Journal of Agriculture, Food Systems, and Community Development
ISSN: 2152-0801 online
https://foodsystemsjournal.org

Introducing an innovative design to examine human-environment dynamics of food deserts responding to COVID-19

SPECIAL ISSUE COSPONSORED BY INFAS:
THE IMPACT OF COVID-19 ON FOOD SYSTEMS

Inter-institutional Network for Food and Agricultural Sustainability

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Submitted August 24, 2020 / Revised December 13, 2020, and January 15 and 17, 2021 / Accepted January 17, 2021 / Published online March 23, 2021

Citation: Liang, C.-L., Kurkalova, L., Hashemi Beni, L., Mulrooney, T., Jha, M., Miao, H., & Monty, G. (2021). Introducing an innovative design to examine human-environment dynamics of food deserts responding to COVID-19. *Journal of Agriculture, Food Systems, and Community Development, 10*(2), 123–133. https://doi.org/10.5304/jafscd.2021.102.037

Abstract

Food desert communities face persistent barriers in accessing affordable fresh and healthy foods, particularly for the underserved and limited-resourced minority population. This research brief proposes an integrated design concept examining human-environment dynamics of food deserts to identify

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Funding Disclosure

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

strategies that would provide effective planning to prevent, prepare for, or respond to disruptive events such as natural disasters or pandemics in the future. The North Carolina example we describe identifies the potential overlapping areas between food deserts and number of COVID-19 cases to demonstrate how an unpredictable event could exacerbate public health in food desert communities to a greater extent than in communities with better food access, availability, and accessibility. The improved understanding of food systems could help in addressing unprecedented challenges such as those due to the COVID-19 crisis.

Keywords
Food Insecurity, Food Desert, COVID-19, Pandemic, Food Systems, Integrated Design

A Brief Overview of Food Issues in the U.S.

Unpredictable events such as the COVID-19 pandemic and market volatility have paralyzed many food supply chains, which also widen the gaps of food insecurity across socio-economic and geographical characteristics (Thilmany, Canales, Low, & Boys, 2020; Ziliak, 2020). There is an urgent need to seek innovative strategies and approaches that will improve well-being and health for individuals, families, communities, and the environment by alleviating gaps corresponding to food access, availability, and affordability.

One of the commonly used community-level measures of food access is the concept of the food desert. According to the U.S. Department of Agriculture (USDA), a food desert is a geographic area characterized by both low income and poor access to healthy food (USDA, 2020). The online Food Access Research Atlas, developed by the USDA, Economic Research Service (USDA ERS), is a tool to map food deserts at the census tract resolution for several alternative measures of low income and low access (USDA ERS, 2020).

In this research brief, we propose a coupled human and natural systems (CHANS) integrated design (Liu et al., 2007) to examine human-environment dynamics of food deserts to identify strategies that would provide effective planning to prevent, prepare for, or respond to disruptive events such as natural disasters or pandemics in the future. The CHANS approach has been identified as a potent framework to address the design for sustainability of regional planning, agriculture, and soil and water resource management (Kline et al., 2017; Lu et al., 2019) In this paper, we utilize data from North Carolina as an example that highlights how an unpredictable event could exacerbate public health in food desert communities. We then explain how the model focused on food deserts could be developed using a CHANS framework and the types of data that the model could use. The initial concept presented here, if fully developed and implemented, could help to mitigate the challenges of food deserts. What is needed is an integrated system design to provide a platform for communities to do the following four activities:

1. Understand the factors influencing the interactions between human decisions in food production and consumption.
2. Evaluate how our choices in agricultural operations and food consumption relate to changes in environmental quality.
3. Gather and maintain concise and consistent longitudinal data to identify existing practices and policies that support or hinder alleviating food insecurity.
4. Reinvigorate new policies and community practices to assist people and organizations in planning and preparing to avoid and reduce the disparity of well-being and health due to food insecurity.

Summarized Literature Review for Food Deserts

Food access is a critical component in community planning, and the issues are significantly different in rural and urban areas (Pothukuchi, 2009). Mergers and acquisitions in the food retail industry have climbed since the late 1990s, resulting in a higher concentration of sales among fewer chain stores (DePillis, 2013; Harris, Kaufman, Martinez, & Price, 2002; USDA, 2017). Most large chain stores such as supercenters and supermarkets are in areas of high population density, while independent and small-scale neighborhood grocery stores are more likely established in low-income neighborhoods and rural regions (Block & Kouba, 2006; Chung & Myers, 1999; Powell, Auld, Chaloupka, O'Malley, & Johnston, 2007). The shifting concentration of large-format chain stores has created increasing challenges to other types of food stores, which links to problematic food access in over half of U.S. counties (USDA, 2017, 2020). Scholars have pointed out the urgency to conduct more studies examining the potential impacts of the food retail industry on food access, particularly in remote rural areas and low-income neighborhoods (Dunn, Dean, Johnson, Leidner, & Sharkey, 2012; Larson, Story, & Nelson, 2009), and on consumers' decisions in purchasing healthy foods.

The COVID-19 crisis has revealed long-standing food insecurity issues, resulting in immediate change in both the food supply chain and food consumption. The production of fruits and vegetables, one of the most labor-intensive sectors of agriculture, has been adversely affected by the pandemic-induced disruptions in the farm labor supply (Ridley & Devadoss, 2020). News reports and videos have revealed commercial farms dumping excess milk or fresh produce, while grocery stores are left with empty shelves and people waiting in long lines to acquire food assistance (McKay, 2020; Yaffe-Bellany & Corkery, 2020). In response, consumers appear to place less importance on nutritional value, instead purchasing more convenient, comforting food such as pizza and ice cream (Ellison, McFadden, Rickard, & Wilson, 2020). The desperation of seeking food assistance seems to be worse in socially disadvantaged, limited-resourced, and underrepresented communities (Gundersen, Hake, Dewey, & Engelhard, 2020; Jablonski et al., 2020; Ziliak, 2020).

Understanding Issues about Food Deserts

The literature on food deserts keeps expanding (Freedman et al., 2016; Hsiao, Sibeko, & Troy, 2019; Walker, Keane, & Burke, 2010). One of the earlier systematic reviews of food desert research, by Beaulac, Kristiansson, and Cummins (2009), synthesized the findings of studies that used geographic or market-basket approaches published between 1966 and 2007. The review discussed the characteristics of food deserts with a focus on the links to social and economic factors, and pointed out that categories and scenarios of food deserts varied significantly across countries. This early review also revealed that low-income, minority, and rural populations seemed to face more challenges in accessing affordable foods in the U.S.

Topics of more recent food desert studies range from geographical distribution to socioeconomic profiles to human behaviors to health implications, which we will now discuss. These studies have evaluated how food desert incidence is related to the geographic distribution of alternative food retailers (Colón-Ramos et al., 2018; Coughenour, Bungum, & Regalado, 2018; McDermot, Igoe, & Stahre, 2017; Vaughan, Cohen, Ghosh-Dastidar, Hunter, & Dubowitz, 2017), and have documented the shopping behavior of food desert residents with barriers in accessing transportation and varieties of grocery stores (Gray et al., 2018; Hardin-Fanning & Gokun, 2014; Ma et al., 2018; Zachary, Palmer, Beckham, & Surkan 2013). The geographic information system (GIS) is one of the most adopted techniques to measure households' spatial accessibility to food retail stores (e.g., Giang, Karpyn, Laurison, Hillier, & Perry, 2008; Michimi & Wimberly, 2010; Mulrooney, Beratan, McGinn, & Branch, 2017; Xu, 2014; Zenk, Schulz, Israel, James, Bao, & Wilson, 2005).

The disparities in diet and diet-related health outcomes between food desert and non–food desert communities (including the disparities in prevalence of chronic diseases) have been a subject of significant research (Abeykoon, Engler-Stringer, & Muhajarine, 2017; Hanson et al., 2018; Liese et al., 2018; Morris et al., 2019; Testa, 2019). Multiple studies ask questions about the effectiveness of the policy interventions aiming to improve the access to healthy, affordable food for the people living in and around food desert areas (Freedman et al., 2016; Hsiao et al., 2019; Smith, Miles-Richardson, Dill, & Archie-Booker, 2013). Despite the significant academic and practitioner interest, effective approaches to the alleviation of the food insecurity problem are still a puzzle.

We propose a novel approach to examine community food systems that explores the potential to promote and support local farmers so that they increase the supply and variety of fresh produce to community-based food stores. It has been challenging to identify empirical studies that attempted to simulate the potential of shifting existing food production at the local level to accommodate small-scale food retail stores in rural or urban areas. A complementary research question arises about the environmental impacts, such as changes in soil and water quality, of re-purposing existing farmland or vacant sites to diversify local food supplies. Answering these questions requires a new approach, one that encompasses the human-environmental relationship of food deserts.

Table 1. Comparison of COVID-19 Effects on Food Deserts versus Non–Food Deserts

	Food Desert	Non–Food Desert
Number of Zip Codes	114	649
COVID Rate (per 10,000)	70.85***	55.71***
COVID Rate (with outliers removed)	59.69*	52.70*

Statistically different at the following significance levels: *p<.1; **p<.05; ***p<.01. *Extreme outliers probably indicating isolated outbreaks (>300 incidences per 10,000) have been removed.* The test results are statistically significantly different between food deserts and non–food deserts even after removing the outliers. This implies that North Carolina food desert communities have higher number of COVID-19 cases (as of July 2020).

The Relationship between COVID-19 and Food Deserts Using North Carolina as an Example

The COVID-19 pandemic highlighted the vulnerability of food desert communities, and we are proposing a new approach to look at the issue. This research brief reports some baseline information in North Carolina as an example. The state is chosen for its data availability. While food desert maps are available nationally at the census tract level, only some states, including North Carolina, report COVID-19 data at a relatively fine spatial scale, making a spatially explicit, GIS analysis possible.

The following data have been used for creating the example:

- Data for COVID-19, as of July 7, 2020, at the ZIP code level (the finest scale currently available) from the COVID-19 North Carolina Dashboard[1] and linked to polygon zip codes stored in a GIS.
- The food desert/non–food desert designation at a more granular, census tract scale, from the USDA Food Access Research Atlas (USDA ERS, 2020). Low-access regions are distinguished between urban regions (>1 mile or 1.6 km) and rural (>10 miles or 16 km) and agglomerated into a single database representing food deserts.
- These COVID-19 rates and food deserts are highlighted in the map (Figure 1).

Because the scales at which data for food deserts (census tract) and COVID-19 rates (zip code) are collected do not match, GIS methods were used to overlay two data on top of each other and to find zip codes that were related to each USDA food desert census tract, highlighting food deserts in this study at the zip code scale. We found that 16.9% of food desert census tracts (367 out of 2,174) were classified as food deserts, while 14.9% of zip codes (114 out of 763) were classified as food deserts.

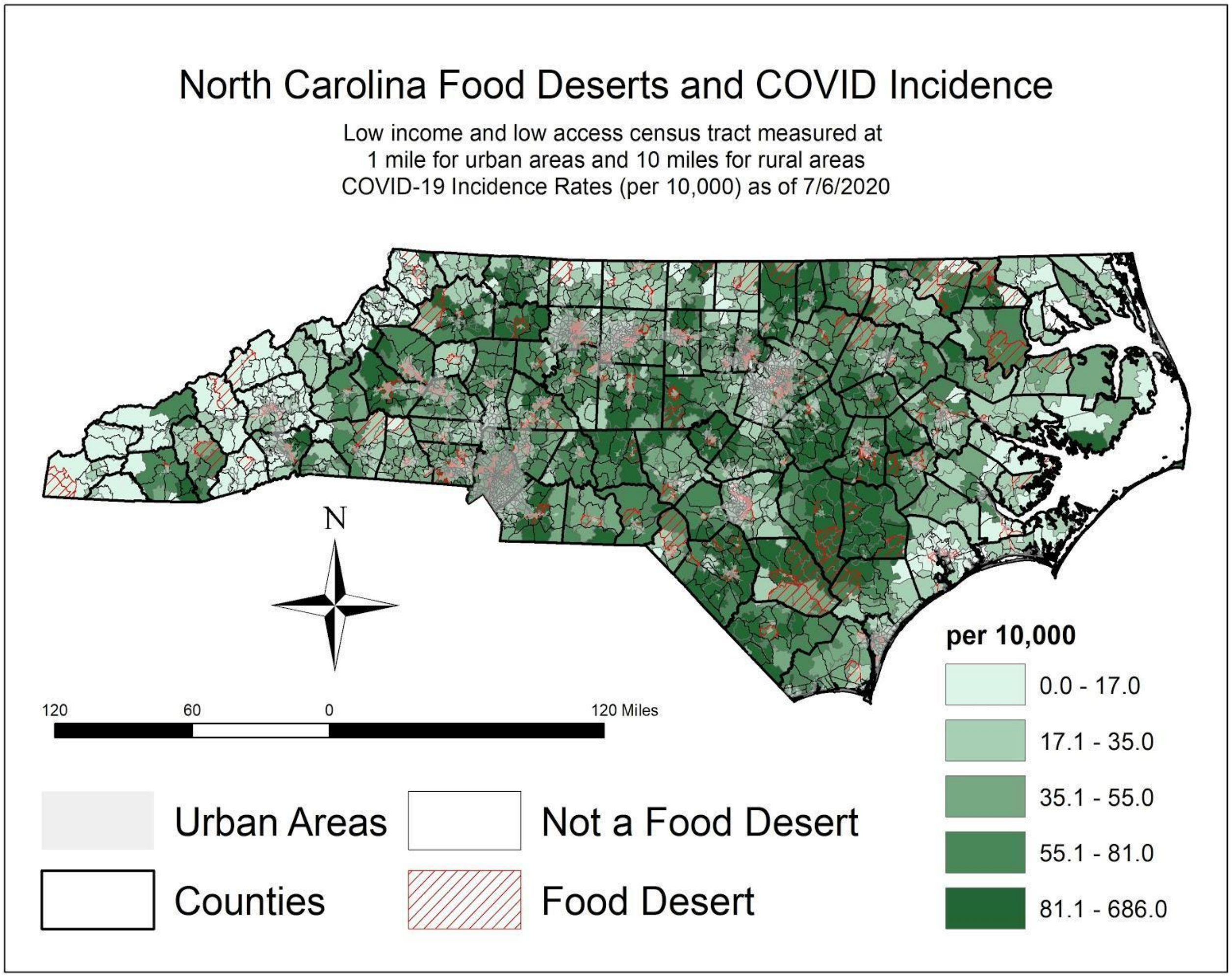
The number of COVID-19 cases was compared between the food desert zip codes and non–food desert zip codes in the study area and analyzed using the two-sample t-test to determine if the two population means are equal. The results showed distinct differences between COVID-19 incidence rates between the food desert and non–food desert areas (Table 1). In North Carolina, the food desert communities appear to have a higher number of COVID-19 cases. This result illustrates that there are overlapping areas between food deserts and the areas of COVID-19 cases and shows how an unpredictable event could exacerbate public health in food desert communities to a greater extent than in non–food desert communities (Figure 1).

Proposing an Innovative Design to Study Human-Environmental Relationship of Food Deserts and to Enhance Community Planning

Agriculture and food systems face a combination of multiple constraints such as weather and climate variations, domestic and international market volatilities, biophysical and/or geographical and tech-

[1] https://covid19.ncdhhs.gov/dashboard

Figure 1. The Overlapping Effect Between the Number of COVID-19 Cases and Food Desert Communities



nology restrictions, and mixed scale of operations and management. We hypothesize that analyzing food desert phenomena in an integrated view that couples human and natural systems will significantly improve the understanding of how to achieve a balance between food security, maximizing production, and minimizing negative environmental impacts. It would be beneficial for communities to build an integrated and scenario-adjustable planning framework to include multidisciplinary datasets and analytical and simulation tools to tackle food system issues during the planning process that will consider resiliency in planning for prevention, preparation, prescription, responsiveness, and recovery during a shock like a hurricane or a pandemic like COVID-19.

The development of an integrated research-based concept for communities to use to examine the interactions between social, economic, and environmental components that correspond to the four objectives described in the introduction could serve as the basis for food systems change that will mitigate the negative impacts of shocks on various community scenarios. The following four stages describe a proposed process to achieve the objectives:

Stage 1: Geo-code the spatial-temporal database for both human and natural factors that jointly influence food availability, accessibility, affordability, and accountability. The human factors might include socio-economic characteristics (e.g., demographics, family compositions) and policy orientations (e.g., zoning, transportation infrastructure).

The natural factors might include land use capacity (e.g., residential versus commercial), land characteristics (e.g., slope, soil), farming activities (e.g., types of farms around the communities), distribution and features of food retailers (e.g., distance and protection from temperature and moisture variations), and community infrastructure such as internet access and communication methods.

Stage 2: Develop an integrated modeling system to link human systems (consumption and production models) to natural systems (land use and GIS models) to better understand and respond to food desert issues. This stage involves a thorough evaluation of existing practices and simulation modeling methods based on research evidence. Some of the robust methods include agent-aased modeling (Muto, Bolivar, & González, 2020; Widener, Metcalf, & Bar-Yam, 2013), which applies multiple factors from social-economic-environmental aspects to identify opportunities for balanced and integrated decision-making.

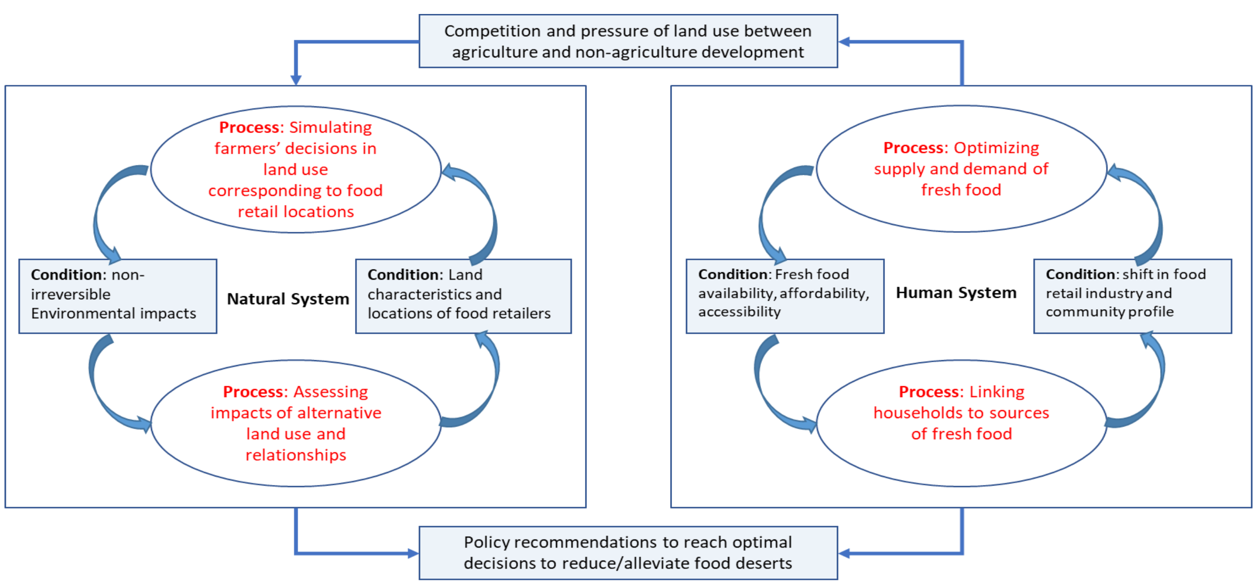
Stage 3: Test the modeling system to validate the reliability and robustness of the method for the study area of interest. This stage involves using data gathered from a food desert community to test the modeling formula and whether the outcomes are reasonable. There are many datasets publicly available for such works. The datasets will be introduced in the following section.

Stage 4: Disseminate the modeling outcome through outreach activities with stakeholders via hands-on demonstrations, interactive discussions, and visualization maps like Figure 1.

Figure 2 presents an example of what an integrated thinking-design platform could look like. Each community has its characteristics to define conditions, influential factors, and the decision-making process. The key is to make sure each community can recruit ideas across all stakeholders to enlist a comprehensive assessment of gaps and opportunities for meaningful collaborations.

The dynamics within human systems: Given the modeled condition of a shifting food retail industry and profile in each community, it is possible to simulate farmers' production decisions to set aside a certain percentage of land, for example to produce a vegetable mix. Local food retailers provide a reasonable inventory level for purchase by local households. Each household makes decisions on where to buy and what to buy, given the produce prices and food retailers' locations (food

Figure 2. High-Level Schematic of the Dynamics of Coupled Human and Natural Systems



availability, affordability, accessibility). Household decisions on food purchases provide feedback to farmers and food retailers who then adjust their production and inventory levels.

The dynamics within natural systems: Given the condition of land characteristics and food retail locations, the natural system can be modeled using a biophysical model, which considers farmers' decisions to change the use of farmland (for example, for vegetable production or commercialization) and other input parameters such as soil characteristics, crop choices, and climate. The model will capture impacts of farmers' land-use decisions on hydrology and the environment, crop and vegetable yield potential, and land and water quality (soil loss, soil water content, nutrients, runoff) with various spatiotemporal scales.

The plan for evaluation of the platform also needs to be well developed following the standard scientific process (Groenveld et al., 2017) to

1. Generate and validate individual components of the modeling and decision-making platform using unbiased and representative sets of input and observed historical data;
2. Integrate the components and validate the integrated systematic approaches to benchmark against the USDA's Food Desert Locator and other reliable sources of information; and
3. Use the modeling and decision-making platform to assess the impacts of specific exogenous changes for a set of social-economic-environmental scenarios for food deserts versus non–food deserts. Some examples might include the shifts of community planning priorities, community characteristics, population migrations, resource allocation, and development infrastructure.

The model proposed in this article demonstrates how a long-term planning process could positively influence human behaviors within the balance of natural systems when a pandemic like COVID-19 occurs. Each household needs to acquire sufficient information to identify the most logical, convenient, and reasonable path to access healthy food. People living in food deserts often lack knowledge and guidance to become acquainted with different types of food and outlets, or such knowledge may be insufficient to change food-purchasing behavior, which in turn, could also be shaped by preferences based on health, culture, religion, and family history. Linking consumers to farmers has grown in interest during the COVID-19 crisis. Local farmers need to weigh the financial outcomes before transitioning into different types of products and practices. Farmers with proper skills sets, knowledge, equipment, and willingness to change might be able to shift land use to produce vegetables when there is sufficient demand from local food retailers and households, or farmers may sell land for commercial development. Once land structures are changed, effects on soil and water quality are created, often irreversibly. When land use is shifted for either food production or commercial development, land characteristics change. Such change may affect long-term soil fertility by switching the crop patterns.

Data Availability to Support This Approach and Next Steps

To design and create an integrated platform takes tremendous time and data. Fortunately, there are multiple datasets that could assist in the development of a platform like the one we propose in this article. Table 1 shows an example of a collective spatial-temporal database that could capture the human systems, natural systems, and their interactions. Additional data and information have been proposed by other scholars using focus groups, interviews, and surveys (Beaulac et al., 2009; Lytle & Sokol, 2017).

Concluding Remarks

This research brief proposes a concept for an integrated design to examine the human-environment dynamics of food deserts and identify strategies that would provide effective planning to prevent, prepare for, or respond to future disruptive events such as natural disasters or pandemics. Scholars have identified concerns and correlations between food access and health disparity for the populations living in food deserts (Allcott et al., 2019; Coleman-Jensen, Rabbitt, Gregory, & Singh, 2020; USDA ERS, 2019). The North Carolina example we present has identified the potential overlapping areas between food deserts and areas of high COVID-19 cases to demonstrate how an unpredictable event could exacerbate public health in food desert communities to a greater extent than in more food-secure communities.

Acknowledgments
We are thankful to three anonymous reviewers whose constructive criticism and comments have improved the manuscript.

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