might carry milk or bread, they mostly sell processed foods and lack fresh & nutritious foods. The mRFEI and other research studies classify convenience stores as unhealthy (Raskind et al., 2020).
Other convenience stores	Unhealthy	See convenience store chains. With exception of designated healthy corner stores (see below)
Other convenience stores (2024 Refrigerator Program)	Healthy	We classify corner stores that were part of the 2024 refrigerator program as healthy due to their increased offering of fresh vegetables and dairy.
Other convenience stores (Healthy Corner Stores)	Healthy	We classify corner stores that were part of the 2024 refrigerator program as healthy due to their increased offering of fresh vegetables and dairy
Pharmacy with food	Uncertain	Pharmacies are considered uncertain. While they do not carry a full range of fresh & nutritious foods, they cannot be compared to convenience stores.

Discount stores	Unhealthy	Discount stores are considered unhealthy in the mRFEI and by other research studies (Raskind et al., 2020).
Department stores with food	Unhealthy	Department stores with food options do not carry a full range of fresh and nutritious foods. These stores are mostly selling shelf-stable processed food and are lacking dairy, meats, vegetables and fruits.
Farmers market	Healthy	Farmers markets carry a full range of fresh and healthy vegetables, meats and dairy.

## FAFH

To assess the availability of healthy FAFH establishments we constructed a methodology based on the 'Food Outlets Dietary Risk' assessment tool and other menu scoring tools (Pulker et al., 2020; Pulker et al., 2023; Raphael, 2022). However, as these tools required physical visits and this was not possible the methodologies were modified to enable them to be conducted remotely without access to these establishments.

As it is well documented that fast-food establishments promote unhealthy eating habits, offering ultra-processed food and often lacking choices of fresh foods, all establishments which were categorised as 'fast food' were assigned as unhealthy (Kirkpatrick et al., 2014; Alexander et al., 2021). We then conducted a search for commonly used fast-food terms such as "burger", "hotdog", "fried chicken", "pizza" and "cake" and assigned establishments with these terms in their names as unhealthy as there was a very high likelihood of this being the case.

The remaining establishments required manual screening to assess the extent at which they offered nutritious options. To do this we looked at online menus and customer photos of each individual establishment and using a checklist we assessed whether the establishment was healthy, neutral, or unhealthy (Table 2). By using customer photos we were able to gain a more comprehensive understanding of what patrons were consuming at the establishment, rather than just looking at menus which can be ambiguous.

**Table 2 - Checklist for assessing healthiness of FAFH**

Risk for unhealthy eating			
Review material	Questions		Dietary risk level
Website/ Menu	<p><b>Availability of healthy food options</b> Over 80% of menu items contain over one nutrient-rich food from this list:</p> <ul style="list-style-type: none"> <li>● Vegetables</li> <li>● Fruits</li> <li>● Whole grains</li> <li>● Legumes &amp; beans</li> <li>● Nuts &amp; seeds</li> <li>● Lean meats</li> <li>● Eggs</li> <li>● Dairy</li> </ul>	→	Healthy

	Between 50% and 80% of menu items contain nutrient-rich foods (vegetables, whole grains, fruits, meats, dairy)	→	<b>Neutral</b>
	<p><b>Availability of unhealthy food options</b> Menu items include less than 50% of items that count as nutrient-rich foods (vegetables, whole grains, fruits, meats, dairy) and are high in foods with added sugar, fats, and empty calories.</p>	→	<b>Unhealthy</b>
	<p><b>Adequacy of healthy options</b> Healthy food items are mainly available as sides and not as a full meal (side salads without nutrient-rich ingredients, such as only lettuce do not count as a healthy option)</p>	→	<b>Unhealthy</b>
<b>Google Photos</b>	<p><b>Availability of unhealthy food items</b> Customer photos shows predominantly deep-fried items (fries, deep-fried fish, fried meats)</p>	→	<b>Unhealthy</b>
	Customer photos show predominantly sugary items (doughnuts, waffles, cakes, cookies, pastries)	→	<b>Unhealthy</b>
	Customer photos predominantly show meals with a high risk of exceeding sodium limits (stir fry sauces)	→	<b>Unhealthy</b>
	<p><b>Availability of healthy food items</b> Customer photos show predominantly a variety of nutrient-rich food items (grains, salads, dairy, fruit)</p>	→	<b>Healthy</b>
	Customer photos show a mix of nutrient-poor (e.g. sides of fries with mains) and nutrient-rich food items (grains, salads, dairy, fruit).	→	<b>Neutral</b>
	<p><b>Portion size</b> Customer photos show predominantly large portion sizes</p>	→	<b>Unhealthy</b>

## Affordability of Nutritious Food

To measure the affordability of food selling establishments in Mecklenburg we developed a method based on Google's price rating. Google's price rating is generated using user feedback and purchasing patterns, therefore providing us with the realities of how much customers are really spending in these businesses. We were able to obtain affordability ratings for some of the businesses through the Google Places API, but this information was missing for a large proportion of establishments and therefore manual assessments were carried out (Google, 2024).

### Food Retail

As Google price ratings were only available for 10% of retailers (including Walmart, Harris Teeter and Whole Foods), we created a new methodology for determining the affordability of the remaining retailers. As some establishments did have google price ratings we were able to develop a framework for assessing the unrated businesses (Table X). An affordability rating of either 'Affordable', 'Moderate', or 'Expensive' was awarded to correlate with the Google Price ratings (Table 3).

Food retailers		
Google Price Rating	Example Store	Affordability Rating
\$	Walmart	Affordable
\$\$	Harris Teeter	Moderate
\$\$\$	Whole Foods	Expensive

**Table 3** - Google price rating, benchmark food retailers and our affordability rating.

To effectively rate food retailers, store categories were used to give affordability ratings (Table 4). Literature, information collected from online reviews/chat forums plus direct price comparisons with rated stores were used to award affordability ratings.

**Table 4** - Affordability rating for unrated retailers.

Affordability rating		
Type	Price comparison	Assigned affordability
<b>Food retail</b>		
Grocery store chains & independent grocery stores, department stores with food	Most supermarket chains are moderately affordable and thus assigned a 2. Only high-end stores comparable to WholeFoods receive an affordability ranking of 3. Limited assortment stores, such as Aldi and Lidl receive a ranking of 1	Affordable - Expensive
Ethnic grocery store	Ethnic stores have been found to be cheaper than most major supermarket chains (Emond et al.,	Affordable

	<i>2012). Thus, all ethnic stores were considered very affordable (1), unless reviewers' comments suggested unreasonably high prices.</i>	
Discount stores	<i>Dollar stores and discount stores are generally cheaper than normal grocery stores and thus assigned a rating of 1</i>	Affordable
Pharmacy with food, convenience store chains & other convenience stores	<i>These stores were assigned an affordability ranking 2 if not available. Convenience stores and pharmacies are deemed more expensive as general supermarkets but not as expensive as e.g. Whole Foods</i>	Moderate
Farmers market	<i>Farmers Markets were assigned an affordability ranking of 2 and exact price information was not available. Fresh local produce is assumed to be priced moderately for the local community.</i>	Moderate

### **FAFH**

For FAFH establishments Google Price rating has one more category representing the fact that some FAFH establishments are very expensive (Table 5). To compensate for this another affordability rating was added for FAFH establishments (Table 5). While there were a larger proportion of FAFH establishments with a Google Price rating from the Google Maps Places API than food retailers there were still a significant amount of businesses without this information and, therefore, which required manual assessment of affordability. To manually assess the affordability rating of FAFH we developed a price range for each category based on the 'average per person spend' for businesses which had been given a google price rating (Table 5). Once these ranges had been established we looked through menus, customer reviews and customer photos of each unrated business to determine the likely 'average per person spend' and provided the business with an affordability rating.

<b>Food away from home</b>		
<b>Google Price Rating</b>	<b>Price Range for Manual Price Rating (per person)</b>	<b>Affordability Rating</b>
\$	\$1 - \$10	Affordable
\$\$	\$10 - \$30	Moderate
\$\$\$	\$30 - \$60	Expensive
\$\$\$\$	\$60 +	Very Expensive

**Table 5 - Google price rating, price range per person and affordability rating for FAFH.**

## Analysing LILAs

The USDA has compiled a methodology for locating LILAs (Dutko et al., 2012). However, there are numerous factors not taken into account in this methodology. Therefore, to counteract this, we developed our own methodology to be more granular and to more closely reflect the definition “*food deserts [LILA] are low-income areas which have little to no access to affordable nutritious food. In urban environments, low access is categorised as living further than 1 mile away from a fully functional grocery store.*” (Dutko et al., 2012). The main differences between the two methodologies is that the USDA takes the whole population of census tracts<sup>2</sup> that it deems to be low-income and low-access whereas in our methodology we calculate the proportions of each block group<sup>3</sup> which are low-income and low-access. The USDA method also does not consider the price of healthy food retailers in its calculation, whereas, we only include retailers which are healthy and affordable as these are the only healthy retailers which would be accessible to low-income households.

Both methodologies were carried out to locate LILAs and the differences in the results were compared (Table 6). The divergent outcomes resulting from the two methodologies are thoroughly elaborated upon in the results section.

**Table 6 - The differences between the USDA methods for calculating LILAs and the new method created at**

Methods For Discovering LILAs	
USDA	Metabolic
Uses <b>total population</b> of <b>census tracts</b> which meet low-income and low-access criteria.	Uses the <b>proportion of households</b> within <b>block groups</b> which are deemed as low-income and have low-access to affordable nutritious.
A census tract is classified as low-income if ONE of the following conditions are met: <ul style="list-style-type: none"> <li>● Poverty rate is &gt;20% of the tract population (poverty threshold level approximately &lt;\$30,000 for a family of 4)(U.S. Census Bureau, 2024.)</li> <li>● Median family income does not exceed 80% metro-area median family income.</li> </ul>	The percentage of low-income households per block-group was calculated. A household was deemed a low-income if: <ul style="list-style-type: none"> <li>● The total household salary was 125% of the poverty threshold level (approximately &lt;\$35,000 for a family of 4)(LSC, 2024; U.S. Census Bureau, 2024).</li> </ul>
A census tract is classified as low-access if: <ul style="list-style-type: none"> <li>● At least 500 residents or 33% of the population is located more than 1 mile from the nearest supermarket or large grocery store.</li> </ul>	The percentage of each block group which was low-access was calculated. <ul style="list-style-type: none"> <li>● Isochrones calculated for households further than 1 mile away from nutritious (health rating 'healthy') and affordable (affordability rating 'Affordable') food retail.</li> </ul>

### Metabolic.

<sup>2</sup> Census Tracts are small, relatively permanent statistical subdivisions of a county or statistically equivalent entity that can be updated by local participants prior to each decennial census as part of the Census Bureau’s Participant Statistical Areas Program (PSAP). Census Tracts are normally made up by 2 to 3 block groups (US Census Bureau, 2014).

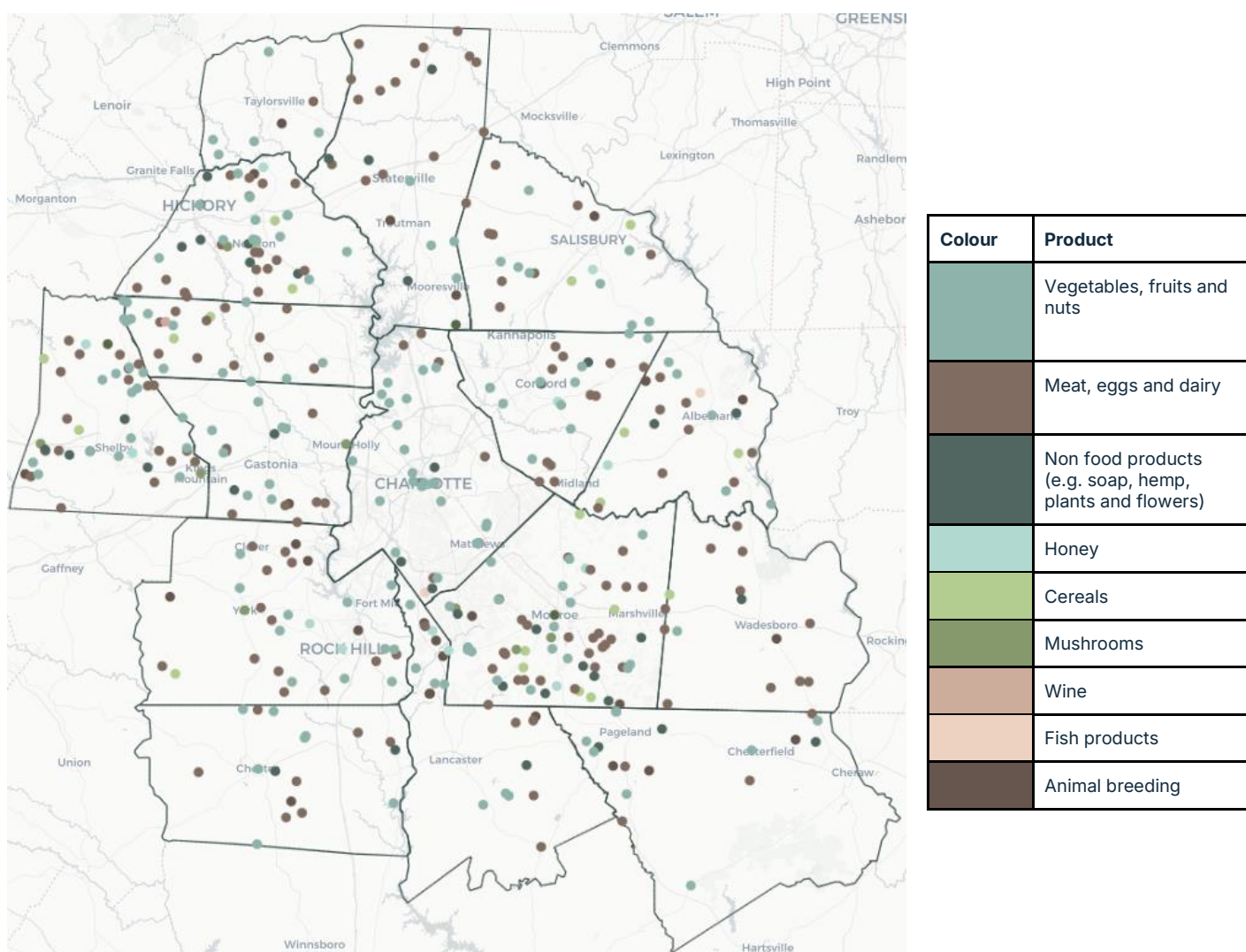
<sup>3</sup> Block Groups (BGs) are statistical divisions of census tracts, are generally defined to contain between 600 and 3,000 people, and are used to present data and control block numbering. A block group consists of clusters of blocks within the same census. Block groups have the same boundaries as Neighborhood Profile Areas - although some NPAs are formed of 2 Block Groups (US Census Bureau, 2014).



# Results

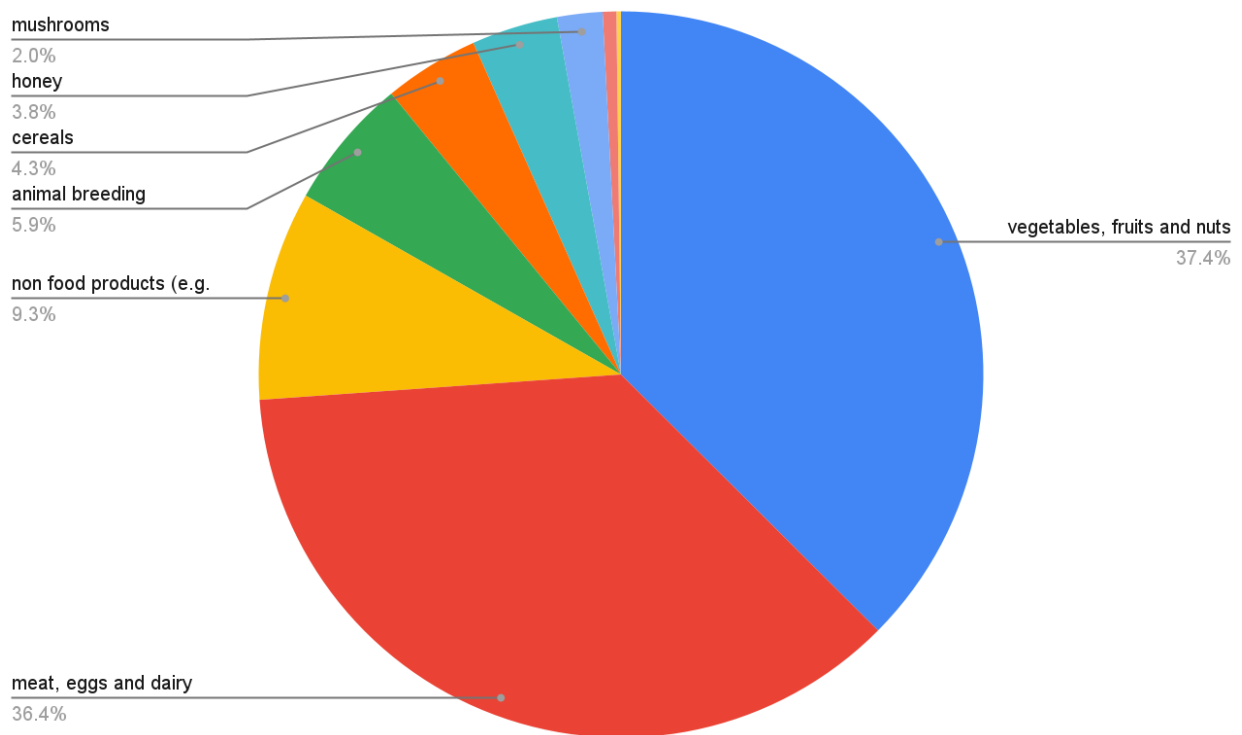
## CMA's Small Farms

494 small farms were located in the CMA region (Figure 3). These small farms produced a range of different agricultural products, and were categorised into the following categories: Vegetables fruits and nuts, Meat eggs and dairy, Non food products (e.g. soap, hemp, plants and flowers), Honey, Cereals, Mushrooms, Wine, Fish products, Animal breeding. The majority of the farms produce either fruits and vegetables or meat and dairy products (73.8%) (Figure 4). When categorised the size of each category ranged from 185 farms producing Vegetables, fruits and nuts to only one farm cultivating grapes for wine (Figure 4).



**Figure 3** - Map showing the location and type of product created at each of the 494 small farms located in the CMA region.

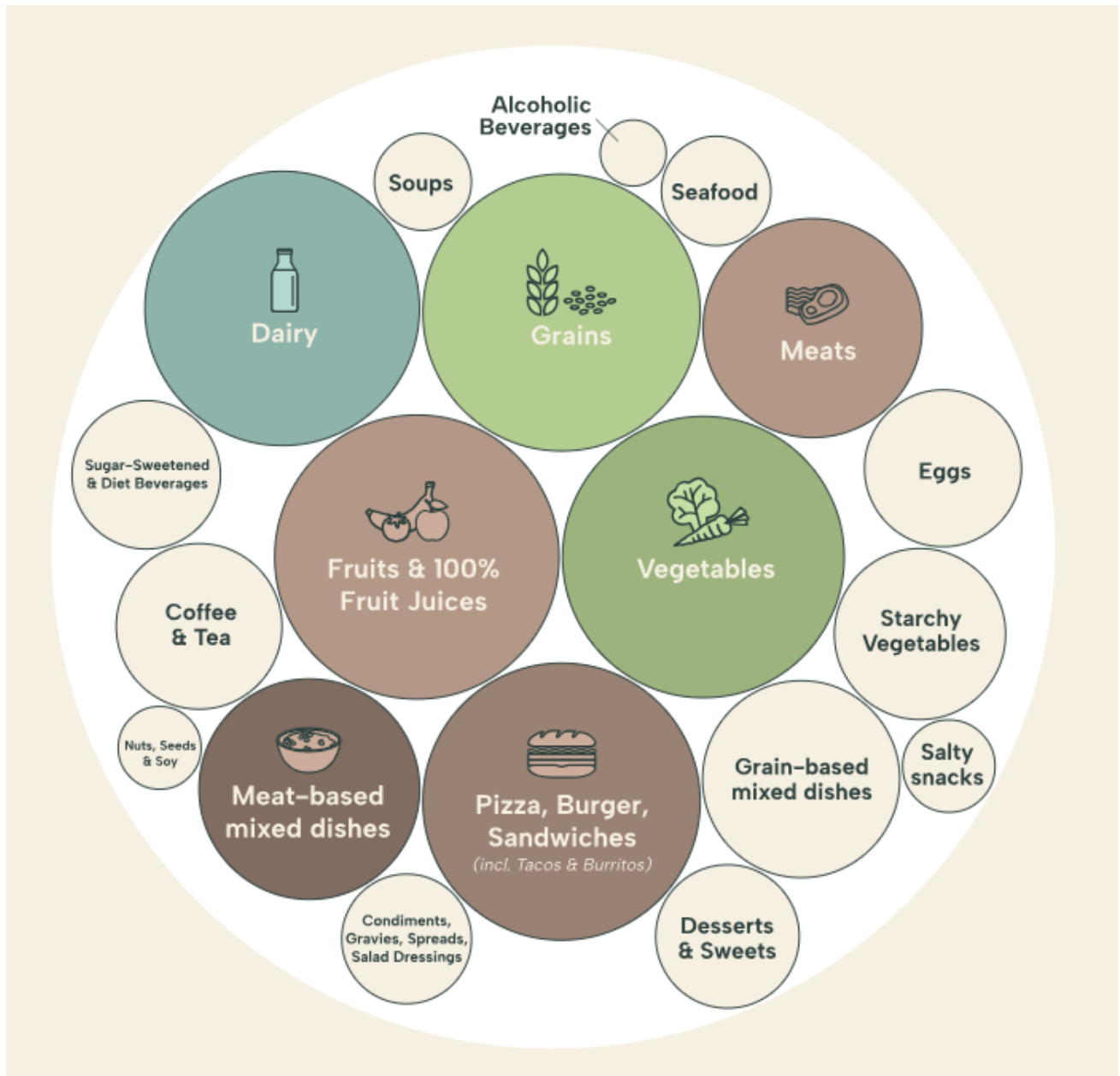




**Figure 4** - Pie chart displaying what is being produced in CMA small farms. 37.4 % farms produce Vegetables, fruits and nuts, 36.8% produce meat, eggs and dairy, 9.3% produce non-food products, 5.9% breed animals, 4.3% cultivate cereals, 3.8% produce honey, 2% grow mushrooms, 0.6% produce fish products and 0.2% produce wine.

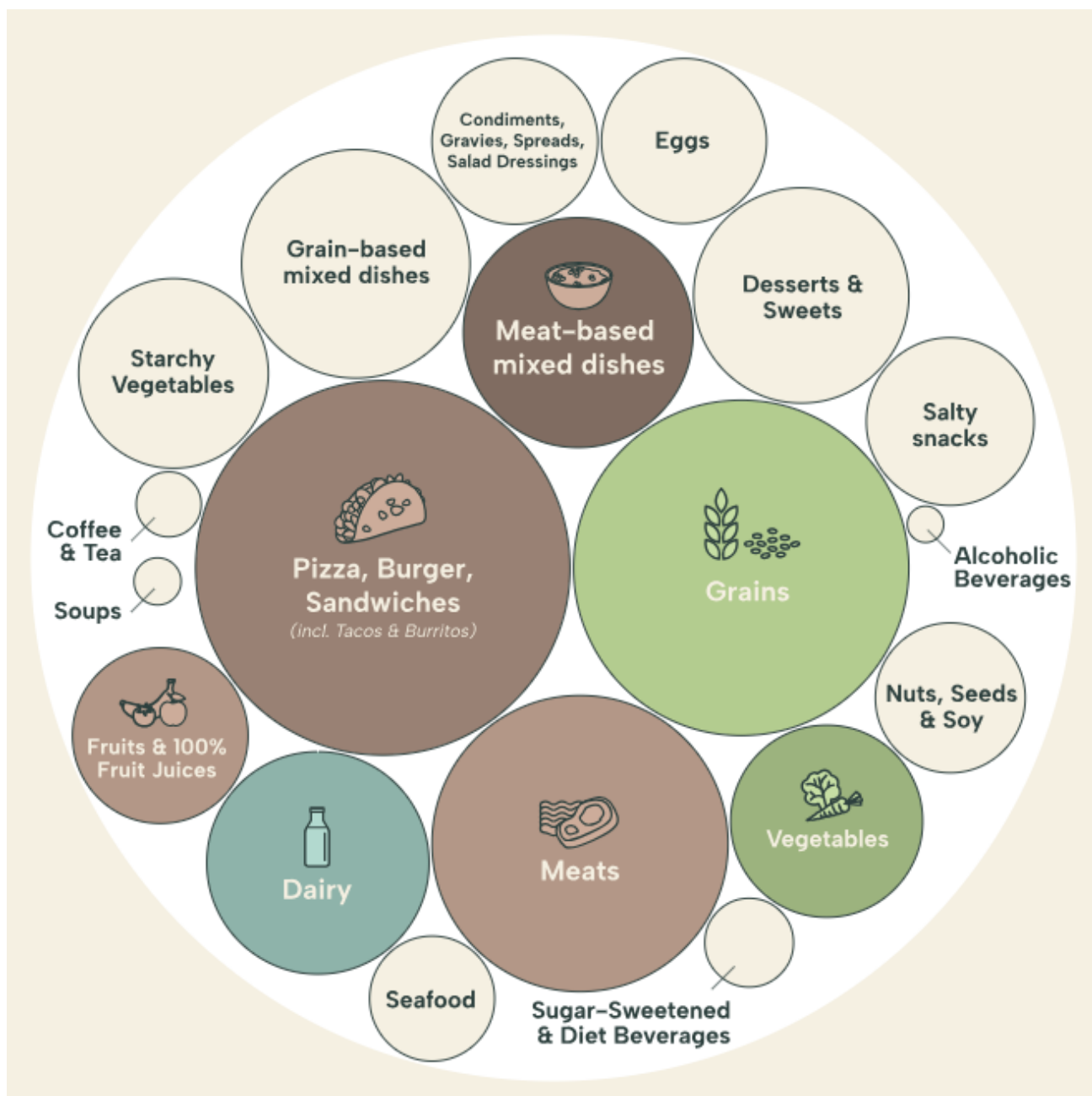
## Mecklenburg's Diet

Over 200 meals were logged throughout the duration of the MyFoodRepo study. Vegetables made up the largest food group eaten, by grams consumed, with over 6 kg of vegetables being eaten by the cohort over the study period (Figure 5). This is closely followed by pizza, burgers, sandwiches (5.8 kg), grains (5.8 kg) and dairy (5.7kg) (Figure 5).



**Figure 5** - Bubble graph displaying the consumption of different food groups by weight. Size of the bubble represents the weight of the food groups consumed in grams.

However, when looking at calorific value rather than weight the results differ. The food group Pizza, Burger, Sandwiches has the highest calorific value at over 15,000 Kcal, followed by grains (12,000 Kcal) and meats (9,400 Kcal) (Figure 6). Although vegetables had the highest weight consumed of any food group, their calorific contribution was under 4,000 Kcal (Figure 6).



**Figure 6** - Bubble graph displaying the consumption of different food groups by calorific value. Size of the bubble represents the Kcal of food groups consumed.

## Availability of Nutritious Food

In total 4,387 food establishments were located, with 898 food retailers and 3,489 FAFH.

### Food Retail

66% of block groups contain no healthy retailers. Furthermore, the distribution of healthy retailers is not evenly spread around the county with the highest concentrations of healthy stores being present in the city centre, the southwest and along arterial and major roads (Figure 7). Higher concentrations of unhealthy retailers can be seen in the crescent around the top of the city centre. Ethnic stores were found to play an important role in providing fresh nutritious food, as they were the sole healthy retailers in 25 block groups, areas which would otherwise be deprived of healthy and nutritious food options.

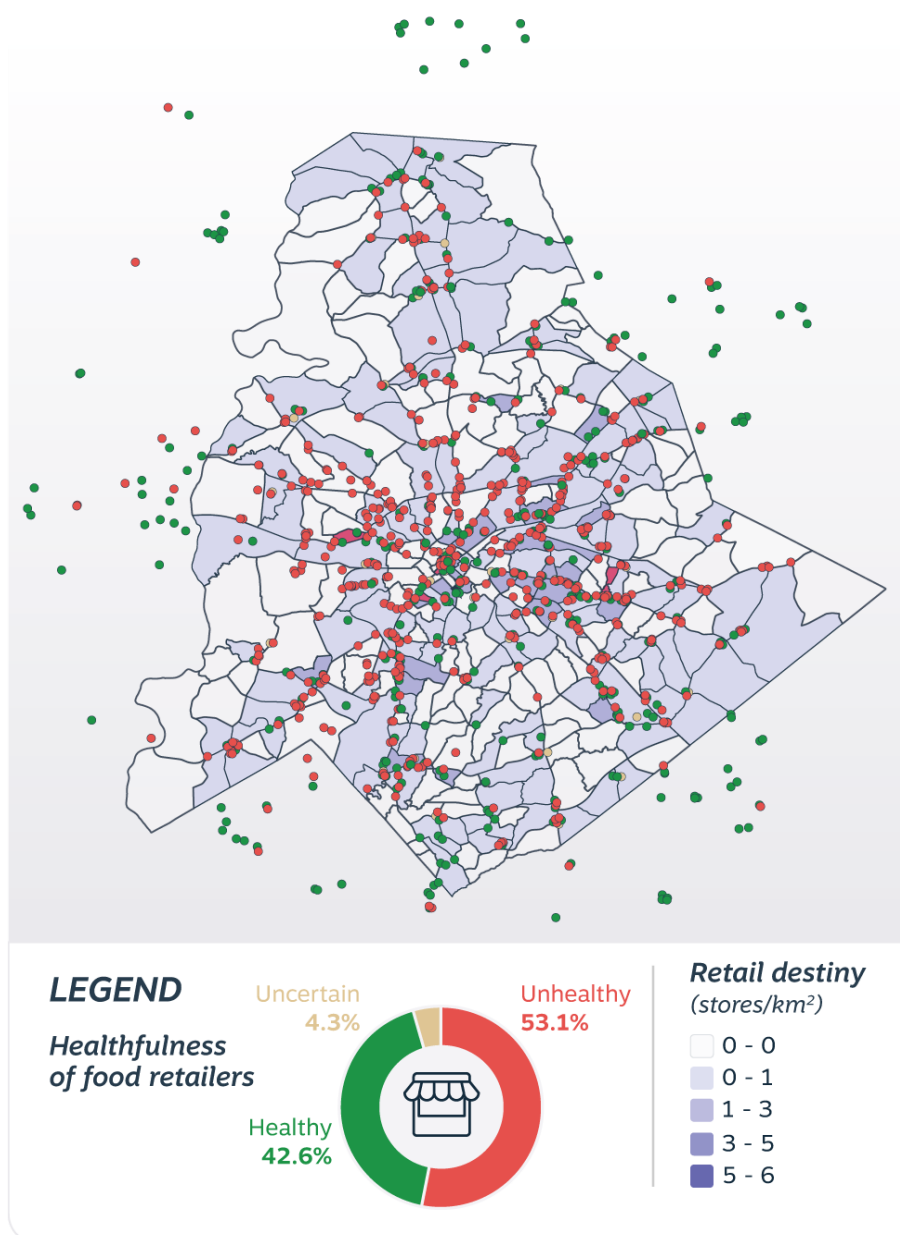


Figure 7 - Map showing the distribution of healthy and unhealthy food retailers across Mecklenburg county.

### FAFH

Over half (59%) of all FAFH options were classified as unhealthy (Figure 8). Once again, the healthy FAFH options which are present are not evenly distributed across the county but in fact concentrated in the city centre, the southwest and in Davidson in the north of the county (Figure 8). On the other hand, unhealthy options are widespread across the entire county (Figure 8).

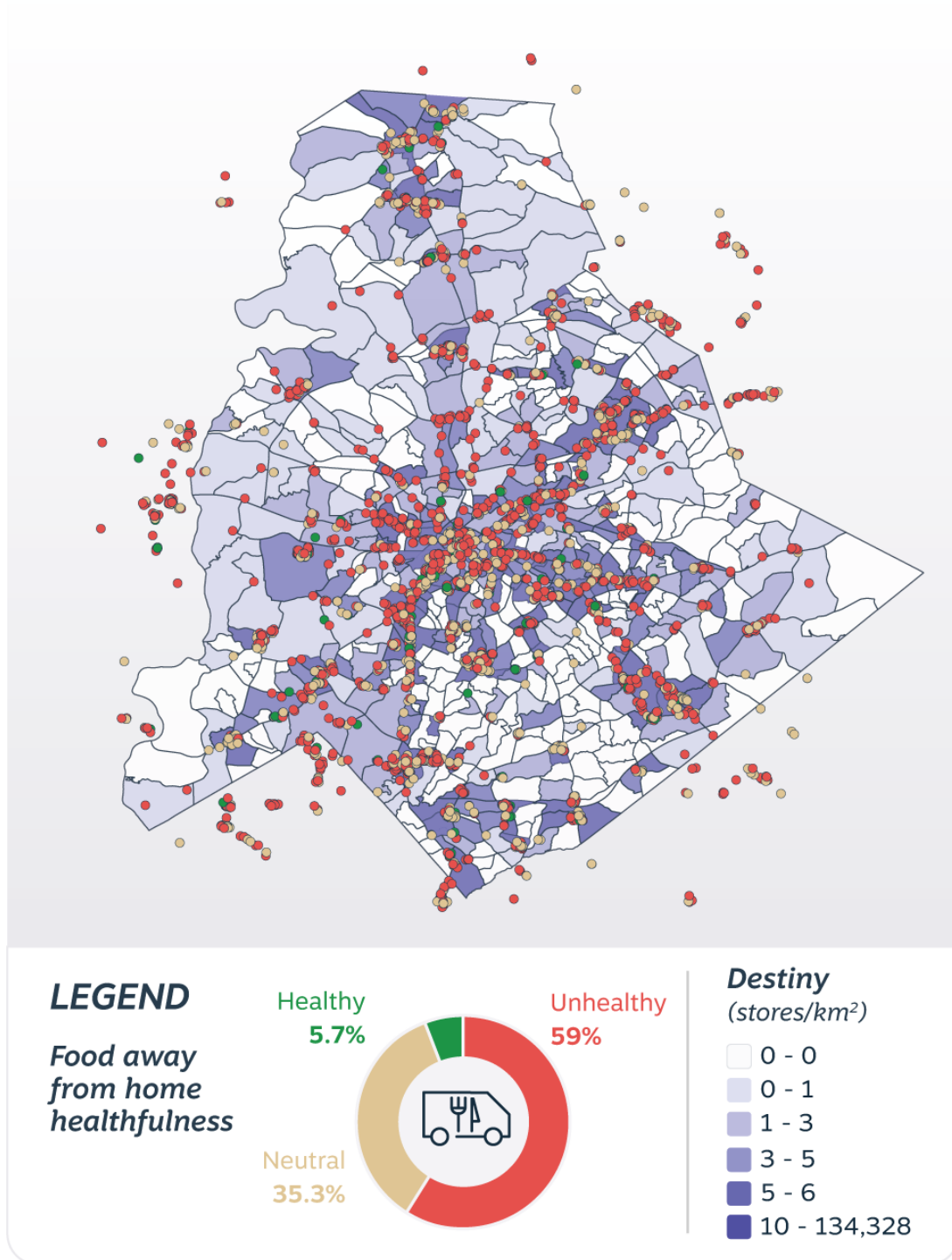


Figure 8 - Map showing the distribution of healthy, neutral and unhealthy FAFH options in Mecklenburg county.

## Affordability of Nutritious Food

### Food Retail

There is a relatively even distribution of affordable healthy and affordable unhealthy retailers (Figure 9). There is a slight increase in percentage of unhealthy moderate retailers compared to healthy moderate retailers, however with regards to expensive retailers there are only healthy options (Figure 9).

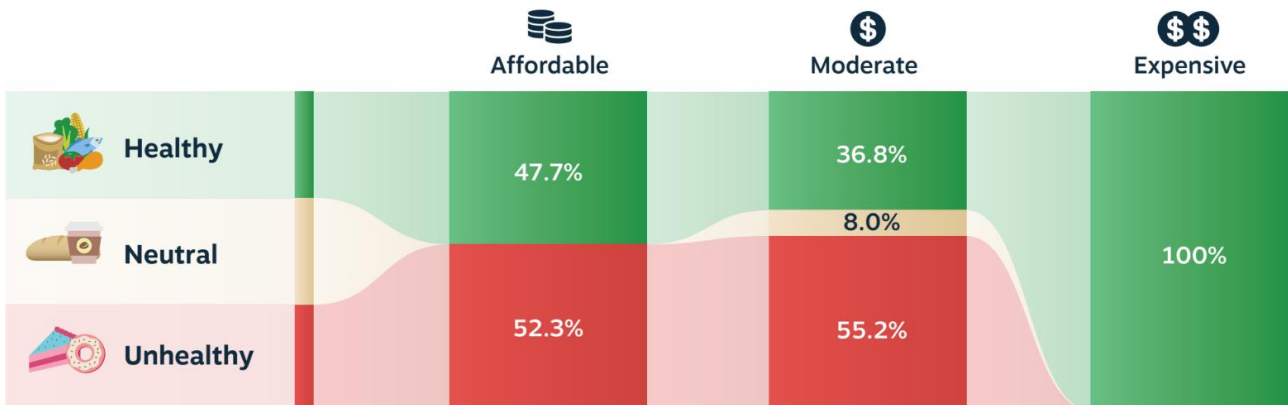


Figure 9 - The relationship between price rating and healthiness of food retailers.

### FAFH

Affordable FAFH options are heavily dominated by unhealthy establishments (Figure 10). However, the share of healthy and neutral options increases as price increases (Figure 10).

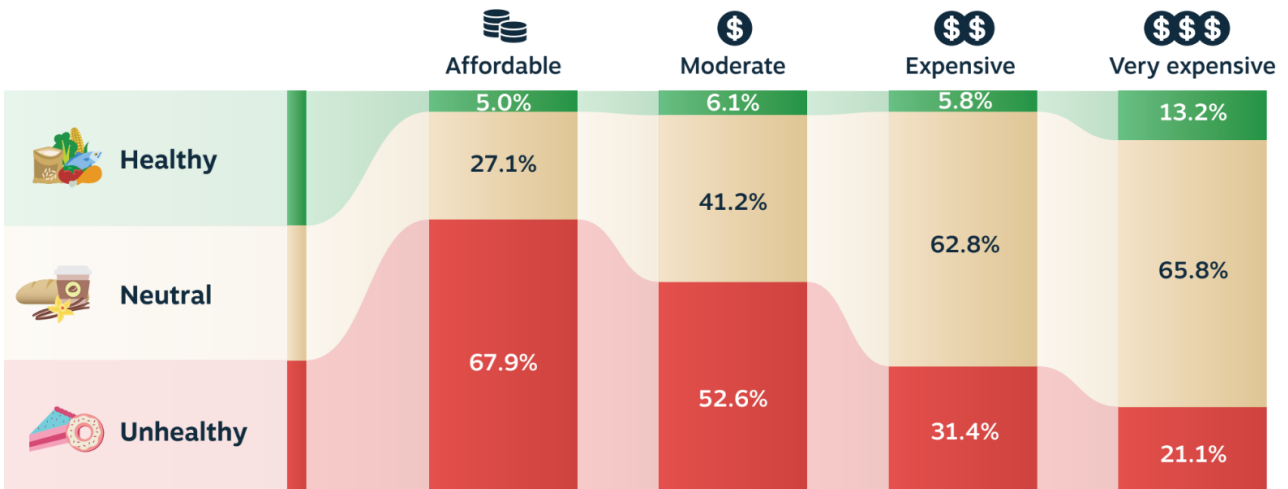


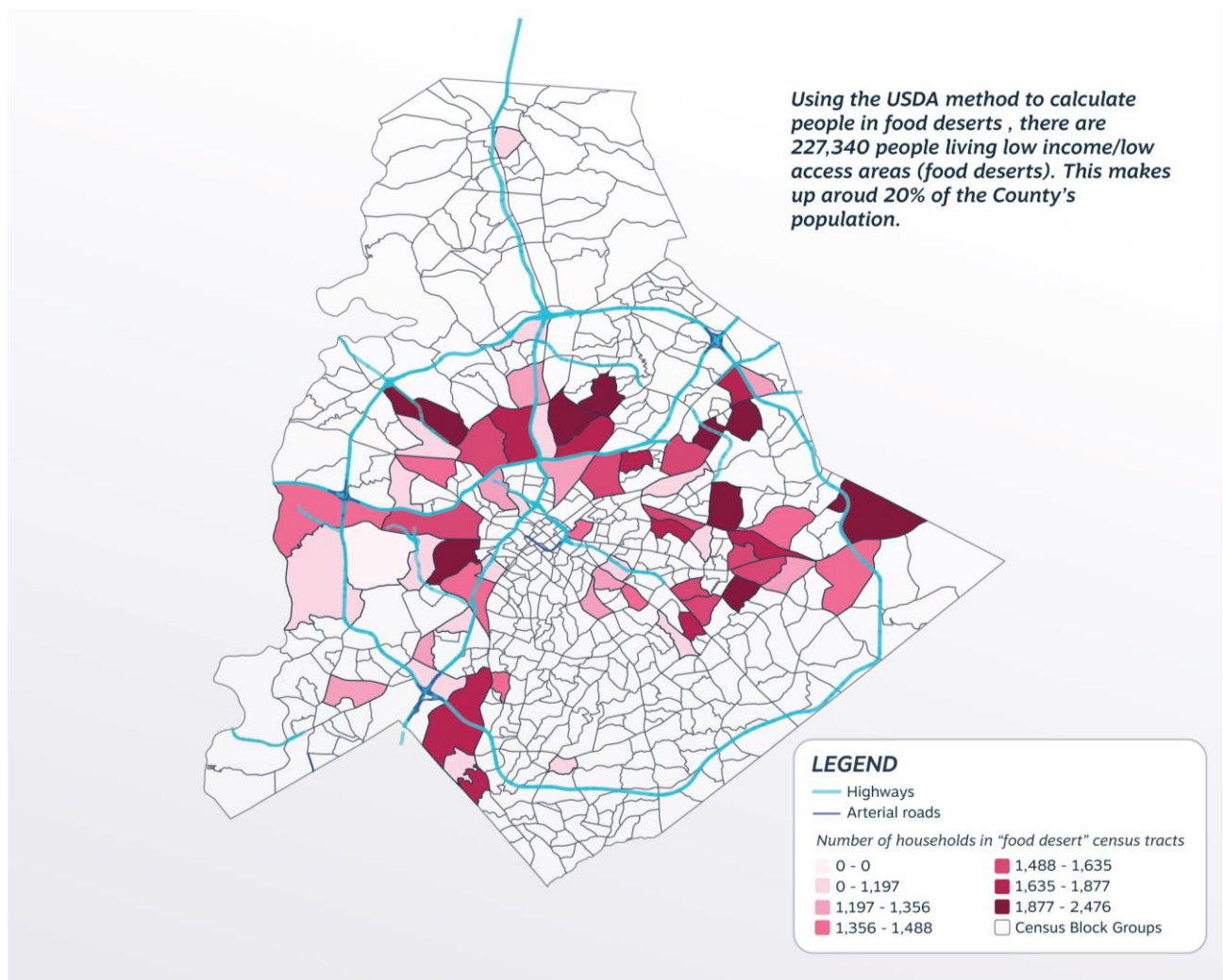
Figure 10 - The relationship between price rating and healthiness of FAFH options.



## LILAs

### USDA

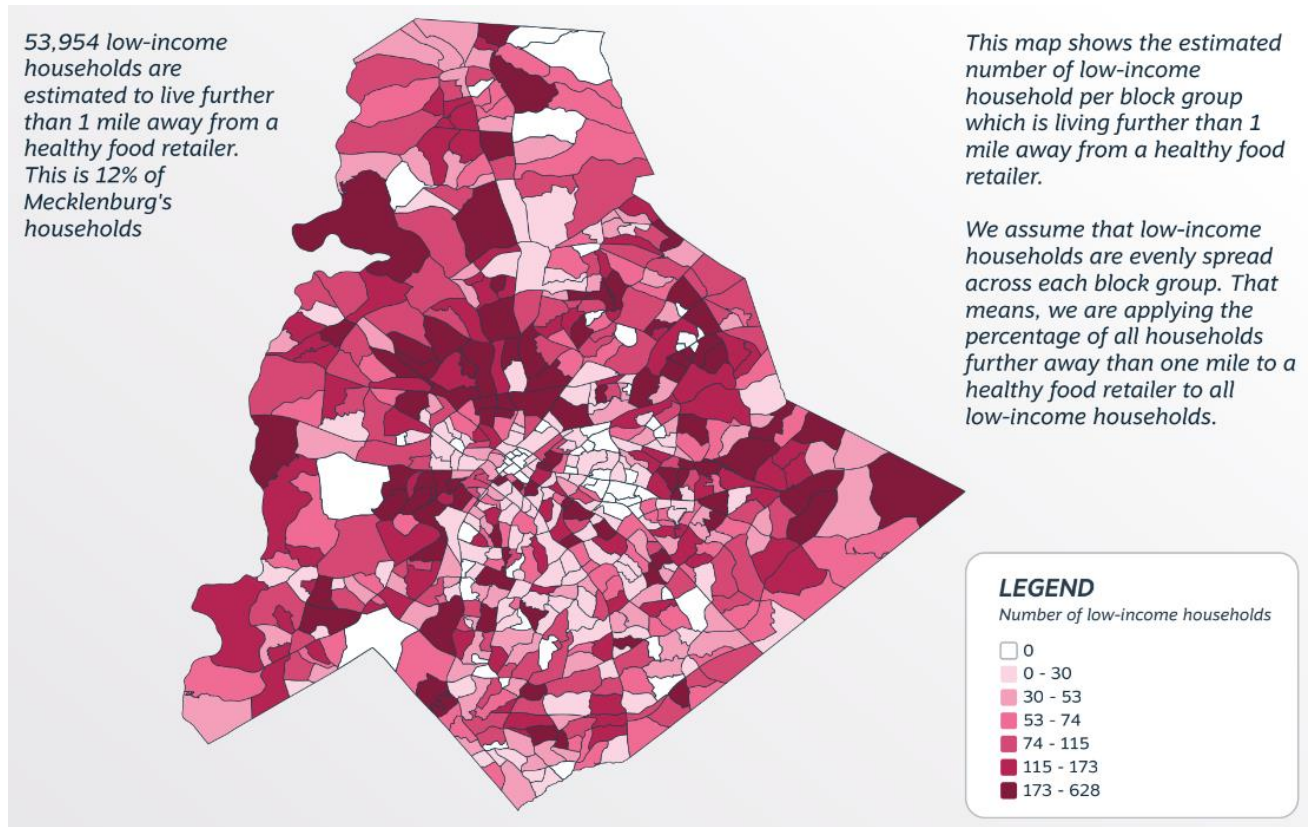
Following the method proposed by the USDA for locating LILAs, we located 89,764 households which we estimate to be living within census tracts considered as LILAs (Figure 11). This analysis suggests that the majority of LILAs are located within the crescent surrounding Charlotte's city centre. However, only 54,949 of these households are actually thought to be located further than one mile from their closest food retailer. Furthermore, of these households only 24,206 of these households are thought to be living under the poverty threshold.



**Figure 11** - Map showing the locations of LILAs located using the USDA's proposed methodology.

## Metabolic

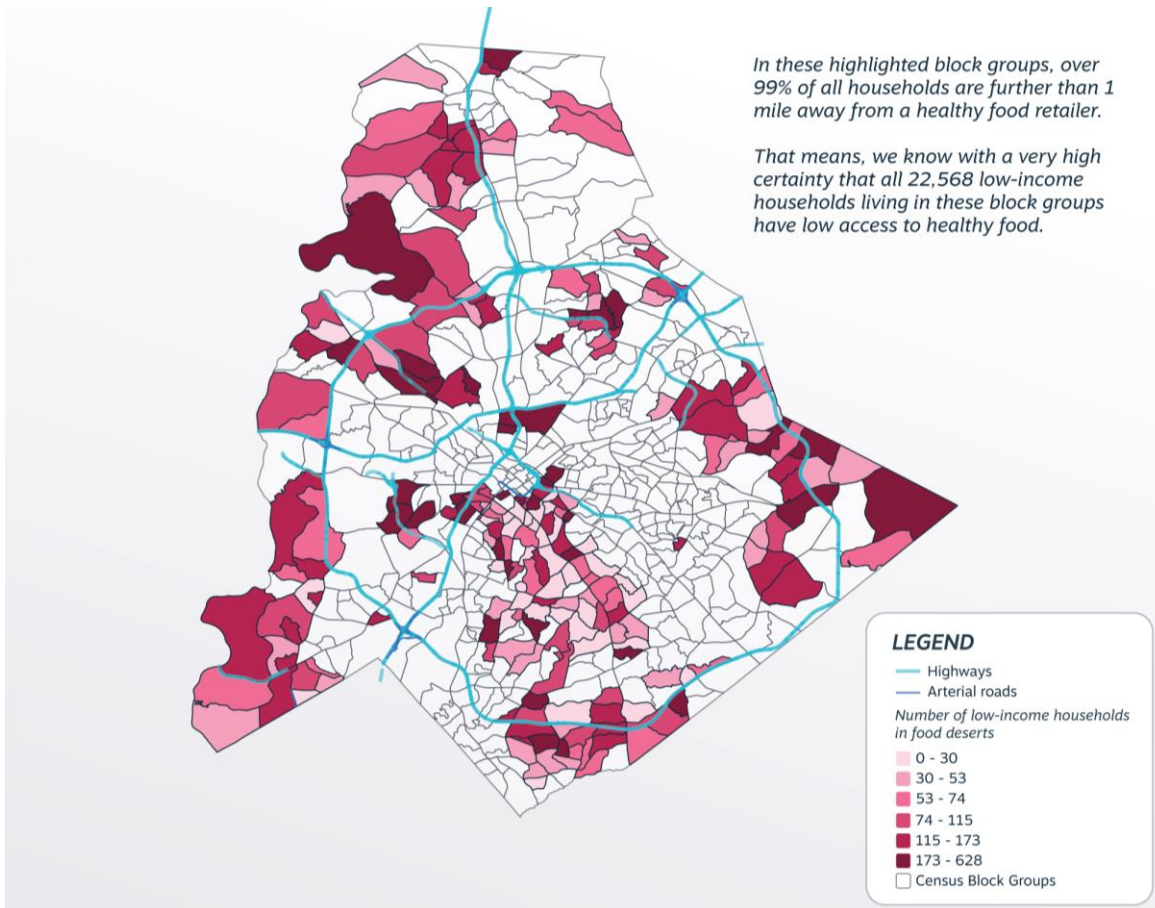
Using the method that we developed at Metabolic to locate LILAs we discovered that only 56 out of the 624 block groups in Mecklenburg contained no household that we predict to be living in LILAs (Figure 12). In total, we estimated that 53,954 (12% of households in Mecklenburg) low-income households were living further than one mile away from an affordable and healthy retailer (Figure 12).



**Figure 12** - Map showing the amount of low-income households in each block group which are located more than one mile away from an affordable healthy retailer.

By looking at block groups in which over 99% of households were located further than 1 mile away from an affordable healthy retailer, we were able to locate 22,568 low-income households which we can say with over a 99% certainty, are living in LILAs (Figure 13).





**Figure 13** - Map showing each block group that we can say with over a 99% certainty that every low-income household is located further than one mile away from an affordable healthy retailer.

# Discussion

## ***To what extent can small farms contribute to the local food system?***

The discovery of 496 farms in the CMA is just a fraction of the 7,660 farms in the region (USDA, 2022). However, as small farms are underreported by the USDA it is likely that many of these farms will not previously have been reported. Therefore, this report has uncovered farms in CMA not previously identified by other metrics.

The farms found in Mecklenburg predominantly produce vegetables, fruits, meat, and animal products — essential food items needed to address nutrition insecurity in the region (Shetty, 2009). This trend may be influenced by the method used to identify these farms, which relied heavily on farmers market vendor lists where these products are most commonly sold (Govindasamy et al., 1998). Nevertheless, the presence of numerous small farms capable of producing these critical food types indicates a potential to mitigate food and nutrition insecurity locally. Moreover, local food production can enhance resilience against global disruptions, such as conflicts and pandemics, by reducing dependency on external supply chains (Béné, 2020). Small farms, often characterised by diversified crop production compared to the monoculture practices of larger farms, contribute to greater sustainability. This diversity supports ecosystem services, such as increased biodiversity and the provision of habitats for pollinators, which are vital for the long-term stability of the regional food system (Shucksmith & Rønningen, 2011; Karlsson et al., 2022). Additionally, purchasing locally produced food can lower an individual's carbon footprint, further promoting sustainability (Hartling, 2019).

There is clear potential for small local farms to enhance the local food system. The current system in CMA is catered toward large-scale industrial agriculture producing feed for livestock. It is known that cultivating fresh produce such as fruits and vegetables increases the availability of nutritious food in the local supply chain (Béné, 2020). Whereas, when land is used for cultivating animal feed it reduces the land availability for human food crops which can potentially compromise local food security (Béné, 2020). This is especially the case when large amounts of animal feed is exported to feeding livestock outside of the region. A shift toward a preference for cultivating human food crops is likely to improve local food insecurity (Béné, 2020).

Determining the full extent of the contribution by small farms requires further data collection and analysis. To achieve this, a more comprehensive, on-the-ground approach is needed to identify farms not included in this study and to apply metrics that evaluate their output. This would reveal not only the farm locations and the types of food they produce, but also provide insights into their capacity to supply sufficient fresh, nutritious produce to address local food and nutrition insecurity.

## ***Can the diet of Mecklenburg Residents be classified as balanced and nutritious?***

While the MyFoodRepo study indicated a preference for fruits and vegetables by weight, a closer look at the calorific value reveals they make up only a small part of participants' diets. A significant portion of energy intake comes from processed foods like pizzas, burgers, sandwiches, as well as grains and meats. This

finding mirrors trends in U.S. diets, where approximately 60% of the average American's caloric intake is from ultra-processed foods (Baraldi et al., 2018). Suggesting that the diet of Mecklenburg's residents cannot be classified as balanced and nutritious.

***To what extent is there equal access to nutritious and affordable food in Mecklenburg county?***

While there are retailers and FAFH which qualify as both nutritious and affordable in Mecklenburg county they are not evenly distributed across the county. The crescent around Charlotte city centre was found to have a lack of healthy food retailers and an abundance of unhealthy retailers. The crescent, an area in Mecklenburg noted for its crescent shape, is characterised by its high level of low-income citizens, high poverty rates, and increased racial and ethnic diversity (CLTPR, 2020). This follows the trend often observed where the poorer neighbourhoods of cities are deprived of healthy food retailers (Schuetz et al., 2012). This practice has been the result of 'supermarket redlining', a practice where large supermarket chains avoid opening stores in under-privileged areas (Eisenhauer, 2001). In reality, these areas have much greater access to convenience stores and dollar stores, which lack the fresh and healthy food required for a balanced diet. Once again this is a common theme seen throughout the USA, where convenience and dollar stores serve as the primary retailers in areas with high poverty rates (Hilmers et al., 2012). There was, however, a presence of ethnic stores in 25 block groups which would have otherwise been devoid of any healthy retailer. The presence of these stores is a lifeline for many residents who wish to access fresh and nutritious food in that area. In other cities in the US, ethnic stores are already noted as powerful tools for alleviating food insecurity providing fresh, nutritious and culturally appropriate food to both native and immigrant populations (Joassart-Marcelli et al., 2017). In addition, as concentrations of healthy retailers were often discovered around arterial roads, it suggests that car use for access to healthy retailers is encouraged in the region. This further reduces access for low-income households who are noted for having lower rates of car ownership than higher income households (Klein et al., 2023). Access to a private car has been found to result in increased consumption of fresh produce, meaning households without are further deprived of fresh and nutritious food (Gustat et al., 2015).

Conversely, there is a clear concentration of stores offering healthy and nutritious food in the more affluent areas of the county. The area sometimes referred to as the 'Wedge', south of Charlotte city centre, as well as the areas around Davidson in the north of Mecklenburg, are noted for their above average household income and higher than county-average proportion of white-americans (CLTPR, 2020). The increased access to healthy food in these neighbourhoods is understandable when you consider the correlation between price and healthiness of food (Figures 9 and 10). In addition, the increased purchasing power afforded to wealthier households means they have a greater choice of retailer and FAFH financially accessible to them. A stark contrast to the lack of choice that low-income households face.

Where there does seem to be an equal distribution of food, was in regard to unhealthy FAFH. The widespread nature of these establishments can be attributed to both a tendency to consume fast-food in the country as a whole, as well as the fact that these food establishments are often the only ones accessible to all socioeconomic groups (Baraldi et al., 2018; Hilmers et al., 2012). Anecdotally, this preference for affordable

unhealthy FAFH was observed in the MyFoodRepo study where many of the participants were regularly consuming food from fast-food outlets.

Geographically and financially, there is a clear imbalance where it concerns access to nutritious and affordable food within the county.

### ***Are the current methods for locating LILAs sufficient?***

There is a significant disparity in the results of locating LILAs depending on which methodology is used, not only with respect to the number of people who are living in LILAs, but also with regards to the locations of these LILAs. When using the USDA method, the LILAs uncovered mirror the historically deprived crescent. Whereas when using the Metabolic method, we can see that in actuality there are LILAs across the entire county. Furthermore, when looking at low-income households that, with >99% certainly, are living further than 1 mile away from an affordable healthy retailer, we see that many of them are living in more affluent areas. Therefore, they have gone under the radar in previous analyses. If a family is low-income and they are living further than a mile away from an affordable healthy retailer, they are food insecure regardless of which area of the county they are living in. It is important not to miss these residents, as they require just as much help and relief as residents living in historically well documented food insecure areas.

The USDA method overestimates households affected by low food access while underestimating the number of low-income households in affluent areas impacted by LILAs, revealing a lack of granularity. Additionally, by not factoring in food affordability, it fails to capture the full challenges faced by these households. An expensive retailer is just as inaccessible to a low-income household as an affordable one located 10 miles away. Thus, proximity alone does not ensure equitable access to nutritious food.

By following the definition of a LILA more closely, the metabolic method is able to more accurately locate food insecure households. This suggests that a change in method for locating LILAs is required.

### ***Limitations***

Due to methodological and geographical limitations, the search for small farms in the CMA only identified those with an online presence. It is highly likely that many regional small farms without an online footprint were overlooked. A more comprehensive, on-the-ground approach would help locate operational farms that lack online visibility, providing a more accurate representation of the area's agricultural landscape.

The MyFoodRepo study recruited only 10 participants, far from a statistically representative sample of Mecklenburg's population, making it difficult to draw definitive conclusions about local food preferences and consumption. The study also relied heavily on participants' ability to consistently log their food intake, resulting in anomalies such as unusually low beverage consumption and caloric intake of around 1,000 calories per day. To improve accuracy in future studies, better strategies for participant recruitment, retention, and data collection are needed to ensure more reliable and representative results.

While the Metabolic method provided more granularity than the USDA's, some ambiguity remains. The method estimated households in LILAs based on the proportion of low-income, low-access individuals within each block group, assuming an even distribution of low-income households, which may not reflect reality. To address this, a more accurate approach would involve on-the-ground surveys of households in food-insecure areas, providing clearer and more precise data.

### **Recommendations**

Based on the findings of this report, the following recommendations are directed towards policymakers in local government and researchers interested in advancing the study.

#### *Support small local farms producing fresh local produce.*

Regional farms growing fruit and vegetables are dwarfed by the industrial scale farms producing animal feed. The local government should provide incentives and revenue opportunities for small local farmers to sell their fresh healthy produce to the local community, strengthening local food and nutrition security.

#### *Increase opportunities for low-income, low-access families to obtain healthy food.*

Local farmers could provide boxes of fresh produce to food insecure residents with funding from the municipality. The municipality could cover the fees on grocery delivery services for households living in LILAs. Thereby, increasing the access food insecure families have to nutritious food.

#### *Encourage the establishment of Healthy FAFH with Healthy Restaurant Designation.*

In some states healthy restaurant designation exists through SPE certification (SPE, n.d.). To qualify for this certification, restaurants must meet a minimum healthiness criteria. The municipality could create a map, website or app which promotes restaurants with this designation. This would encourage restaurants to offer a greater range of healthy options to gain this certification and in return gain free promotion.

#### *Scale up the existing Healthy Corner Stores initiative and support the setting up of independent ethnic stores.*

The number of healthy corner stores in Mecklenburg County is significantly outnumbered by unhealthy food outlets. To address this, the Healthy Corner Store initiative should be substantially expanded, with a particular focus on the LILA areas identified in this report. Additionally, the municipality should provide grants or administrative support to entrepreneurs opening small ethnic grocery stores in underserved communities. This strategy aims to amplify the positive impact that ethnic stores are already making in these neighbourhoods.

#### *Further investigate LILAs hidden in higher income neighbourhoods.*

On the ground studies should be conducted to be even more granular when locating LILA areas. These would include surveys in food insecure locations. This would provide the most accurate data that could be used for combating these LILA areas.

## **Conclusions**

Despite the significant regional food production industry, and the 4,387 food establishments located in Mecklenburg County, there are still considerable levels of local food and nutrition inequality. This analysis highlights the crucial role small farms can play in strengthening Mecklenburg County's local food system. Despite being underreported by traditional metrics, small farms are capable of producing critical food items like vegetables, fruits, and animal products, which are essential in combating nutrition insecurity. Their diversified agricultural practices not only contribute to local food security but also enhance ecosystem sustainability through increased biodiversity and ecosystem services. To better understand the extent at to which these small farms can alleviate local food insecurity, more data should be collected on the output on these small farms.

There remains a clear divide in access to nutritious food across the county, with low-income areas, particularly in the "crescent," facing significant barriers in accessing healthy retailers. Efforts to bridge these gaps require support for small farms, expansion of healthy food access initiatives, and targeted policies to address LILA areas. Furthermore, this report emphasises the importance of adopting more granular, accurate and inclusive methods for identifying food-insecure households, particularly in wealthier neighbourhoods where hidden pockets of LILAs may exist.

To build a more resilient and equitable food system, policymakers should support local agricultural efforts, expand food access programs, and refine their understanding of food insecurity through comprehensive, on-the-ground research. These steps can help ensure that all residents, regardless of location or income level, have access to nutritious, affordable food.

## **Acknowledgments**

I would like to extend my deepest gratitude to the Metabolic Institute for hosting me over the past 6 months and helping me grow and develop as a professional. I will always look back at this time very fondly. I would like to especially thank Antoine for his unwavering support, guiding me in the right direction and for being an exceptional supervisor. I would like to thank Frenzi for all the help and fun we had working together. I would like to thank Joris for dedicating time to helping me get to grips with the basics of python. Additionally, I want to extend my thanks to Jaco for your valuable feedback on this report.

## References

- Alexander, E., Rutkow, L., Gudzone, K.A., Cohen, J.E. and McGinty, E.E., 2021. Trends in the healthiness of US fast food meals, 2008–2017. *European Journal of Clinical Nutrition*, 75(5), pp.775–781.
- Aman, J.J.C. and Smith-Colin, J., 2020. Transit Deserts: Equity analysis of public transit accessibility. *Journal of Transport Geography*, 89, p.102869.
- Baraldi, L.G., Steele, E.M., Canella, D.S. and Monteiro, C.A., 2018. Consumption of ultra-processed foods and associated sociodemographic factors in the USA between 2007 and 2012: evidence from a nationally representative cross-sectional study. *BMJ open*, 8(3), p.e020574.
- Béné, C., 2020. Resilience of local food systems and links to food security—A review of some important concepts in the context of COVID-19 and other shocks. *Food security*, 12(4), pp.805–822.
- Benton, T.G., Bieg, C., Harwatt, H., Pudasaini, R. and Wellesley, L., 2021. Food system impacts on biodiversity loss. *Three levers for food system transformation in support of nature*. Chatham House, London, pp.02–03.
- CalorieFriend, 2024. *CalorieFriend: Nutrition Tracking Simplified*. Available at: <https://www.caloriefriend.com/en> [Accessed: 9 September 2024].
- CDC, 2012. *Census tract level state maps of the modified food environment index (mRFEI)*. Available at: <https://stacks.cdc.gov/view/cdc/61367> [Accessed: 16 September 2024].
- CLTPR, 2020. *Charlotte's Arc and Wedge*. CLT Public Relations. Available at: <https://www.cltp.com/articles/arc-wedge> [Accessed: 25 September 2024].
- Cole, M.B., Augustin, M.A., Robertson, M.J. and Manners, J.M., 2018. The science of food security. *npj Science of Food*, 2(1), p.14.
- Crippa, M., Solazzo, E., Guizzardi, D., Monforti-Ferrario, F., Tubiello, F.N. and Leip, A.J.N.F., 2021. Food systems are responsible for a third of global anthropogenic GHG emissions. *Nature food*, 2(3), pp.198–209.
- Crowe, J., Lacy, C. and Columbus, Y., 2018. Barriers to food security and community stress in an urban food desert. *Urban Science*, 2(2), p.46.
- Dutko, P., Ver Ploeg, M. and Farrigan, T., 2012. Characteristics and influential factors of food deserts.
- Eisenhauer, E., 2001. In poor health: Supermarket redlining and urban nutrition. *GeoJournal*, 53, pp.125–133.
- Emond, J.A., Madanat, H.N. and Ayala, G.X., 2012. Do Latino and non-Latino grocery stores differ in the availability and affordability of healthy food items in a low-income, metropolitan region?. *Public health nutrition*, 15(2), pp.360–369.
- Food and Agriculture Organization of the United Nations (FAO), 2024. *FAOSTAT: Crops and Livestock Products*. Available at: <https://www.fao.org/faostat/en/#data/QCL> [Accessed 15 August 2024].
- Google, 2024. *Places API*. Available at: <https://developers.google.com/maps/documentation/places/web-service> [Accessed 19 September 2024].
- Google, 2024. *Supported Place Types*. Available at: [https://developers.google.com/maps/documentation/places/web-service/supported\\_types](https://developers.google.com/maps/documentation/places/web-service/supported_types) [Accessed 19 September 2024].
- Govindasamy, R., Zurbruggen, M., Italia, J., Adelaja, A.O., Nitzsche, P. and VanVranken, R., 1998. Farmers markets: Consumer trends, preferences, and characteristics.



- Gustat, J., O'Malley, K., Lockett, B.G. and Johnson, C.C., 2015. Fresh produce consumption and the association between frequency of food shopping, car access, and distance to supermarkets. *Preventive Medicine Reports*, 2, pp.47-52.
- Hartling, X.C., 2019. A quick guide to building a local food system and reducing carbon footprint. *e-Journal of Social & Behavioural Research in Business*, 10(2), pp.1-9.
- Hayes, A., Tan, E.J., Killedar, A. and Lung, T., 2019. Socioeconomic inequalities in obesity: modelling future trends in Australia. *BMJ open*, 9(3), p.e026525.
- Hilmers, A., Hilmers, D.C. and Dave, J., 2012. Neighborhood disparities in access to healthy foods and their effects on environmental justice. *American journal of public health*, 102(9), pp.1644-1654.
- Joassart-Marcelli, P., Rossiter, J.S. and Bosco, F.J., 2017. Ethnic markets and community food security in an urban "food desert". *Environment and Planning a*, 49(7), pp.1642-1663.
- Kirkpatrick, S.I., Reedy, J., Kahle, L.L., Harris, J.L., Ohri-Vachaspati, P. and Krebs-Smith, S.M., 2014. Fast-food menu offerings vary in dietary quality, but are consistently poor. *Public health nutrition*, 17(4), pp.924-931.
- Klein, N.J., Basu, R. and Smart, M.J., 2023. Transitions into and out of Car ownership among low-income households in the United States. *Journal of Planning Education and Research*, p.0739456X231163755.
- Legal Services Corporation (LSC), 2024. *Today's Low-Income America*. Available at: <https://justicegap.lsc.gov/resource/section-2-todays-low-income-america/> [Accessed 19 September 2024].
- Lin, F., Li, X., Jia, N., Feng, F., Huang, H., Huang, J., Fan, S., Ciais, P. and Song, X.P., 2023. The impact of Russia-Ukraine conflict on global food security. *Global Food Security*, 36, p.100661.
- McDonagh, J., Farrell, M. and Conway, S., 2017. The role of small-scale farms and food security. *Sustainability challenges in the agrofood sector*, pp.33-47.
- McFadden, P., 2020. *Eating healthy in a food desert: Mecklenburg leaders seek new solutions*. [online] Available at: <https://ui.charlotte.edu/story/eating-healthy-food-desert-mecklenburg-leaders-seek-new-solutions> [Accessed 12 Aug. 2024].
- Mecklenburg County., 2024. *Food Security*. [online] Available at: <https://health.mecknc.gov/population-health/chronic-disease-policy-and-prevention/food-security> [Accessed 12 Aug. 2024].
- MyFoodRepo, 2024. *MyFoodRepo: Track What You Eat*. Available at: <https://www.myfoodrepo.org/> (Accessed: 9 September 2024).
- Piedmont Triad Regional Council (PTRC), 2024. *NC Food System Assessment Dashboard*. Available at: <https://maps.ptrc.org/NCFoods/?page=Page-2> [Accessed 19 September 2024].
- Pulker, C.E., Aberle, L.M., Butcher, L.M., Whitton, C., Law, K.K., Large, A.L., Pollard, C.M. and Trapp, G.S., 2023. Development of the menu assessment scoring tool (mast) to assess the nutritional quality of food service menus. *International Journal of Environmental Research and Public Health*, 20(5), p.3998.
- Pulker, C.E., Trapp, G.S., Fallows, M., Hooper, P., McKee, H. and Pollard, C.M., 2020. Food Outlets Dietary Risk (FODR) assessment tool: study protocol for assessing the public health nutrition risks of community food environments. *Nutrition journal*, 19, pp.1-9.
- Rabbitt, M.P., Hales, L.J., Burke, M.P. and Coleman-Jensen, A., 2023. Household food security in the United States in 2022.
- Raphael, A., 2022. *Healthy menu scoring tool (HMST): Content validity, face validity and internal consistency approaches in development and validation* (Doctoral dissertation, ResearchSpace@ Auckland).



Raskind, I.G., Kegler, M.C., Girard, A.W., Dunlop, A.L. and Kramer, M.R., 2020. An activity space approach to understanding how food access is associated with dietary intake and BMI among urban, low-income African American women. *Health & place*, 66, p.102458.

Salm, L., Nisbett, N., Cramer, L., Gillespie, S. and Thornton, P., 2021. How climate change interacts with inequity to affect nutrition. *Wiley Interdisciplinary Reviews: Climate Change*, 12(2), p.e696.

Schuetz, J., Kolko, J. and Meltzer, R., 2012. Are poor neighborhoods "retail deserts"? *Regional Science and Urban Economics*, 42(1-2), pp.269-285.

Shetty, P., 2009. Incorporating nutritional considerations when addressing food insecurity. *Food Security*, 1, pp.431-440.

Shucksmith, M. and Rønningen, K., 2011. The Uplands after neoliberalism?—The role of the small farm in rural sustainability. *Journal of Rural Studies*, 27(3), pp.275-287.

Simelane, K.S. and Worth, S., 2020. Food and nutrition security theory. *Food and Nutrition Bulletin*, 41(3), pp.367-379.

SPE, n.d. *Promoting sustainability in the food service industry*. Available at: <http://specertified.com/> [Accessed 6 October 2024].

Teigiserova, D.A., Hamelin, L. and Thomsen, M., 2019. Review of high-value food waste and food residues biorefineries with focus on unavoidable wastes from processing. *Resources, Conservation and Recycling*, 149, pp.413-426.

U.S. Census Bureau, 2024. *Glossary*. Available at: <https://www.census.gov/glossary/> [Accessed 19 September 2024].

U.S. Census Bureau, 2024. *Historical Poverty Thresholds: Poverty Threshold Table 2023*. Available at: <https://www.census.gov/data/tables/time-series/demo/income-poverty/historical-poverty-thresholds.html> [Accessed 19 September 2024].

U.S. Census Bureau., 2023. *QuickFacts: Charlotte city, North Carolina*. [online] Available at: <https://www.census.gov/quickfacts/fact/table/charlottecitynorthcarolina> [Accessed 12 Aug. 2024].

U.S. Environmental Protection Agency (EPA), 2023. *Regulatory Definitions of Large CAFOs, Medium CAFO, and Small CAFOs*. [pdf] Available at: [https://www.epa.gov/sites/default/files/2015-08/documents/sector\\_table.pdf](https://www.epa.gov/sites/default/files/2015-08/documents/sector_table.pdf) [Accessed 5 September 2024].

United States Department of Agriculture (USDA), 2022. *Cropland Data Layer Release*. USDA National Agricultural Statistics Service. Available at: [https://www.nass.usda.gov/Research\\_and\\_Science/Cropland/Release/](https://www.nass.usda.gov/Research_and_Science/Cropland/Release/) [Accessed 6 Oct. 2024].

United States Department of Agriculture (USDA), 2024. *Food Access Research Atlas: Documentation*. USDA Economic Research Service. Available at: <https://www.ers.usda.gov/data-products/food-access-research-atlas/documentation> [Accessed 6 Oct. 2024].

USDA, 2022. *2022 Census of Agriculture: North Carolina State and County Data, Volume 1, Chapter 2*. Available at: [https://www.nass.usda.gov/Publications/AgCensus/2022/Full\\_Report/Volume\\_1,\\_Chapter\\_2\\_County\\_Level/North\\_Carolina/](https://www.nass.usda.gov/Publications/AgCensus/2022/Full_Report/Volume_1,_Chapter_2_County_Level/North_Carolina/) [Accessed 4 September 2024].

USDA, 2022. *2022 Census of Agriculture: South Carolina State and County Data, Volume 1, Chapter 2*. Available at: [https://www.nass.usda.gov/Publications/AgCensus/2022/Full\\_Report/Volume\\_1,\\_Chapter\\_2\\_County\\_Level/South\\_Carolina/](https://www.nass.usda.gov/Publications/AgCensus/2022/Full_Report/Volume_1,_Chapter_2_County_Level/South_Carolina/) [Accessed 4 September 2024].

Wheeler, T. and Von Braun, J., 2013. Climate change impacts on global food security. *Science*, 341(6145), pp.508-513.

Žmija, K., Czekaj, M. and Žmija, D., 2019. The role of small farms in local food systems. *Roczniki (Annals)*, 2019(4).