

Assessing Changes in Food Pantry Access after Extreme Events

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Abstract: Food pantries play a growing role in supporting households facing or at risk of food insecurity in the United States. They also support emergency response and recovery following disasters and extreme weather events. Although food pantries are often placed in close proximity to communities with the highest rates of poverty and risk of food insecurity, access to these facilities can be disrupted during and after extreme events. Decreased access to food pantries following disasters can be particularly problematic as the need for these services is also likely to grow after such events. Despite the vast body of research on food retail access and food environments, relatively little research has utilized spatial analysis to understand food pantry access, particularly after extreme events. Using Geographic Information Systems (GIS), we characterize changes in access to food pantries following flooding events in Harris County, Texas – a highly populated and flood prone region with high levels of food insecurity and poverty. Specifically, our study models disruptions in road networks due to flooding and assesses the impacts of these disruptions on proximity to food pantries. The results reveal that much of Harris County sees only small increases in travel distance to food pantries due to extreme flooding, but some areas may be unable to access food pantries at all. This research highlights the potential and some of the limits of private food assistance networks to support emergency response efforts.

Keywords

food security, food assistance, food environments, food banks, spatial inequity

Abbreviations

ACS – American Community Survey
CFSM – Core Food Security Module
D-SNAP – Disaster Supplemental Nutrition Assistance Program
FEMA – Federal Emergency Management Administration
GIS – Geographic Information Systems
IPCC – Intergovernmental Panel on Climate Change
SNAP – Supplemental Nutrition Assistance Program
TEFAP – The Emergency Food Assistance Program
USDA – United States Department of Agriculture
WIC – Women, Infants, and Children

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Introduction

Despite an abundant food supply in the United States, many individuals have inadequate or uncertain access to enough food to meet their dietary needs. According to the U.S. Department of Agriculture (USDA), an estimated 10.5% of households were food insecure in 2020 and over 3.9% of households experienced “very low food security” (Coleman-Jensen et al. 2021a).¹ Multiple federal programs support food access for households at risk of food insecurity, including the USDA Supplemental Nutrition Assistance Program (SNAP), which provided benefits to about 39.9 million people on average per month in 2020 (Toosi et al. 2021). Alongside these federal programs, food banks and food pantries increasingly support people at risk of food insecurity (Daponte and Bade 2006). Among food insecure households, 36.5% of food insecure households and 45.5% of very food insecure households used a food pantry in 2020 (Coleman-Jensen et al. 2021a).

In addition to supporting daily food needs, food pantries also support emergency response and management, providing critical assistance following extreme events and disasters (Feeding America n.d.). Following such events, these facilities often experience increased demand for their services as people navigate losses of income, normal food supplies, and other resources. Although federal programs provide food aid after disasters, there can be a lag in the implementation and obstacles to enrollment (Horton 2012). In contrast, food pantries are often positioned to provide immediate support. Extreme events and disruptions to critical infrastructure, however, can affect the functioning of and accessibility to food pantries (Rosenheim et al. 2021). For instance, transportation infrastructure disruptions can prevent supplies, staff, volunteers, and clients from reaching food pantries. As extreme weather events become more frequent due to climate change (IPCC 2021; Stott 2016), disruptions to food access are also likely to increase (Ebi and Bowen 2016; Ingram et al. 2010), thereby increasing demand for emergency food aid.

As food pantries grow in importance as a source of food in the everyday lives of people and following disasters, there is a need to better understand access to these facilities. Despite the many studies on access to food retailers (e.g., Larson et al. 2009; Ver Ploeg et al. 2009), little

¹ In these households, at least one member experienced disruption to regular eating patterns or reduced consumption due to lack of money and resources (Coleman-Jensen 2021).

research has addressed access to food pantries (see below for exceptions), and none to our knowledge examines access after extreme events. Access to food pantries after disasters, however, is essential to regular users and many others seeking emergency food assistance after extreme events. Here, we draw on proximity-based measures of food access to analyze the impacts of flooding on food pantry access. Our analysis only addresses a single dimension of food pantry access – spatial accessibility (see Caspi et al. 2016 for discussion of other dimensions of food access) – but we argue that spatial proximity is an important consideration in the context of disaster response. Our analysis focuses on Harris County, Texas, which contains the City of Houston. This populous and rapidly growing area is subject to frequent extreme events and flooding. The region is also characterized by high levels of poverty (15.9% in 2020; U.S. Census) and food insecurity (13.9% in 2019; Feeding America 2022). Here, we model the impacts of flooding on access to the county’s food pantries and discuss spatially differentiated patterns of change in access. In the following sections, we provide a brief overview of food assistance programs and food pantries in the United States and spatial analysis of food access. Following this background, we present our study of Harris County and discuss the study’s implications and limitations. Combined with other approaches to characterize the impacts on the operations of and access to food pantries, this research seeks to support sustained access to food assistance programs and expanded access to emergency food assistance after disasters.

Background

Public and private food assistance programs in the United States

Food insecurity is a persistent problem in the United States and hit record levels in 2011, when 14.9% of households experienced low or very low food security.² Since 2011, this number has decreased or remained stable, but food insecurity affected over 38 million Americans in 2020 (Coleman-Jensen et al. 2021a). Several federal programs exist to increase food access and to reduce food insecurity, including SNAP (commonly referred to as Food Stamps), the Special Supplemental Nutrition Program for Women, Infants, and Children (WIC), and the National School Lunch Program. SNAP is the largest of these programs and provides low-income households with credits to purchase an array of qualifying products. Participation in SNAP has

² The USDA began collecting food insecurity data in 1995 and recorded the highest proportion of food insecure households in 2011.

grown over the past two decades, peaking at 47.6 million people in 2013 (Tiehen 2020). The number of participants declined over the following six years but rose again during the COVID-19 pandemic to 41.5 million in 2021 (Jones et al. 2022).

In addition to these federal programs, many people in the United States utilize private food assistance programs. Specifically, a growing network of private food banks collects and stores food supplies and distributes these goods to food pantries that disseminate them directly to people at risk for food insecurity. The USDA reports that food pantry use is on the rise and reached a record high in 2020 with 6.7% of households acquiring food from a food pantry (Tiehen 2020). Likewise, Feeding America estimates that their private food assistance programs served at least 60 million people in 2020 (about 1 in 5 people in the United States), a 50% increase from the prior year (Feeding America 2021). Many food pantry users also utilize the SNAP program – including 41% of households served by Feeding America – but many food pantry users do not utilize this resource. Reasons for non-participation include not qualifying for federal programs (e.g., some immigrants), lack of awareness of programs, and stigma surrounding participation (Pinard et al. 2017).

The growth in food pantry users corresponds to an expansion in the number of food banks and food pantries since the 1980s. For example, Feeding America, the largest network of food banks in the United States, has grown from just thirteen food banks in 1979 to over 230 food banks that distribute to over 60,000 food pantries (Feeding America 2008). This expansion is largely due to a series of changes in federal programs, particularly the establishment of The Emergency Food Assistance Program (TEFAP) in 1983.³ TEFAP purchases commodities from U.S. producers and provides these foods to state agencies that distribute the goods, primarily to food pantries and banks. TEFAP also creates tax incentives for manufacturers and retailers to donate surplus food supplies (Gottlieb and Joshi 2013). In recent years, TEFAP expanded and distributed over 2.2 billion pounds of food in 2020 (Coleman-Jensen et al. 2021b). The creation and growth of TEFAP, restrictions on participation in the food stamp program, the economic downturn of the 1980s, and inadequate food stamp benefits all contributed to a rapid expansion of private food assistance in the 1980s and 1990s (Daponte and Bade 2006; Gottlieb and Joshi 2013).

³ TEFAP was originally called the Temporary Emergency Food Assistance Program but changed its name to The Emergency Food Assistance Program in 1990.

Food pantries and emergency response

Following extreme events, food systems may experience numerous disruptions affecting all components of food security – spanning availability, access, stability, and utilization of food (Brown et al. 2015; Gregory et al. 2005). For example, impassible roads may prevent access to food suppliers, energy loss and labor shortages may cause retail closures, and food supplies may be damaged. Analyses of several cities have revealed that many food warehouses and distribution centers are at high risk for impacts from extreme events (Zeuli and Nijhuis 2017). Disruptions to the operations of and access to these facilities could have far reaching implications for regional food availability. At the household level, energy loss and property damage may contribute to loss of food, prevent food preparation, and affect sanitation. One of the few studies to explore food access after a disaster in the United States found that electricity loss, costs associated with evacuation, and property damage all reduced food access after hurricanes (Clay 2019; Clay and Ross 2020). Job losses and lost wages after extreme events also detrimentally impact food security (Berner and O’Brien 2004). As a result, food insecurity is a major concern following extreme events, particularly for socially vulnerable populations (Flores et al. 2020). These impacts on food security may extend for months after a disaster, even after recovery from other damages (Subaiya et al. 2019).

Those affected by disasters may receive food assistance through the Disaster Supplemental Nutritional Assistance Program (D-SNAP), which extends SNAP benefits to households that may not otherwise qualify (USDA-FNS 2014). This program provides critical assistance, but USDA recommends that states delay implementation of D-SNAP until one week after a disaster in order to allow food retailers to resume operations (USDA-FNS 2014). D-SNAP also requires in-person registration, which may present challenges for households with limited transportation after disasters. Therefore, other assistance programs, such as food pantries, play an important role during this period when federal benefits may be difficult to access or use. Unsurprisingly, many food pantries experience increased visits and demand following disasters, such as hurricanes (Berner and O’Brien 2004; Rosenheim et al. 2021; Slider-Whichard et al. 2020). While filling gaps in federal assistance programs, food pantries also coordinate with federal agencies to support emergency response. Other organizations and agencies often coordinate with food pantries for emergency response and recovery efforts, utilizing food

pantries' existing network of volunteers, staff, and physical infrastructure (Chriest and Niles 2018). Feeding America, for instance, has partnered with FEMA and the American Red Cross to support resource distribution following disasters.

Food pantries, however, share similar vulnerabilities to food retailers. Increased demand, infrastructural disruptions, or transit interruptions could all limit the ability of food pantries to obtain and distribute adequate supplies. Following Hurricane Harvey, for example, demand for food assistance increased, but distribution from some pantries initially decreased due to power loss, flooding, and other disruptions (Rosenheim et al. 2021). Impacts on food retailers may also affect food pantries, as closures simultaneously increase demand for food assistance and disrupt the flow of donations from retailers. As with other “critical infrastructures,” disruptions to food systems have significant cascading impacts on other aspects of society (Brinkmann and Bauer 2016). As such, there is a need to understand both the disruptions to the operations of food banks and food pantries, as well as the disruptions in access to these facilities for those in need.

Modeling food access

A large body of research has employed spatial analysis techniques to assess spatially differentiated patterns of access to food sources (Lytle and Sokol 2017) and to explore how proximity to different food sources shapes health outcomes (Bodor et al. 2010; Gordon-Larsen 2014; Larson et al. 2009; Morland and Filomena 2007). Numerous studies on “food deserts” have characterized food access by combining measures of distance to food retailers with measurement of socioeconomic indicators (Walker et al. 2010). This research generally defines levels of access based on distances to retailers, particularly supermarkets. The USDA, for example, defines low access in urban areas as being more than 1-mile from a supermarket (USDA 2013). Other studies, however, note that people often purchase food at locations further from their homes (Ghosh-Dastidar et al. 2014; Hirsch and Hillier 2013; Kerr et al. 2012), and may be in proximity to other vendors as they travel throughout the day (Shannon and Christian 2017). As such, studies employ a diversity of approaches to measure proximity and food access.

Food deserts research has emphasized proximity to supermarkets as an indicator of access but has often neglected the other locations where people acquire food (Shannon 2014; Short et al. 2007; Taylor and Ard 2015), including food pantries. In contrast to the extensive research on access to food retailers, few studies have employed spatially explicit approaches to characterize

access to food pantries. A small number of studies have utilized GIS to examine (in)accessibility to food pantries among high need communities (Bletzacker et al. 2009; Bradley and Vitous 2021; Caspi et al. 2016; Simmet et al. 2017). Mabli and colleagues (2013) conducted a nationwide study of pantry access in locations without supermarkets, revealing that 40 percent of census tracts without supermarkets had food pantries. Other research has focused on identifying gaps in access to food assistance programs employing proximity-based approaches similar to those used to identify food deserts (Bacon and Baker 2017; Curran and Armenia 2021; Waity 2016). Bacon and Baker (2017), for example, classified census tracts in Santa Clara County, California, based on their food insecurity and distance from food pantries to identify gaps in food pantry access.

As with food retailers, mobility patterns may alter food pantry use, as users may not utilize the closest facility to their homes or those within arbitrary census units (cf. Liu 2015). Assumptions about the closest facility also often rely on Euclidean (straight-line) measurements, but some recent studies measure distance to food pantries along transportation networks instead (Caspi et al. 2016; Schramski et al. 2021). Caspi et al. (2016), for example, calculated distances along road networks from census tracts to food pantries and compared these distances to socioeconomic characteristics. Access, however, also has a temporal component and pantry utilization may be limited by hours of operation (Kaplan et al. 2020). The aforementioned studies explore access to food pantries under normal conditions, but food pantries also play a growing role following extreme events that may alter access. As such, we build upon these proximity-based studies to understand changes in food pantry access during and following extreme events.

Methods

Given the increased risk of food insecurity after disasters and the role of food pantries in response efforts, we model proximity to food pantries under “normal” conditions and following flooding events. Below, we describe the application of this approach to understand food pantry access in Harris County.

Study area

Our analysis focuses on Harris County, Texas, one of the most populated and fastest growing counties in the United States, with 4.7 million residents total and 2.3 million people in Houston alone (U.S. Census Bureau 2021). This area has experienced numerous disasters in recent

years, and flooding has become a frequent occurrence, including three 500-year floods within three sequential years. Among these were the unprecedented floods from Hurricane Harvey in 2017, when 130cm of rain fell over six days (Emanuel 2017; Risser and Wehner 2017). The likelihood of such events has been greatly increased by the dual processes of climate change and urbanization (Emanuel 2017, Zhang et al. 2018). Such events cause massive transit disruptions in Harris County, creating challenges for evacuation and emergency response in this highly car dependent region (Pulcinella et al. 2019). Flooding is also particularly concerning for low-income households – 15.9% of the Harris County population was in poverty in 2020 (U.S. Census Bureau 2021) – which are disproportionately located within floodplains and more exposed to storm surges (Pulcinella et al. 2019). These disparities intersect with patterns of racial segregation in the highly racially and ethnically diverse county, which the American Community Survey (ACS) reports is 28.7% white alone 20% Black or African American, 7.3% Asian, and 43.7% Hispanic or Latino (U.S. Census Bureau 2018). Based on socioeconomic data from the census, Feeding America estimates that 13.9% of Harris County residents and 20.1% of its children were food insecure in 2019, compared to national rates of 10.9% and 17%, respectively (Feeding America 2022). Harris County’s intersecting challenges of food insecurity, increasing extreme events, and widespread transportation disruptions from flooding raise concerns for emergency response and food access following extreme events. Given these converging concerns, we examine how flooding alters road networks and changes travel distances to the Houston Food Bank’s 162 food distribution sites across Harris County.

Data

We collected GIS data on flood risk, socioeconomic characteristics of the population, the location of food assistance distribution sites (Figure 1), and the road network. The flood risk data for all of Harris County were produced by the Federal Emergency Management Agency (FEMA; Figure 2).⁴ We used U.S. Census ACS 5-year estimates of population, poverty, unemployment, and renter occupied housing for 2014-2018 (U.S. Census Bureau 2019) at the block group level (N=2,144 for Harris County). We obtained boundaries for the block groups and the population-weighted centroids from the U.S. Census and street network data from OpenStreetMap. We

⁴ The FEMA data span several flood insurance rate map (FIRM) panels, with effective dates ranging from 2007 to 2019. All data are the most recent available panels.

obtained street addresses of food distribution sites (n=162) served by Feeding America’s Houston Food Bank from the food bank’s web site and geocoded these addresses in ArcGIS. These food distribution sites include brick and mortar locations, mobile operations, and large scale “super sites.” Henceforth, we refer to these distribution sites collectively as food pantries but discuss limitations of this in the final section of the paper. Other food pantries outside of the Feeding America network may operate in the region, but information is limited for these other sources. Furthermore, we focused on those pantries affiliated with Feeding America due to its ongoing partnership with FEMA and its known role in supporting emergency response.

<<INSERT FIGURE 1 ABOUT HERE>>

<<INSERT FIGURE 2 ABOUT HERE>>

Calculating changes in food pantry access

Our objective is to understand access to food pantries via a fully operating road network in comparison to a road network obstructed by flooding, referred to throughout as the “normal scenario” and “disruption scenario”, respectively (see Figure 2). We measured changes in access in two ways: 1) calculating the service area of each food pantry and estimating the number of census block groups intersecting these services areas under each scenario (facility-centric approach) and 2) calculating the travel distance to the nearest food pantry for each census block group under both scenarios (user-centric approach). For both of these approaches, described in detail below, we used network distance calculations (distances along road networks), as opposed to straight-line distances. All of the analyses described below were conducted in ArcMap using the Network Analyst extension.

Normal and disruption scenarios

In order to compare access to food pantries under the normal and disruption scenarios, we prepared two separate road network datasets. For the normal scenario, we created a 1-mile buffer around Harris County and clipped the OpenStreetMap data using this layer. We created the road network for the disruption scenario analysis by erasing sections of the road network that fall within the high flood risk zone (one percent or greater probability of annual flooding) – classified as zones

A, AE, AO, and VE polygons in the FEMA dataset.⁵ For the disruption scenario, we also erased food pantries that intersected these flood zones, reducing the number of food pantries from 162 to 136.

Facility-centric approach

For the facility-centric analysis, we built upon Bacon and Baker (2017) and USDA (2013), which utilized one-mile buffer distances to define food access levels in urban areas. Houston, however, is heavily reliant upon automobile transportation, and past literature has shown that people frequently travel longer distances to access food sources, including food pantries (Ghosh-Dastidar et al. 2014; Hirsch and Hillier 2013; Kerr et al. 2012; Liu et al. 2015). We therefore constructed 1-mile, 2-mile, 3-mile, 4-mile, and 5-mile network buffers around each food pantry for both the normal scenario and the disruption scenario.⁶ Figure 3 provides an example of the differences in the normal (Figure 3a) and disruption scenario (Figure 3b) network buffers for a subset of Houston. Rather than assuming a universally acceptable travel distance, we use multiple buffer distances to explore the sensitivity of our approach to different assumptions about travel distances. Since over 70% of our study area is defined as urban by the Census, we began with a 1-mile buffer, which is widely used for defining food access in urban areas (USDA 2013). Given the high automobile dependence and travel distances in Harris County, we incrementally increased our buffer size to 5 miles. We stopped at five miles because this which was more than double the average distance from block groups to the closest food pantry (discussed in results).

<<INSERT FIGURE 3 ABOUT HERE>>

We then assigned an access level to each census block group based on its intersection with the network buffers. Following USDA criteria from the Food Access Research Atlas

⁵ The FEMA flood zones designate flood insurance rates based upon the probability of flood inundation events. Zones A, AE, AO and VE are all designated as Special Flood Hazard Areas (SFHA), which requires properties in these locations to have flood proof construction and flood insurance. These areas are likely to be inundated by a 100-year flood.

⁶ Network buffers define distances based on travel along the road network. Network buffers better reflect travel distances in the real world, which are constrained by transportation infrastructure. In contrast, circular buffers use the straight-line distance between points. The actual travel distances along road networks may exceed the specified circular buffer distance.

(USDA 2013), we define three categories of access based on the amount of overlap between each individual block group and the buffers around the food pantries. The access levels are defined as follows: low access block groups have 33 percent or less of their area within the food pantry buffers, some access block groups have 34 to 66 percent of their area within the buffers, and high access block groups have 67 percent or more of their area within the buffers. We assigned an access level to each of the block groups for both scenarios and for each different buffer distance (10 possible combinations). We compared the number of block groups in each access level across both scenarios in order to identify how many block groups changed access due to road network disruptions.

Finally, we sought to quantify the change in access for populations that were likely to already be food insecure. Given our attention to the spatially differentiated patterns of food access after flooding events, we required estimates at a relatively fine scale (smaller spatial units). Data for food security, however, are not readily available below the county level. Therefore, we adapt existing approaches to estimate food insecurity utilizing census data to derive a food insecurity index (FII) at the Census block group level. We follow the formulation of FII used by Bacon and Baker (2017), which builds upon a prior national study of food insecurity (Gunderson et al. 2015) that modeled the relationship between several census variables and measures of household food insecurity from the USDA Core Food Security Module.⁷ Feeding America utilizes this model for estimation of county level food insecurity in their *Map the Meal Gap* project (Gunderson et al. 2015). This model, however, includes several census variables, particularly measurements of income and race, that are not available at the census block group level. Given these limits, we modified Bacon and Baker's (2017) Census tract level approach, which only uses the three most important variables from Feeding America's model, using the following variables available at the block group level: proportion of families at or below the federal poverty line (Poverty%), proportion of households with one or more unemployed person (Unemployed%), and the percent of people in renter-occupied housing (Rent%). We maintain their weights for each variable, which they derived from prior literature and consultation with food pantry managers:

⁷ The USDA's Core Food Security Module (CFSM) is a supplement to the community population survey, conducted by the U.S. Census. The CFSM contains a series of questions related to food security, which are then used to assign a food security level to households.

$$\text{Equation (1): } FII = \frac{[50*Poverty\%+40*Unemployed\%+10*Rent\%]}{100}$$

We then explored the intersection between the food insecurity index scores and changes in food access levels.

User-centric approach

Proximity-based approaches eschew an array of other factors that may affect access to and utilization of food pantries, but we assume that proximity is of greater importance following extreme events when mobility is altered and limited. Nonetheless, the approaches described above also introduce an array of assumptions in the selection of buffer size. For this reason, we complemented this analysis with a measure of the distance from each census block group to the closest food pantry. This user-centric approach measured the network distance from the population-weighted centroid of each block group to the nearest food pantry. We used population-weighted centroids, which account for the distribution of population within a census block group and may vary from geographic centers (see Kuai and Zhao 2017). We used the Closest Facility tool in ArcMap's Network Analyst extension to perform this analysis for both the normal and disruption scenarios.

Results

Facility centric approach

Level of food access under normal scenario and disruption scenario

Figure 4 depicts the food pantry access levels for the 1-mile buffer only. The count of block groups in each access level for all buffer sizes is shown in Table 1. Note that this method does not distinguish between total loss of access and low access, thus block groups with no viable routes to food pantries in the disruption scenario are still classified as low access. In contrast, the user-centric approach differentiates no access areas. In general, areas with high food pantry access are concentrated in the central part of the county around central Houston. Under the disruption scenario (Figure 4b), however, several high access areas in the normal scenario (Figure 4A) transition to some or low access. These changes result from increased distances due to obstructed roads and inaccessibility of food pantries within the flood zone. Many of these

differences are apparent in the southwestern portion of the county, but this phenomenon can be seen in several areas.

<<INSERT FIGURE 4 ABOUT HERE>>

Table 1 shows the number of block groups for each access level under both the normal and disruption scenarios. The results are reported for each of the different network buffer distances. For both the normal and disruption scenarios, the results are sensitive to the choice of buffer size – the number of low and some access block groups declines as buffer size increases. For a 1-mile buffer in the normal scenario, the majority (68.6%) of the county has low access to food pantries, but this quickly declines as the buffer sizes grow. In contrast, the number of high access block groups increases with buffer size, and the majority of block groups are high access when using a 2-mile or larger buffer. At all buffer sizes, the number of low access block groups increases and high access block groups decreases with the disruption scenario. Across all buffer sizes, the proportional decrease in high access block groups from the normal to the disruption scenario is similar, but the proportional increases in low and some access block groups are much higher at larger buffer sizes.

<<INSERT TABLE 1 ABOUT HERE>>

We also calculated the number of block groups that transition from high or some access in the normal scenario to low access in the disruption scenario (Table 2). With increasing buffer size, more block groups go from high to low access, but there are also more high access block groups overall with increasing buffer size. As such, the proportion of high access block groups in the normal scenario that are classified as low access in the disruption scenario is similar across all buffer sizes. For all buffer sizes, the proportion of high access block groups in the normal scenario that become low access during the disruption scenario ranged from 21.0% (1-mile buffer) to 26.8% (2-mile buffer). The proportion of some access block groups that transitioned to low access, however, varied much more. In general, as the buffer size increases, a larger proportion of some access block groups transition to low access in the disruption scenario. These values ranged from 38.3% (1-mile buffer) to 83.9% (5-mile buffer).

<<INSERT TABLE 2 ABOUT HERE>>

When accounting for the number of people in each of these block groups, the affected population size differs greatly. For the 1-mile buffer, 96 block groups, with a total population of 157,918 people, went from high access to low access. This number nearly quadruples for the 2-mile buffer and increases to 964,827 for the 5-mile buffer. Among the 217 block groups that were classified as some access under the normal scenario with a 1-mile buffer, 83 block groups, with a total population of 155,201 people, were low access in the disruption scenario. The population counts decline slightly for all other buffer sizes, except the 4-mile buffer (179,480 people). Depending upon the assumed buffer size, block groups containing between 4.8% (1-mile) and 20.7% (3-mile) of families in poverty (N=145,031) go from high access to low access.

Intersection of food access and food insecurity index

We also compared the decreases in access for different levels of food insecurity (as measured by the FII). Figure 5 shows the results of the FII calculations for Harris County by block group. Following Bacon and Baker (2017), the classes represented here are derived using the Jenks' natural breaks on the FII score. In general, food insecurity index scores are lowest (food security is better) in the area immediately west/southwest of downtown Houston – located in the center of the county – and in the periphery of the county. FII scores are higher (food security is worse) in the areas on the southwestern border of the county and to the north and southeast of downtown. Unsurprisingly, these FII values correspond closely to the distribution of poverty, as poverty is one of the variables included in the FII.

<<INSERT FIGURE 5 ABOUT HERE>>

Locations of food pantries are selected with some consideration of need; thus, they are often concentrated in areas of higher poverty. As such, many high FII areas also have high access to food pantries under normal conditions. Table 3 reports the proportion of block groups in each FII class that go from high access in the normal scenario to low access in the disruption scenario. In general, the results show that flooding caused a larger proportion of low FII areas to change

from high to low access. Given the density of food pantries in many areas with a high FII, block groups may experience disruptions in access to one food pantry but still be within the specified buffer distance to others. As a result, flooding may have less impact on access in some high food insecurity areas with multiple food pantries. Nonetheless, more than 1 in 5 of the block groups in the highest FII class (most food insecure) went from high to low access for the 1-mile and 2-mile buffers. Note that the results of the facility-centric approach in this section include areas with no food pantry access in the low access category. In the following section, the user-centric approach will distinguish these locations with no access.

<<INSERT TABLE 3 ABOUT HERE>>

User-centric approach

The distance from the population-weighted centroid of each block group to the nearest food pantry displays similar patterns of access. Compared to the rest of the county, the block groups in central Harris County generally have shorter travel distances to food pantries for both the normal and the disruption scenarios. Moving outward from the center of Harris County, the distances to food pantries generally increase (Figure 6). Table 4 shows the number of block groups based on their distances to the nearest food pantries. The largest number of block groups are between one to two miles from the closest food pantry for both the normal and the disruption scenarios. Under the normal scenario, 27.4% of the block groups are less than one mile from the nearest food pantry, but this drops to 20.7% under the disruption scenario. Another 37.9% and 26.9% of block groups are within one to two miles of a pantry under the normal and disruption scenarios, respectively. In the normal scenario, the proportion of families in poverty within two miles of food pantries is higher than the proportion of the general population within this distance. This holds true in the disruption scenario also, but 26,486 fewer families in poverty are within 2 miles of a food pantry after disruptions.

<<INSERT FIGURE 6 ABOUT HERE>>

<<INSERT TABLE 4 ABOUT HERE>>

Although many block groups maintain close proximity to food pantries, a total of 461 (21.5%) block groups have no food pantry access under the disruption scenario. These block groups have a total population of 1,117,477 people. Approximately 10% of the families in these block groups are below the poverty line (28,206 out of 275,163), representing nearly 20% of all families in poverty. Due to flooding, these ‘no access’ block groups have no viable pathway from the centroid to a food pantry. For block groups near the edge of our study area, it is possible that people may actually be able to access food pantries that are in other counties but were excluded from this study. In other cases, ‘no access’ areas are partially constrained by water bodies or highways, causing greater impacts when the limited exit routes are obstructed by flooding. Nonetheless, some normally well-connected interior block groups, such as in southwestern Harris County, also lose food pantry access (see Figure 6b). Again, these calculations are based on connectivity of the population-weighted centroid, so likely overestimate true loss of access, as some portions of a block group may maintain road network connectivity.

The average distance to the nearest facility is 2.0 miles for the normal scenario and increases to 2.4 miles for the disruption scenario (for those that still have access). Most block groups experience a change in distance of a half-mile or less (Table 5). A larger proportion of block groups had no access (21.5%) than had an increase in distance over one mile (15.1%)

<<INSERT TABLE 5 ABOUT HERE>>

Discussion

Supporting access in Harris County

The results of this analysis highlight the opportunities to leverage existing networks of food pantries for emergency response, but also demonstrate how extreme events can alter access to food aid. On the one hand, the numerous food distribution sites in the Houston Food Bank network continue to be accessible for many Harris County residents after flooding. The average travel distance only increases by 0.4 miles and most (>70%) block groups with high access in the normal scenario remain high access in the disruption scenario. Given that food pantries are intentionally concentrated in high need areas, this also offers hope that this infrastructure can continue to support the food insecure after extreme events. On the other hand, road disruptions

reduce or even eliminate access for some areas, and hundreds of thousands of people, including thousands of families in poverty, live in block groups where travel distances increased by more than two miles. Many of the impacted locations are prone to flooding that will also cause damage to property and harm to residents, adding additional challenges that will also affect access. Emergency preparation in these areas must therefore consider disruptions to road networks for both evacuation strategies and food access for those that remain and return. Areas with intersecting high poverty and high risk of flooding will likely have longer recovery times and disruptions to food assistance programs. Overall, the results demonstrate the need for an attention to the spatially and economically differentiated impacts of disasters on access to food assistance.

While these issues are particularly salient in Harris County, they are not unique to this area. Rather, many cities will experience impacts of climate change on their food systems. Although many cities are developing climate adaption plans, few incorporate food systems in these strategies (Brinkmann and Bauer 2016). The approach developed here can support cities that seek to integrate food systems into their climate adaptation and resiliency plans (e.g., Biehl et al. 2018; Zeuli and Nijhuis 2017) and also support food banks in preparing for extreme events. Information on changes in distance to food sources after extreme events can be integrated into emergency preparedness and recovery. Specifically, this information can enhance plans for distribution of food resources (Kinsey et al. 2019), particularly to areas that may face prolonged issues with access.

As this analysis shows, loss of access may be a greater concern than increased travel distances in Harris County. In advance of extreme events, food pantries and emergency management agencies could use this information to help distribute resources and establish alternative distribution sites in those areas likely to experience major disruptions or become isolated. Efforts may target areas, such as southwestern Harris County, that were classified as no access and that have high poverty and food insecurity. Likewise, resources from food pantries likely to become inaccessible may be relocated to other sites to prevent losses and to support the increased demand at other locations. For example, we identify at least 26 food assistance distribution sites that are within the flood plain and are likely to experience disruptions in operations and access. The communities normally served by these facilities may also be targeted for additional resources following extreme events to support more rapid recovery.

Limits and future directions

We have focused on proximity-based measures of access, but many factors besides distance are likely to influence food pantry use, even after extreme events. Utilization and selection of food pantries may be affected by food selection, behavior of staff, hours of operation, qualifications for access, and stigma (Verpy et al. 2003). Due to the high dependence on car transportation in Harris County, these other factors likely play a larger role in many residents' decisions about food pantry use than proximity. In this context, temporal dimensions of access, such as the operating hours of food pantries, may be more important than proximity for food pantry access. Of course, for those that do not own cars, proximity of food pantries to home and to public transportation will likely affect food pantry use (Wright et al. 2020). Given these other factors that affect pantry access and utilization, we acknowledge the limitations of our method to describe general access to food pantries. Instead, we suggest that this approach captures one element of (in)accessibility following extreme events.

The characteristics of our datasets also affect our analysis. We likely greatly overestimate the number of sites that would be operating after an extreme event, as many sites in our database have limited hours and capacity. We also include only food pantries associated with Feeding America, which partners with over 80% of private food assistance programs but is not an exhaustive network. The FEMA flood data is also limited in its estimates of flooding extent in urban areas, where structures and impervious surfaces greatly alter hydrological processes (NRC 2009). Using these flood data with the OpenStreetMap road data, we were also unable to distinguish elevated roads that are above flood waters or roads that are below grade and susceptible to flooding. Further research should account for these infrastructural elements to understand impacts on Harris County's extensive highway system and the many roadways designed to transport water for flood management. Future work may also consider the residence time of flood waters, which may range in duration from hours to multiple days.

Simply avoiding flood waters does not mean food pantries will be able to continue operations. Rather, impacts of extreme events on labor and food supplies also limit the capacity of food pantries. For example, flooding may also prevent deliveries of supplies and the transportation of volunteers and staff, who will also be managing their own emergencies related to such events. Indeed, many food pantries reported disruptions to their deliveries as well as

labor shortages following Hurricane Harvey (Rosenheim et al. 2021). As such, we likely overestimate the number of functioning food pantries after extreme events. Future research may use empirical data on past disruptions to food pantries to account for food supplies, labor availability, and behavioral changes after extreme events.

Finally, this research should be considered in the context of prior critiques of research on food deserts and food environments, particularly arguments that the presence of healthy food is insufficient to ensure access (Alkon et al. 2013; Cummins 2002). Attentive to these critiques, some scholars have focused on understanding community assets and to situate spatialized food injustices in the context of broader political economic processes (De Master and Daniels 2019; Shannon 2014). Political economic analyses of food pantries emphasize that the growth of private food assistance is reflective of the retreat of state social welfare programs (Caraher and Furey 2018) and these assistance programs do not address core causes of food insecurity (Poppendieck 1999). As private food assistance organizations play a growing role in emergency response, more critical analysis is needed to understand the implications of and reasons for this transformation. Much more work is needed to engage community members and other organizations in the process of designing and evaluating methods such as these and to identify the ways that spatial analytical methods may support (or undermine) efforts for food justice.

Conclusion

Food pantries play an increasingly important role in supporting food security across the United States, and also play a growing role in emergency response. Following extreme weather events, access to food assistance can be critical for food insecure households, which often have only a limited supply of food on hand. Managing disruptions to food access for households experiencing food insecurity is a priority of many emergency response efforts, but disruptions to transportation, energy, and labor can all present obstacles to operating and accessing food assistance facilities. In order to improve continuity of food assistance services and to fully leverage existing infrastructure for emergency response, it is essential to know how food access is impacted by extreme events. Our analysis contributes to this by exploring the locations where flooding impacts food pantry access. Our case study of flood-prone Harris County demonstrates that the existing food pantry locations remain accessible for the majority of residents and travel distances only modestly increase for most. Nonetheless, flooding still affects access for hundreds

of thousands of people in the city, including many families in poverty and areas with a high likelihood of food insecurity. This analysis suggests that the existing network of food pantries may be able to support food distribution and emergency response efforts following extreme events in Harris County, but additional efforts are needed to provide alternative distribution strategies in many areas. Likewise, this approach can inform decisions to prepare the communities most vulnerable to food insecurity and most likely to lose access to food assistance facilities. Although we focus on flooding events and street networks here, this approach could be extended to understand food access impacts associated with other events (e.g., earthquakes or fire) and other transportation infrastructure (e.g., rail) disruptions.

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TABLES

Table 1. Number of block groups in each access level by buffer size and scenario

Buffer size	Low/No access block groups			Some access block groups			High access block groups		
	Normal	Disruption	Proportion Change	Normal	Disruption	Proportion Change	Normal	Disruption	Proportion Change
1-mile	1,470 (68.6%)	1,646 (76.8%)	12.0%	217 (10.1%)	177 (8.3%)	-18.4%	457 (21.3%)	321 (15.0%)	-29.8%
2-mile	692 (32.3%)	1,109 (51.7%)	60.3%	118 (5.5%)	182 (8.5%)	54.2%	1,334 (62.2%)	853 (39.8%)	-36.1%
3-mile	381 (17.8%)	853 (39.8%)	123.9%	86 (4.0%)	186 (8.7%)	116.3%	1,677 (78.2%)	1,105 (51.5%)	-34.1%
4-mile	249 (11.6%)	727 (33.9%)	192.0%	63 (2.9%)	160 (7.5%)	154.0%	1,832 (85.4%)	1,257 (58.6%)	-31.4%
5-mile	143 (6.7%)	628 (29.3%)	339.2%	56 (2.6%)	168 (7.8%)	200.0%	1,945 (90.7%)	1,348 (62.9%)	-30.7%

Note: N=2,144 block groups.

Table 2. Block groups classified as high access in the normal scenario that are classified as low access or some access in the disruption scenario

Buffer Size	High access (normal) to low access (disruption)				Some access (normal) to low access (disruption)			
	Block groups	Proportion of high changed to low*	Population**	Families in poverty***	Block groups	Proportion of some changed to low*	Population**	Families in poverty***
1-mile	96	21.0%	157,918 (3.4%)	6978 (4.8%)	83	38.2%	155,201 (3.4%)	6441 (4.4%)
2-mile	357	26.8%	629,998 (13.7%)	25575 (17.6%)	60	50.8%	140,163 (3.0%)	3912 (2.7%)
3-mile	411	24.5%	828,955 (18%)	30047 (20.7%)	63	73.3%	145,625 (3.2%)	3605 (2.5%)
4-mile	428	23.4%	914,364 (19.9%)	30009 (20.7%)	50	79.4%	179,480 (3.9%)	3541 (2.4%)
5-mile	438	22.5%	964,827 (21%)	28752 (19.8%)	47	83.9%	142,587 (3.1%)	2185 (1.5%)

*Change measures the proportion of high/some access block groups in the normal scenario that become low access in the disruption scenario.

**Population is the count of the total population within the block groups that changed. The percentage represents the proportion of the population in Harris County in these block groups. This calculation assumes all people in a block group have the same access level. In reality, there is heterogeneity in access levels within block groups.

***Count is the sum of all families in poverty within the block groups that changed for specified categories. This number is used as the numerator and the total number of families in poverty in Harris County is used for the denominator to calculate the percentage.

Table 3. Proportion of high access block groups in the normal scenario that are classified as low access in the disruption scenario by food insecurity index value and buffer distance.

FII	Buffer Size				
	1-mile	2-mile	3-mile	4-mile	5-mile
≤8.2	22.62	32.39	27.38	29.26	30.36
8.3–15.7	25.44	22.89	25.90	22.37	21.09
15.8–24.7	18.60	28.74	22.82	21.52	20.30
24.8–36.9	17.35	24.05	22.88	20.00	15.79
≥37	21.88	20.69	12.70	13.64	13.24

Percentage calculated using the total number of high access block groups in each FII class as the denominator.

Table 4. Number of block groups (and their total population) by distance to nearest food pantry for each scenario.

Distance to closest food pantry	Normal Scenario			Disruption Scenario		
	Block groups	Population*	Families in poverty**	Block groups	Population*	Families in poverty**
<=1 mile	587 (27.4%)	977,648 (21.2%)	45,116 (31.1%)	444 (20.7%)	727,817 (15.8%)	34,345 (23.7%)
1-2 miles	813 (37.9%)	1,542,571 (33.5%)	54,743 (37.7%)	578 (27%)	1,103,161 (24%)	39,028 (26.9%)
2-3 miles	345 (16.1%)	779,795 (16.9%)	22,440 (15.5%)	265 (12.4%)	526,227 (11.4%)	16,007 (11%)
3-4 miles	154 (7.2%)	416,470 (9.0%)	9,277 (6.4%)	134 (6.3%)	307,044 (6.7%)	9,371 (6.5%)
4-5 miles	100 (4.7%)	308,415 (6.7%)	5,281 (3.7%)	107 (5%)	285,195 (6.2%)	7,204 (5%)
>5 miles	145 (6.8%)	577,624 (12.6%)	8,174 (5.6%)	155 (7.2%)	535,602 (11.6%)	10,870 (7.5%)
No Access	0	0	0	461 (21.5%)	1,117,477 (24.3%)	28,206 (19.4%)

*See notes on Table 2 for estimates of population

**See notes on Table 2 for estimates of families in poverty.

Table 5. Counts of block groups, their populations, and number of families in poverty by changes in distance to the closest food pantry.

Change in distance	Block groups	Total Population	Families in poverty
<=0.5 mile	1228 (57.3%)	2,345,527 (51.0%)	83,714 (57.7%)
0.5-1 mile	131 (6.1%)	322,948 (7.0%)	9,844 (6.8%)
1-2 miles	167 (7.8%)	357,100 (7.8%)	12,045 (8.3%)
2-3 miles	77 (3.6%)	197,302 (4.3%)	5,562 (3.8%)
3-4 miles	30 (1.4%)	87,922 (1.9%)	2,211 (1.5%)
4-5 miles	13 (0.6%)	37,702 (0.8%)	858 (0.6%)
>5 miles	37 (1.7%)	136,545 (3.0%)	2,591 (1.8%)
No Access	461 (21.5%)	1,117,477 (24.3%)	28,206 (19.4%)

*See notes on Table 2 for estimates of population

**See notes on Table 2 for estimates of families in poverty.

FIGURES

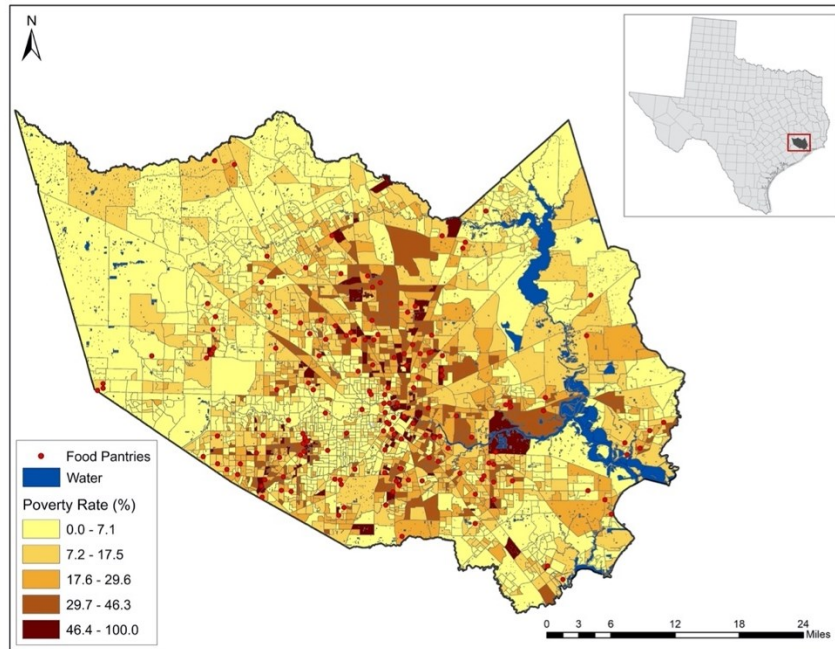


Figure 1. Food pantry locations and percentage of households at or below the poverty line by Census block group in Harris County, Texas. Water extent reflects normal conditions. Data sources: U.S. Census ACS 5-year estimates 2014-2018; Houston Food Bank

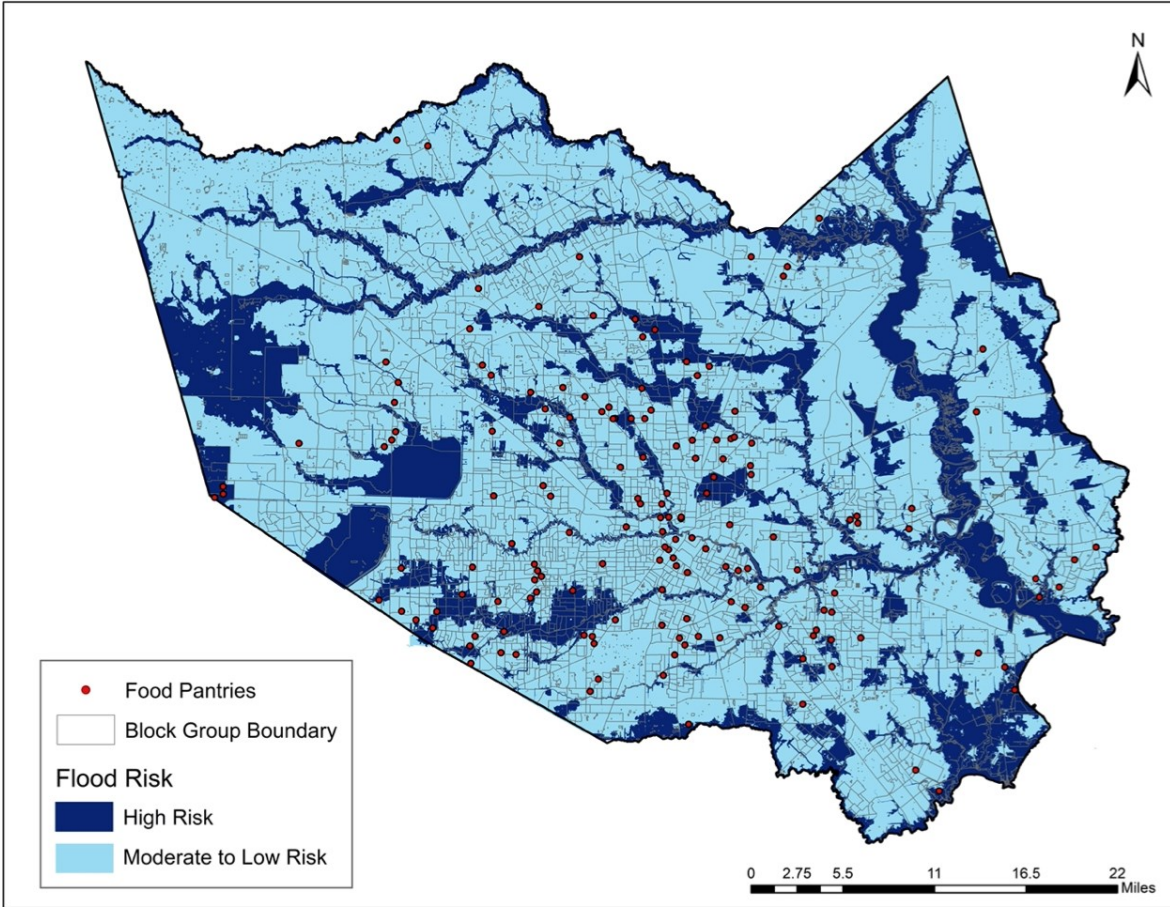


Figure 2. Flood risk in Harris County. Data Sources: U.S. Census; FEMA; Houston Food Bank

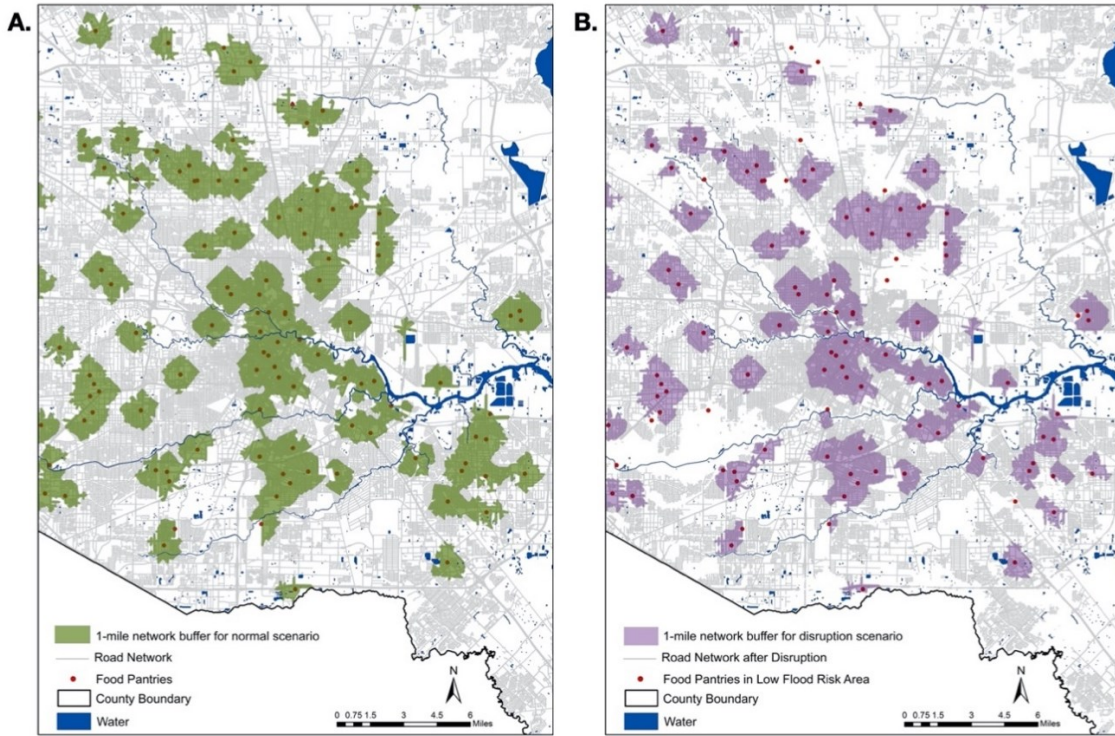


Figure 3. Example of road network disruptions and change in network buffers in (a) normal versus (b) disruption scenarios. Note, both panels depict “normal” water extent and do not reflect flooding conditions. Data sources: Authors’ calculations; Houston Food Bank; OpenStreetMap.

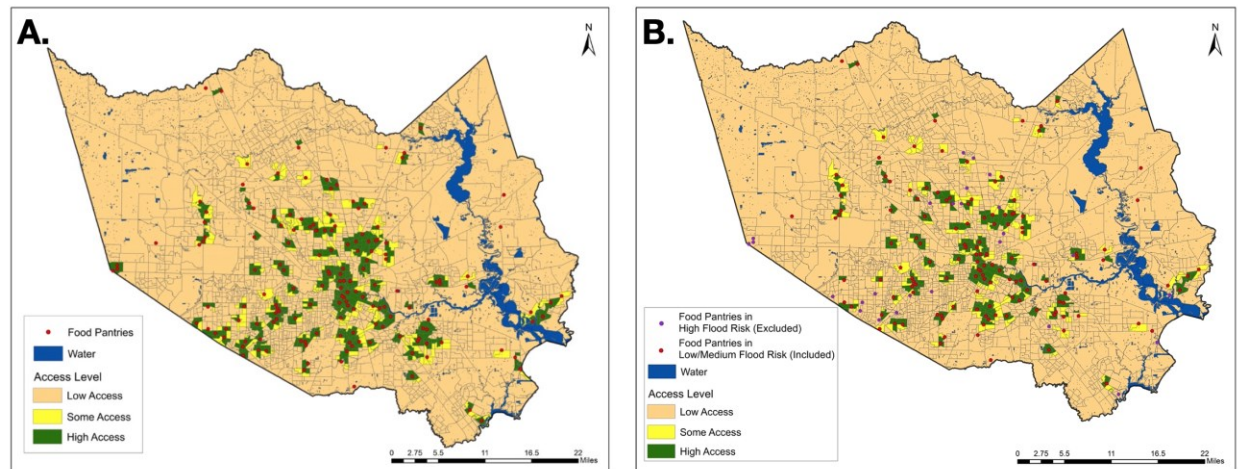


Figure 4. Food pantry access levels in the (a) normal and (b) disruption scenarios. Note, both panels depict “normal” water extent and do not reflect flooding conditions. Data sources: Authors’ calculations; Houston Food Bank; U.S. Census.

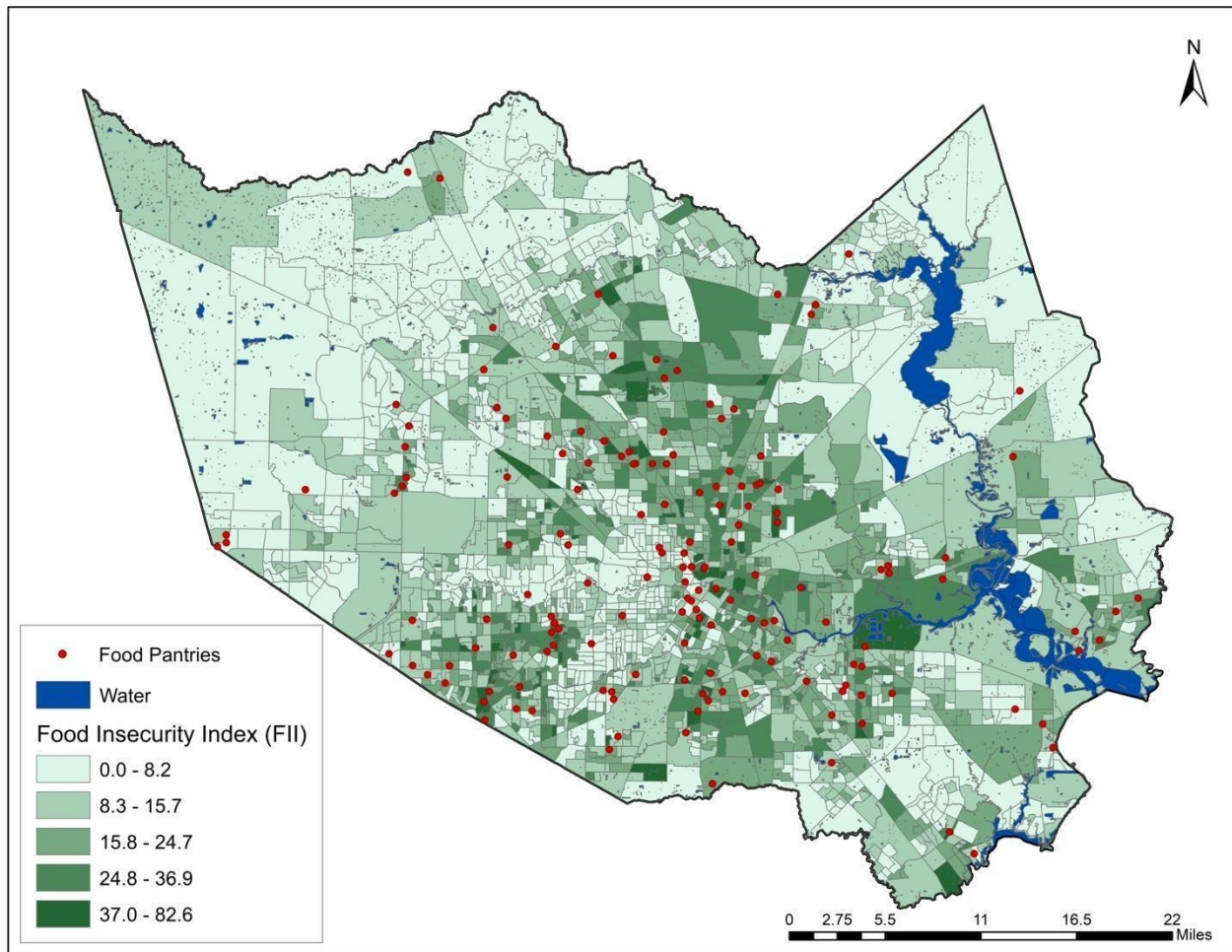


Figure 5. Food insecurity index score by Census block group for Harris County. Data sources: Authors' calculation using U.S. Census ACS 5-year estimates 2014-2018; Houston Food Bank.

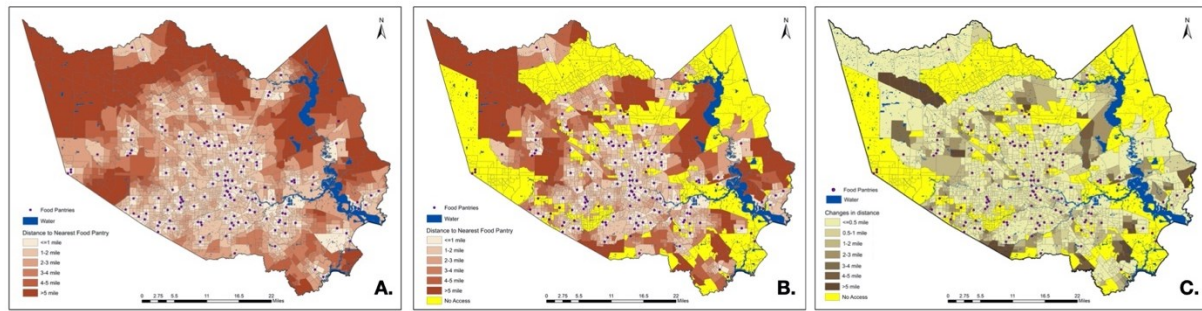


Figure 6. Distance to nearest food pantry from block group population weighted centroid for (a) normal scenario and (b) disruption scenario, and (c) change in distance to closest food pantry. Note, all panels depict “normal” water extent and do not reflect flooding conditions. Data sources: Authors’ calculations; U.S. Census; Houston Food Bank.