ABSTRACT

Title of Thesis: INVESTIGATION OF ENVIRONMENTAL HAZARDS NEAR URBAN AGRICULTURAL SITES AND FOOD HANDLING BEHAVIORS OF CONSUMERS

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Despite knowledge of the presence of environmental contaminants at legacy sites including Toxic Release Inventory (TRI) facilities, land restoration sites (LRPs), and Superfund sites, limited research has been done to investigate proximity to environmental hazards and potential exposure risks of consumers to urban-grown produce. We conducted a spatial analysis on the distribution of legacy sites, healthy food priority areas, and urban farms by various sociodemographic factors and surveyed consumers to assess food handling behaviors. We found that more residents were unemployed, had less than a high school diploma and had a lower median household income in census tracts that hosted an urban farm and a TRI facility. Also, across most socio demographic groups, more than half of the individuals stated they ‘always’ washed the produce items surveyed. This research provides insight into the distribution of environmental hazards near urban farms and food handling behaviors of consumers of urban-grown produce.

INVESTIGATION OF ENVIRONMENTAL HAZARDS NEAR URBAN AGRICULTURAL SITES AND FOOD HANDLING BEHAVIORS OF CONSUMERS

by

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TRI: Toxic Release Inventory Facility

LRP: Land Restoration Site

CHAPTER 1: INTRODUCTION

Environmental, social, and economic factors have played an important role in influencing people's lifestyles and risks for developing diet-related health problems.[1] The food environment is the physical presence of food that affects a person's diet, a person's proximity to food store locations, the distribution of food stores, food service, and any physical entity by which food may be obtained, or a connected system that allows access to food[2]. The retail food environment includes the community level (i.e., the presence and locations of food stores, markets, or both) and the consumer level (i.e., healthful affordable foods in stores, in markets, or in both)[2]. Researchers have examined the availability of the retail food environment, to provide evidence on the extent to which neighborhoods factors were related to behavioral choices and diet-related health issues.[1, 3 – 6]

Although healthy eating habits are ultimately a matter of individual choice, local food environments have influenced those choices.[7] The availability of food stores that sold high-quality, nutritious food at affordable prices were an important factor for encouraging individuals to choose these items and subsequently reduced their risk for obesity and diabetes.[7 – 9] People who lived near grocery stores were more likely to eat the recommended amount of fruits and vegetables and less likely to be obese or have a diagnosis of diabetes.[10 – 11] While access to convenience stores, on the other hand, was associated with a poorer diet[12 – 14] and poorer weight status.[11, 15]

The United States Department of Agriculture (USDA) defines a food desert as parts of the country vapid of fresh fruits, vegetables, and other healthful whole foods, usually found in impoverished areas largely due to a lack of grocery stores, farmers' markets, and healthy food providers. For those who are low-income, maintaining a healthy diet can be difficult to achieve due to various factors.[6, 16 – 17] First, those with a lower income have a more difficult time purchasing healthier foods, due to the increased cost associated with healthy eating.[16] Second, many urban areas lack a supermarket, thereby limiting access to healthy food for residents. Furthermore, residing in a food desert can be even more damaging for residents without access to a vehicle for transport to food stores outside the immediate neighborhood.[16, 18 – 19]

Food deserts offer residents few, if any, high-quality, full-service supermarkets but many corner stores and fast food restaurants.[1, 20 – 21] Food swamps are typically located in food deserts and offer residents unhealthy food options, usually dense in calories and high in sodium and sugar.[22] A diet filled with processed foods, frequently containing high contents of fat, sugar and sodium, often leads to poorer health outcomes compared to a diet high in complex carbohydrates and fiber.[16, 23 – 26]

The extent to which food store availability differs by socioeconomic status, racial and ethnic characteristics have been examined in several locations across the United States.[1, 4, 27] Low-income, predominantly African-American neighborhoods have fewer supermarkets, more corners stores, and lower availability of healthy foods, such as fresh produce and low-sugar, low-fat snack foods, as compared to higher-income, predominantly white neighborhoods.[28 – 30] Study results based on multi-state samples have found that low- versus high-income neighborhoods and predominantly Black versus White neighborhoods had fewer numbers of available supermarkets but significantly more small convenience stores.[1,21, 31] National studies of metropolitan and urban areas have found that low- versus high-SES neighborhoods had fewer available supermarkets.[1,32] Other studies have conducted in-store surveys to assess the availability, variety, quality, and price of particularly healthy items.[33] Among these studies, 13 found that food stores in lower-income neighborhoods and communities of color are less likely to stock healthy foods, offer lower quality items, and have higher process compared to stores in higher-income or predominantly white communities.[21, 30, 34, 35, 36 – 42, 43 – 44] Local government assessments have found similar results in boroughs in New York City and Chicago.[24, 45]

In Baltimore, the Baltimore Food Policy Initiative and Center for a Livable Future (CLF) created Baltimore City Food Environment Maps. Of the approximately 621,000 people living in Baltimore City, 23.5% live in areas identified as Healthy Food Priority Areas. A healthy food priority area is defined as "an area where the distance to a supermarket or supermarket alternative is more than 1/4 mile, the median household income is at or below 185% of the Federal Poverty Level, over 30% of households have no vehicle available, and the average Healthy Food Availability Index score for all food stores is low (0 – 9.5)"[46]. The types of stores located in healthy food priority areas differed from the types of stores located outside healthy food priority areas. The stores outside the priority areas had 47 supermarkets, 422 small grocery and corner stores, 177 convenience stores, and all 6 public markets; while, the stores in the priority areas had no supermarkets, 103 small grocery and corner stores, 6 convenience stores, and zero public markets.[46] In addition, all food stores located outside priority areas had a greater availability of healthy foods than stores located in priority areas.[46]

Areas that qualify as a priority area were also predominantly African-American neighborhoods. The percentage of African-Americans who lived in a priority area was

35% compared to a city average of 23.5%. For Hispanic residents, it was 11.4%, Asians 6.9%, and Whites 8.9% [46] compared to city average of 4.8%, 2.5%, and 30.3, respectively.[47] The 2018 Food Environment report indicates that of all the children who lived in Baltimore, 28.3% lived in a priority area.[46] The 2018 Food Environment Map showed that 23.5% lived in healthy food priority areas. The map displayed food access disparities in regions of the City, primarily in West and East Baltimore, while central city had more access to food. The map also indicated that most urban farms were located within healthy food priority areas. Thus, urban farms could provide access to alternative methods of healthy food options.

Urban agriculture sites contribute to the local food system by providing greater access to healthy food choices. Urban agriculture has evolved into a strategy for improving overall community and sustainable development in neighborhoods, including promoting social, environmental, economic and health concerns.[48] Prior research showed that community gardening could facilitate social interaction, community involvement and volunteerism, and education of agriculture techniques.[48 – 50] Urban agriculture and gardening have become an important community development strategy, turning vacant lots into green spaces.[48, 51] Finally, urban agriculture initiatives have shown to improve access to food and provide for better nutrition.[52 – 57] However, limited research has been performed regarding proximity to environmental hazards in relation to urban farms. Environmental hazards may include Toxic Release Inventory (TRI) facilities, landfills, incinerators hazardous waste sites, sewer and water plants, land restoration sites, or brownfields.[58] There is a need to explore this association because environmental contaminants, such as heavy metals, can be present in urban soils and may be absorbed by plants or reside on the leaves and outer surface of vegetables and fruits.[59 – 63] Once ingested, heavy metals may have detrimental health impacts on consumers, especially susceptible populations such as children, the elderly, or those who are immunocompromised.[64 – 66]

SPECIFIC AIMS

This project has three aims: 1) Examine the proximity of environmental hazards to urban farms in Baltimore City; 2) Understand the distribution of urban farms in relation to sociodemographic factors and environmental hazards in Baltimore City; and 3) Investigate knowledge and behavior of consumers of urban-grown produce in relation to locations, food types, and washing practices in Baltimore City. We used QGIS to spatially examine the distribution of land restoration sites (LRPs), Toxic Release Inventory (TRI) facilities, and Superfund sites in Baltimore City. We also surveyed a subset of Baltimore City residents to assess consumption of urban-grown produce, when it is seasonally abundant, and washing methods for urban-grown food. The goal of this study is to understand the distribution of environmental hazards near urban farms and food handling behaviors of consumers of urban-grown produce.

Research Questions

For Specific Aim #1, we have the following research questions:

1) Are there differences in values of EJScreen environmental indicators within a 1, 2 and 5 kilometers of an urban farm?
2) How do these values compare to the Maryland state average?

3) What is the count of environmental hazards within 1, 2 and 5 kilometers and urban farms?

For Specific Aim #2, we have the following research questions:

4) What is the spatial distribution of urban farms, environmental hazards, and healthy food priority areas by various sociodemographic factors?
5) What is the mean distribution of sociodemographic measures of census tracts who host an urban farm and/or a TRI facility and census tracts who do not host an urban farm and/or TRI facility?

For Specific Aim #3, we have the following research questions:

6) How often do consumers eat city-grown carrots, kale, squash, bell peppers, and tomatoes when they are seasonally abundant?
7) What types of washing practices do residents have when handling urban-grown produce?

CHAPTER 2: LITERATURE REVIEW

Food Disparities and Environmental Justice

The United States Environmental Protection Agency (US EPA) defines environmental justice as ‘the fair treatment and meaningful involvement of all people regardless of race, color, national origin, or income with respect to the development, implementation and enforcement of environmental laws, regulations and policies.[67] Community food security may be defined as “all persons obtaining, at all times, a culturally acceptable, nutritionally adequate diet through local, non-emergency sources”[68 – 69]. Community food security and environmental justice are parallel social movements interested in equity and justice and system-wide factors.[68, 70 - 71] Both movements identify the need to empower communities and incorporate considerations of equity and justice.[68, 72] Community food security differs from hunger intervention by representing a community need, rather than an individual’s condition, as associated with hunger.[68, 73] Community food security can examine the food system itself, from production, distribution and transportation;[74] however, we will investigate how community-based food processing enterprises, such as urban farming helps to relieve community food insecurity.

Food insecurity is a lack of consistent access to enough food for an active, healthy life.[75] In 2015, an estimated 12.7% or 15.8 million households were food insecure.[75, 76 – 77] Disparities exist across different neighborhoods in terms of access to healthy or higher quality foods.[11, 29, 78] Some investigators have documented disparities in the costs of food,[79 – 81] due to the lower cost of energy-dense foods and the higher costs of nutrient-rich foods.[82] Darmon found energy-dense foods, such as fats and oils, added sugars, and refined grains provided calories at a lower cost, while low-energy-density lean meats, fish, vegetables, and fruit are the most expensive energy sources. Similar findings have been obtained in the United States,[82 – 83] Australia,[84] and the Netherlands.[85] Other studies have focused on the types of foods available within food stores.[86 – 88] Larger sized food stores, such as supermarkets, versus smaller stores and chain stores have been shown to stock a greater selection of produce and healthy food items at a lower cost, due to the economics of scale and, often to competition.[1, 74] A study in rural Maryland found that the most common food source types, convenience stores and nontraditional stores, had the lowest healthy food availability.[88] Another study documented the lack of availability of foods recommended for people with diabetes in East Harlem, New York compared with availability in the Upper East Side, an adjacent more affluent and predominantly White neighborhoods.[37]

In addition, researchers have found differences in the availability of certain types of food stores.[23, 25, 31, 37, 79, 89, 90, 91] The type and number of food stores present have been shown to vary according to the racial and income composition of neighborhoods, with supermarkets generally more common in White and wealthier areas compared to neighborhoods with people of color and lower-incomes.[21, 31, 91] Studies have shown that neighborhoods with a higher proportion of African-American residents have fewer supermarkets and fewer high-quality food options,[25, 44, 31] as well as disproportionate number of fast food restaurants.[23] A study in Detroit, Michigan found disparities in supermarket accessibility on the basis of race among the most impoverished neighborhoods.[91] African-Americans resided, on average, 1.1 miles farther from the nearest supermarket than members of the most impoverished White neighborhoods.[91]

Neighborhoods with higher income levels and higher proportions of White residents tend to have greater access to supermarkets or large chain food stores, while poorer neighborhoods and those with higher proportions of Black or Hispanic residents may have relatively high access to small grocery stores.[25, 92]

Everyone has the right to equal access to products and services capable of satisfying basic needs, yet the poor may be systematically prevented from doing so.[93 – 94] People in poverty are those subjected to socioeconomic disadvantages that limit and restrict their ability to access and afford basic products and services.[93, 95] Income inequality may be magnified by the costs of food security.[93] Access to healthy food in disrupted food systems requires consumers to either pay high prices for travel or suffer food-insecure conditions.[93] If poor households pay more to access healthy foods, the household budget and/or consumption must be adjusted.[4, 93 – 94, 96] Studies of the food environment rarely include mode of travel.[92] For those who lack a private automobile, the extent and frequency of public transit service may be pivotal for accessing resources.[92, 97] In locations with infrequent or unreliable transit service, use of public transit for food shopping is likely to be time consuming and inefficient.[92, 98 – 99] For example, a study in Baltimore City, Maryland found that distance and inconvenient public transportation made it difficult for residents to access supermarkets without a car[100]. If travel is not an option, households will have to endure food desert or food swamp conditions, with the corresponding health consequences and costs.[93, 101 – 102]

Disparities in the built environment put low-income, urban residents at increased risk for an unhealthy diet and obesity.[103] Residents of low-income neighborhoods may rely on small groceries and convenience stores for food,[41, 104] which compared to supermarkets, devote dramatically more shelf space to highly processed foods (e.g., four times the space to carbonated beverages) and less space for healthy foods (e.g., 64% less for fresh fruits) [105]. Another study in Southeastern Louisiana and Los Angeles measured the amount of shelf space of food items in urban small food stores and found that such stores had a limited amount of space for fresh fruit and vegetables. Over 50% of these did not carry any fresh fruits and 35% did not have any fresh vegetables.[106] A majority of non-White and low-income neighborhoods can have an abundance of food retailers that sell energy-dense, less healthy foods that 'swamp' out the healthy food choices that could be available, leading areas to be labeled as 'food swamps'.[103] The lack of access to healthy foods can contribute to poor health outcomes including obesity. One study found that the presence of convenience stores was associated with a higher prevalence of obesity and overweight residents.[11]

Alternative food outlets, such as urban agriculture, can help relieve food insecurity. The alternative food movement seeks to rethink food production and food consumption through emphasizing a local food environment that promotes a regional economy, sustainable growing practices, and social justice.[107 – 108] Much of the research and practices associated with the alternative food movement can be understood from a food justice theory, related to environmental justice, race, history, and socioeconomics.[70, 107] Food justice is communities exercising their right to grow, sell, and eat healthy food.[490] The framework ensures that the benefits and risks of how food is grown, processed, transported, distributed and consumed are shared equitably.[68] Food justice scrutinizes the current system of power, resource control, and lack of participation within the food system by calling for alternative solutions such as local agriculture, farmers' markets, and community supported agriculture.[107 – 109]

The rise in demand across the United States and abroad for farmers' markets, community gardens, and community-supported agriculture tends to support the notion that people are becoming more aware of and involved in local agriculture production.[109] Much of the research on food security and urban agriculture has been done in developing countries; however, some research supports that urban agriculture can impact food security by increasing food availability, access, consumption, and through income generated through the sale of produce in US cities.[71]

Urban agriculture initiatives have become important resources for community food security.[69, 110] A study in Newark, New Jersey showed that 44.9% of respondents considered growing their own food a socio-economic benefit of community gardening.[53] An upstate New York survey indicated that 60% of low-income gardeners chose to garden because it provided them with a significant food supply.[49] In Philadelphia, Meenar found that 67% of urban agriculture participants strongly agreed that urban farms contribute to alleviate the food gap.[107] Gardeners in Toronto thought of the food in their gardens as a substitute for store-bought food; they also believed gardening made a considerable difference in their household food budget.[52] Additional studies have found that participating in an urban garden may improve fruit and vegetable intake among urban adults.[111 – 114]

Urban and community gardens have been found to have social-cultural, environmental, and health and benefits. Numerous studies have documented how community gardens enhance the social capital of communities through increasing social networks and foster social integration.[50 – 52, 115 – 119] The strong socio-cultural values surrounding growing food and cooking food, help to facilitate the role of gardens as a social bridge. These sites can also provide services for youth development, education, and skills/workforce training.[115] For instance, researchers found that Latino gardeners in New York City stated urban agricultural sites remain to be important educational sites.[51] In addition, urban green spaces can increase biodiversity, reduce air pollution through filtration of particulates by vegetation, and increase rainwater draining.[115] The practice of urban agriculture generally increases social capital, civic involvement, community efficacy, and empowerment[107] and may increase food security by improving access to food and provide better nutrition.[53 – 55]

As urban agriculture grows in popularity, vacant parcels in post-industrial cities have become a prime target for cultivation.[62] Many efforts to transform vacant land into fruitful agricultural spaces are driven by the motivations to provide healthy and nutritious fresh produce to residents of 'food deserts', low-income areas where fresh produce and healthy food options are limited, largely due to a lack of grocery stores, farmers markets and healthy food providers.[62, 120] However, as healthy food production begins on vacant parcels in urban settings, public concern is growing over potential environmental hazards.[60, 62, 121] Many vacant lots contain contaminants, some of which may be legacy material from an industrial site, or contaminants from traffic-related exposure.[62, 122 – 123] Additionally, these urban agriculture sites are located within or nearby the very food deserts that food justice-oriented urban agriculturists intend to serve.[49, 62] It is important to investigate the spatial distribution of legacy sites and the potential for soil contamination to protect the public from potential risks associated with the consumption of urban-grown produce.[62]

Food Landscape in Baltimore City

Food is readily available in diverse retail establishments, although the quality and healthfulness of products varies widely.[124] The availability of healthy foods in retail stores is one aspect of food access.[46] Baltimore City has several food retail establishments, including supermarkets, small groceries and corner stores, "behind glass" corner stores, convenience stores, virtual supermarkets, and public markets.[46] Proximity to and type of food retail stores may influence an individual's ability to purchase healthy foods.[46] The Johns Hopkins Center for a Livable Future (CLF) created the Healthy Food Availability Index (HFAI) tool, derived from the Nutrition Environment Measures Survey for Stores (NEMS), to measure and assess healthy food in stores.[46]

The HFAI tool awards points to stores based on the presence of a market basket of basic staple food items, as well as whether there are healthy options available including lean protein, whole wheat grains, low-fat dairy, and produce.[46] Scores can range from 0 to 28.5, with a higher score indicating a greater presence of healthy foods.[46] Research from BFPI and CLF found that supermarket have the highest average HFAI score of all food retail categories, indicating a greater presence of healthy foods.[46] Small grocery and corner stores are the most common type of food retail store, with over 500 locations surveyed across the city, and have the widest range of HFAI scores. Most convenience stores are national chains and stocking decisions likely happen at a corporate level and individual stores may have less flexibility in what they offer.[46] The historic public markets vary in size and offerings.[46] Most public markets tend to have a larger proportion of carryout stalls to stable food items (i.e., fruits, vegetables, grains, etc.)[46].

In Baltimore City, the distribution of food store types varies enormously between predominantly African-American neighborhoods and predominantly White neighborhoods (see Figure 2). In White neighborhoods, 42% of food stores are corner stores, 37% are convenience stores, 13% are supermarkets, and 5% are farmers markets; only 1% are behind-glass stores. In African-American neighborhoods, 54% of food stores are corner stores, 19% are behind-glass stores, and 17% are convenience stores; only 8% of food stores in African-American neighborhoods are supermarkets, while farmers market makes up 1% of food stores.[100] Differential access to healthy foods may contribute to health disparities across race/ethnicity and socioeconomic status.[29]

Researchers have investigated food disparities in Baltimore City[21, 29] and its impact on human health.[103, 125 – 126] Franco examined the relationships among the availability of healthy foods and racial and income neighborhood composition.[29] They found that 43% of predominantly Black neighborhoods and 46% of lower-income neighborhoods had the lowest availability of healthy foods, versus 4% and 13%, respectively in predominantly White and higher-income neighborhoods [29]. Additionally, supermarkets in predominantly Black and lower-income neighborhoods had lower HFAI scores than supermarkets in predominantly White and higher-income neighborhoods.[29] Diez examined differences in the local food environment in Madrid and Baltimore. In Madrid, 77% of the residents could access healthy foods within 200 meters, versus 1% of the residents in Baltimore. The study also found that Madrid has access to more public markets than Baltimore.[491] Finally, a study assessed the association between local food environments and neighborhood racial/ethnic and socioeconomic composition in selected census tracts in North Carolina, Maryland, and New York. They found that predominantly Black census tracts in Maryland had fewer supermarkets and more liquor stores and predominantly White census tracts.[21]

CLF conducted a healthy food availability survey in a predominantly low-income, African American neighborhood and predominantly high-income, White neighborhood.[100] The HFAI supermarket score in the low-income, African-American neighborhood was about one-half that of the high-income, White neighborhood.[100] In every category, except breakfast cereal, the availability of a healthy option was much lower in the African-American supermarket compared to the supermarket in the White neighborhood.[100]

Factors in the community food environment may influence obesity and chronic disease risks by creating a food climate that does not support healthy eating.[127] A study explored food purchasing patterns among adolescents in low-income areas of Baltimore City and found that these individuals living in food swamps consumed more snacks and fewer fruits and vegetables, compared with girls living in areas that were not food swamps.[103] Another study observed the relationship between the types of food sources and food purchasing patterns and found that corner-store shoppers obtained more unhealthy foods than people shopping at other food stores.[126] A study evaluated the association between healthy foods and BMI and found a positive association between the availability of healthy food and a higher BMI and attributed this association to the possibility that individuals could be traveling outside their neighborhood to obtain healthy food.[125]

Decreased access to healthy food means low-income, people of color suffer more from diet-related diseases, like obesity and diabetes, than those in higher-income and predominantly White neighborhoods.[6] Given these threats to health and quality of life, increasing healthy eating in disadvantaged urban communities is a critical public health and policy issue.[100] Urban farms and gardens can increase access to healthy fruits and vegetables on a community level.[100]

Urban agriculture can range from urban farms occupying multiple acres of land to smaller community garden plots available to community members to garden.[46] While many urban agriculture projects (both community gardens and farms) are not intended to replace traditional food retail and may not be able to feed a significant number of people, they are part of the food solution by augmenting household access to a variety of fresh food.[46] There are 24 urban farms in Baltimore City. The urban farms range in model, size, and products grown. Many farms sell produce through farm stands, at Baltimore City farmers markets, and some urban farms have mobile sites.[46]

Urban agriculture produce can be accessed via farmers' markets, community supported agriculture memberships, home gardens, school gardens, and Baltimore grown produce in public markets. Of the 24 urban farms, 13 farms sell at least one farmers market and 4 farms sell at more than one farmers market. Two farms sell at one public market, two farms sell through a mobile market and six farms have a farm stand on site. Of the 19 food producing farms, there are approximately 262 community supported agriculture members.

Urban Agriculture Policy in Baltimore City

Urban agriculture encompasses an array of food producing methods, including school gardens, community gardens, backyard gardens, indoor farming, hydroponics, and urban farms.[115, 128 – 129] Several policies are in place to support farmers to grow local produce on vacant land, such as the 2015 Urban Agriculture Tax Credit, the City Owned Land Leasing Initiative, and the Urban Agriculture Training Program.[130] On June 5, 2017, Baltimore City's enacted and corrected zoning code went into effect.[131] Article 32 §14 – 307, states for any community-managed open-space garden or farm that produces food for human consumption, measures must be taken to test and, if necessary, remediate the soil in accordance with guidelines adopted by the Department of Planning. The Department of Planning soil safety policy states that all sites that are intended to grow food in or adjust to existing soil must be tested for lead, arsenic, cadmium, and chromium and the need to test for additional contaminants will be generated by a site assessment.[132]

The soil safety policy has specific recommendations on the quantity of lead allowed in soil, see table 2 in Appendix 1. For sites tested for lead of 2,000 ppm or greater, farmers are required to bring in clean soil from an outside source, maintain a strict plan to prevent that soil from being contaminated, as well as prevent human exposure to the existing soil. Farmers are also urged to consider using a different site to grow food.[132] In addition to the 24 urban farms in Baltimore City, there are several community, school, and backyard gardens. The soil safety policies apply to all community-managed open space gardens or farms in Baltimore City, but not backyard gardens.

Urban Agriculture Perception and Risk Communication

Studies have observed associations between community gardening and health,[49, 52 – 53, 55, 111, 134 – 135] social,[53] and economic benefits,[52 – 53, 136] and gardening in general has been associated with cardiovascular and mental health benefits.[137 – 139] A case study in Toronto, Ontario found that through participant observation, focus groups and in-depth interview, community gardens were perceived by gardeners to provide improved access to food, improved nutrition, increased physical activity and improved mental health.[52] Gardening in urban settings may also present health risks associated with exposure to contaminants such as, heavy metals, organic chemicals, and asbestos that may be present in urban soils.[140] Understanding the perception of gardeners and consumers on urban agriculture is important for stakeholders to increase the share of citizens who take part in urban agriculture and provide information on how to minimize health risks associated with urban gardening.

Subjective knowledge and attitude play a role in consumer behavior.[141] Moreover, each consumer differs in how they personally perceive products, which depends on their abilities, preferences and experiences.[141] In reference to urban agriculture, a study performed in 2011 found that consumers have a higher willingness to pay for local products.[142] Since the late 1990s, consumers started to purchase local foods instead of organic foods.[143] Research has shown that 86% of consumers considered it an advantage and held a positive attitude towards purchasing locally grown food.[144] Previous research also found that consumers have a higher willingness to pay for local compared to organic apples and local compared to organic and GMO-free potatoes.[145] How consumers perceive urban agriculture is important to understand these motivations of purchase.

A study surveyed university students and found that consumers had a mostly positive attitude toward urban agriculture and the reasons that prevent them purchasing urban produce are associated with cost and convenience. Another survey reported that about 60% of respondents felt that locally grown produce had superior food safety level than conventional produce.[146] Another study revealed that consumers perceived locally grown produce as safer and carried less risk than produce grown elsewhere because of the shorter distance traveled to farmers' markets versus other markets.[147] However, most studies associated with consumers' perceptions about locally grown foods did not include food safety in their research scope.[148 – 149] An additional study found that consumers generally hold a positive food safety perception that may be in contrast to actual microbial safety of produce obtained from farmer's markets and highlight the need for consumer education, specifically related to food safety awareness.[150] Although there has been an increasing shift of consumers towards purchasing local foods, the attitudes for purchasing local foods differs.

Researchers have also investigated local food shopping behavior. One study interviewed shoppers at a farmer's market and found that 84% of participants stated the reason for shopping at farmers markets is the perceived freshness and quality of the produce.[151] Another study suggests that rural consumers gave a much greater importance if the food was locally produced than urban consumers. Yet, both urban and rural consumers reported that they were strongly or extremely likely to choose locally produced food, if available at the right place and right price.[152] Megicks found that when consumers buy local foods, they are often choosing to do so for reasons that not only relate to the product itself but also their priorities and perceptions of food-related issues.[153] Tregear found that in addition to extrinsic food factors (e.g., environment, welfare, and origin), pragmatic features of food, such as price and quality, are important determinants for food purchasing behaviors.[154] Recognizing that consumers have a multifaceted appreciation of what local food buying can offer in terms of its extensive benefits, and the difficulties that they may encounter when acquiring it, contributes to understanding local food shopping behavior.[153]

Studies have identified a variety of concerns for urban gardeners and consumers of urban-grown produce. Consumers in one study were asked their environmental, ethical, and health considerations when purchasing from local markets. In California, consumers were concerned about the use of pesticides and fertilizers.[155] Another team interviewed gardeners and identified their primary concern was insecure land tenure. Other concerns included physical safety for female gardeners, funding, and contaminated soil.[52]

Additionally, perceptions of soil contamination risks differ for urban gardeners. Kim found that concern about soil contamination is generally low and gardeners were more concerned about chemicals added to the gardening environment than what contaminants may already be present in soil.[140] Informants expressed a need for information related to the management of soil contamination to be accessible in a central place for gardeners.[140] Wong asked gardeners about concerns of soil contamination and found that more than half were not concerned about possible soil contamination nor the impact of soil contamination on their health.[156] Most gardeners stated they were aware of heavy metal contamination but were not aware of practices they could use to reduce their exposure.[156] Harms surveyed urban farmers and found that most indicated they did not have sufficient knowledge of how to minimize health risks associated with gardening in contaminated environments.[157] Better risk communication and soil remediation strategies must be used to express soil contamination concerns with both gardeners and consumers, yet limited work has been done in this area.

The goal of risk communication is to provide useful, relevant and accurate information in an understandable language and format for a particular audience or risk group.[158] People who consume produce grown in contaminated environments risk ingesting soil particles on the surfaces of plants.[159] Most studies have worked to characterize urban soil contamination,[59, 62 – 63, 160] yet, in the US, limited research has been done to investigate the role of risk communication and urban agriculture. Researchers in Ghana have investigated this topic[161 – 162] and suggested community-based public health education interventions, using accessible media that target farmers and consumers.[162] Public health education should center on sound practices of food hygiene and proper handling and preparation of vegetables before consumption.[162] In particular, proper washing or cooking of these vegetables before eating must be stressed.[163]

Factors influencing response to risk communication are impacted by personal risk perception, previous personal experience with risk, sources of information and trust in those sources, and preferences for information.[164] Engagement in preventive health behaviors, such as produce washing, are not merely determined by the awareness of objective health risks but influenced by health beliefs and specific health cognitions.[165] Developing programs to educate communities about environmental hazards affecting their health and quality of life is an essential component for a community to understand their true risk.[166] This is especially true in post-industrial cities, where urban agriculture initiatives are at an increased risk of heavy metal contamination from industrial processes and deteriorated housing.[160]

Environmental Contamination in Baltimore City

Heavy metals, which are typical contaminants in urban environments, are important indicators of environmental pollution.[167] Heavy metals in urban soils may originate directly from industrial activities, municipal wastes, traffic emissions and domestic activities.[168] In urban areas, industrials sources that release heavy metals often impact surrounding soils.[168] In Philadelphia, Pennsylvania, Gregory found that areas with a history of industrial activity yielded concentrations of Pb well above those found in areas with no history of industrial activity and the proximity of sites closer to lead smelters were the cause of the contamination.[169] Another study investigated Pb concentrations in rural and urban areas of South Carolina and found that urban areas had significantly higher concentrations of Pb than rural areas.[170] Pilgrim and Schroeder measured elevated concentrations of Cd, Cu, Pb, and Zn in urban and rural sites in Canada and found elevated levels of lead in urban areas.[171] Chen found urban soils to have a significantly higher mean As, Cd, Cu, Pb and Zn concentrations than forest and rural soils.[172] Finally, Aelion measured soil metal concentrations in two rural and one urban area and found that both rural areas had lower concentrations of metals, lower soil toxicity, and a small number of facilities with significant associations between distance and soil metals.[173] Post-industrial cities, like Baltimore, Maryland, tend to have elevated levels of heavy metals in urban soils.[174]

Metal transport is not only dependent on the physicochemical properties of the metals but mostly on the physical and chemical properties of the soil, like for example: soil organic matter content, clay fraction content, mineralogical composition, pH, and more, all of which collectively determine the binding ability of soil.[175] The properties of the soil may change due to climate change but mostly due to anthropogenic impact.[175] Urban agriculture implies exposure of urban farming to physical and chemical contaminants. Among the many contaminants derived from anthropogenic sources, heavy metals such as lead (Pb), chromium (Cr), arsenic (As), zinc (Zn), cadmium (Cd), copper (Cu), mercury (Hg) and nickel (Ni) are the most commonly found at contaminated sites.[176]

Yesilonis investigated the spatial distribution of heavy metals in Baltimore and found that Pb concentrations varied widely in the City. Almost 11% of the plots sampled had concentrations above EPA's Pb soil screening guideline of 400 mg/kg. For Cr contamination, 5.7% of plots exceeded EPA guidelines, and for Cd, Co, Ni, and Zn, none of the plots exceeded EPA guidelines.[177] An additional study found that elevated lead levels were highest in the city center where roadways are concentrated, suggesting that the historic use of leaded gasoline was a major source of contamination.[178] Another study compared soil lead concentrations in the Baltimore-Washington metropolitan area and found that urban yards exhibited up to 10-fold higher concentrations than in rural yards. Moreover, these differences were greater for older parcels and structures.[174] Soil sampling of 61 residential properties from 2007 – 2008 in Baltimore City revealed that 53% had soil Pb that exceeded the US EPA reportable limit of 400 ppm.[179] Also, data from the Baltimore Ecosystem study exhibited that soil lead concentrations exceeded the

US national guideline in 10% of samples soils. Finally, researchers found that soil lead concentrations in an older and economically depressed neighborhood in southwest Baltimore exceeded the national guideline in 16% of sampled soils.[180] Given the exceedances found in Baltimore-based studies and results from other cities, soil lead is greatly elevated in urban areas.[174]

Lead has entered soil systems through the historic combustion of leaded gasoline and the deterioration of lead-based paint,[65] as well as multiple industrial sources, including smelters,[181] incinerators,[182] and coal-burning plants.[183] Although gasoline and paint no longer contain lead, their past use has resulted in the accumulation of lead in the environment, with four to five million metric tons deposited from leaded-fuel alone.[184] From 2006 – 2016, 378 lead paint hazard violations were filed in Baltimore City.[185] Not all properties with lead hazards are on the list of violations and some properties may have hazards but have never been assessed.[185] Lead enriched soil is mobile and can be redistributed in the environment when soil particles move with wind and water.[186] Unless proper precautions are implemented, lead-based paint can contaminate dust or soil when it deteriorates or is disturbed during maintenance, repainting, remodeling, demolition, or paint removal.[187] Residences with deteriorated lead-based paint are more likely to have higher levels of lead in house dust and the surrounding soil.[187]

Baltimore City is an industrial city with a history of lead contamination. In industrial regions of the city, Pb is generally attributed to atmospheric deposition downwind from smelting.[188 – 190] Along highways, Pb contamination is attributed to exhaust emissions.[191 – 192] In residential areas, most Pb contamination is attributed to paint used for housing.[193 – 195] Over 6 million milligrams of Pb was used in paint in the US between the 1880s and the late 1970s, peaking at 1.2 million milligrams used in the in the 1920s[62]. Even though Pb concentrations in paint declined steeply by mid-century, high levels of Pb remain on the interior and exterior walls of houses to this day.[65]

Brownfields and Land Restoration Sites

A brownfield is a property, the expansion, redevelopment, or reuse of which may be complicated by the presence or potential presence of a hazardous substance, pollutant, or contaminant.[196] Brownfield sites include abandoned industrial facilities, warehouses, and other commercial properties such as former gas stations and dry-cleaning establishments. It is estimated that there are more than 450,000 brownfields in the US.[196] Similar to brownfields, the Maryland land restoration site program (LRP) is a hazardous waste program that focuses on cleaning up uncontrolled hazardous waste sites throughout Maryland. Within the LRP, three programs exist to investigate eligible properties with known or perceived controlled hazardous substance contamination, protect public health and the environment, accelerate cleanup of properties, and provide liability releases and finality to site cleanup: 1) the Voluntary Cleanup Program (VCP), 2) the brownfields initiative, and 3) state remediation sites. Without proper remediation, brownfields could remain a potential source of many pollutants, which might cause adverse effects on the environment and health problems among nearby residents.[197]

Characteristics of contaminated brownfield properties come from research using case study designs.[198] Many case studies describe some of the characteristics of the contaminated properties, which include the history of the property, location, the contamination, liability concerns, costs of remediation, and the incentives used to promote the remediation and redevelopment of the property.[198] Before a brownfield property can be redeveloped, contaminants found at levels that may pose health risks to community members are generally removed, treated, capped, or contained in ways that limit exposure risks appropriate to the planned reuse.[196]

Health threats associated with urban pollution are exacerbated for people living near contaminated parcels, such as brownfields, but there are various health consequences to urban residents exposed to contaminants found at brownfields.[199] These health complications include cardiovascular risk, low-level lead exposure, pulmonary risk, perinatal and infant mortality, low birth weight, and noise pollution.[200 – 203] The remediation of brownfields can address public health threats posed by hazardous and toxic contamination. These threats can be circulated through various exposure to and from drinking water, ingestion (soil issues), inhalation (air quality issues), dermal (absorption issues), breast milk (prenatal and postnatal issues), and human activity (produce use and residential issues)[202, 204]. The cleanup and redevelopment of brownfields are issues that will affect the poor, working-class individuals, and communities of color.[205] The prospects of cleanup and redevelopment may have economic benefits.[201, 199] However, expedited cleanup and redevelopment may come at the community's expense – environmental, social, economic, and public health harm – given the environmental unknowns of brownfields and the sensitive populations living in affected areas.[201]

Litt categorized brownfields into three zones, based on hazard potential, and examined population health within each zone in Southwest Baltimore. They found that communities living in the most hazardous brownfields zone, when compared with communities living in the least hazardous brownfields zones, experienced statistically higher mortality rates due to cancer (27% excess), lung cancer (33% excess), respiratory disease (39% excess), and the major causes (index of liver, diabetes, stroke, COPD, heart diseases, cancer, injury, and influenza and pneumonia; 20% excess)[201]. Another study evaluated the health risk of soil heavy metals in housing units built on brownfields in a city in China and found that compared with the original brownfields, soil heavy metals contents and their health risks in housing units have significantly decreased.[197] They found no non-carcinogenic risks and slight carcinogenic risks for the residents in these housing units.[197] Despite their dormant status, brownfields properties may pose potential chemical and physical risks to nearby residential communities.[201]

Few studies have examined racial and socioeconomic disparities at brownfield sites.[205, 206 – 207] For example, McCarthy found that brownfield sites in Milwaukee, Wisconsin are generally concentrated in census tracts with higher percentages of African-American, Hispanic, and low-income populations, than compared to the city average.[206] Another study assessed racial and socioeconomic disparities at brownfield locations in the Detroit region and found that brownfields are disproportionately located in poor neighborhoods and communities of color.[207]

Superfund Sites

In 1980, Congress established the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA), or Superfund, to clean up contaminated sites.[208] The National Priority List (NPL) is the list of sites of national priority, with known or threatened releases of hazardous substances, pollutants, or contaminants throughout the United States and its territories.[209] There are two Superfund sites in

Baltimore City, Chemical Metals Industries, Inc. (CMI) and Kane and Lombard Street Drums. Kane. Lombard Street is on the National Priority List (NPL), while CMI is a deleted site.

CMI operated a chemical manufacturing facility and recovered precious metals.[210] The site has a history of having elevated levels of lead and volatile organic compounds (VOCs) in shallow soil, significant levels of VOCs and metals in groundwater samples, and identified VOCs in the air from locations on or adjacent to the site.[211] Kane & Lombard Street Drums is a former landfill.[212] The groundwater beneath the site, and in the vicinity, is contaminated with VOCs, due to past waste disposal.[212]

There are health concerns regarding residential proximity to Superfund sites. The primary ways Superfund sites can affect local residents are through direct contact with the site, migration of toxic dirt or fumes through the air, or invasion of the water supply for houses that rely on well water.[213] A study measured determinants of cord serum polychlorinated biphenyl (PCB) levels among infants born between a 5 year span to mothers living near a PCB-contaminated Superfund site.[214] They considered residential proximity an important risk factor to PCB exposure, as it may capture both inhalation and dermal exposure, and considered socioeconomic or lifestyle-related exposure risks, such as smoking and diet.[214] They found no evidence that living closer to a Superfund site was associated with increased cord serum PCB levels.[214] However, children born before or during dredging, an excavation activity usually carried out under shallow water with the purpose of gathering bottom sediments up, had consistently higher cord serum PCB levels than children born after dredging, suggesting a possible effect of PCB-contaminated site and dredging with PCB cord blood-levels.[214]

Several studies have examined health problems associated with proximity exposure to Superfund sites. A study found statistically significant excesses of deaths from hypertensive disease, ischemic heart disease, and stroke for residents among certain populations near a heavy metal Superfund site.[215] A study in Houston, Texas found that residents living near two Superfund sites had a higher prevalence of neurologic symptoms than residents of a nearby community with limited exposure.[216] Kilburn found that exposed subjects were significantly impaired for body balance and visual reaction time tests when compared to residents who resided 35k outside the modeled plume of contamination.[217] In Ottawa County, Oklahoma, Neuberger found excess mortality for stroke and heart disease, when the exposed County was compared to the state, but not when compared to exposed cities to the non-exposed rest of the County[218]. Budnick found a significant increase in the number of bladder cancer deaths among White males and a significant increase in the number of other cancer deaths for the general population in three surrounding counties.[219] Finally, a study found that infants living close to a Superfund site before its cleanup, were more likely to have a congenital anomaly.[213]

Environmental justice concerns are also noted with the distribution of Superfund sites.[220 – 223] Superfund sites are mostly found in non-White and low-income populations.[223] One study found that a one percent increase in non-White populations was associated with a 0.2% decrease in the probability of a Superfund listing.[223] Another study examined whether the presence of a Superfund site affects the surrounding communities in Illinois. They found that race, rather than class, was a major indicator of environmental inequality. Results found that percent non-White was significantly higher than the percent of White populations within a one-mile radius surrounding Superfund sites.[222] Burwell-Nancy assessed the distribution of Superfund sites in South Carolina and found burden disparities in non-White and low-income populations at the block and census tract levels.[221]

Toxic Release Inventory (TRI) Facilities

In 1986, Congress passed EPCRA, section 313 of which created the Toxics Release Inventory (TRI)[224]. TRI tracks the management of certain toxic chemicals that may pose a threat to human health and the environment.[224] US facilities in different industry sectors must report annually the volume of toxic chemicals released to the environment and/or managed through recycling, energy recovery and treatment.[224] For reporting criteria, the facility must have 10 full-time equivalent employees, is in a TRI-covered industry sector, and meets chemical thresholds for one or more TRI chemicals during the calendar year.[224] In general, facilities that report are typically larger and involved in manufacturing, metal mining, electric power generation, chemical manufacturing and hazardous waste treatment.[224] Approximately 320 chemicals are covered by the TRI program and are typically those that cause cancer or other chronic human health effects, significant adverse acute human health effects, and significant adverse environmental effects.[224] Not all industry sectors are covered by the TRI program and not all facilities in covered sectors are required to report to TRI[224].

The number of facilities reporting to TRI in Baltimore has been in decline since the 1980, from 82 in 1987 to 42 in 2010[225]. This may be explained, in part, by the deindustrialization of Baltimore's economy and the shift of suburban locations as centers of employment and industry.[225] From 1987 to 1995, the City of Baltimore has 25 TRI facilities reporting chemical atmospheric releases for metal and metal compounds, totaling an estimated 197 ton of pollutant stack emissions.[177] In 2016, the City had a total of 19 TRI facilities, a decline of 6 reporting facilities.[226]

Previous research on TRI facilities and population health outcomes is limited but includes findings suggesting that such sites pose health risks.[227] Agarwal found significant associations between TRI air releases and infant mortality rates.[228] Suarez found that mothers in Texas living near TRI sites with chemical air releases had an increased risk for children born with neural tube defects.[229] Boeglin reported a significant association between TRI reported VOC releases and the incidence of some types of cancers in an Indiana sample.[230] A study in Utah also found 93 census tracts to have an excess relative risk of bladder cancer and 81 tracts with a lower relative risk, sustained over 32 years. These high relative risk areas for bladder cancer were associated with the presence of TRI sites.[231] Another study saw an increased risk for mothers living within 1 mile of a TRI site and living within 1 mile of a facility releasing carcinogens for having children diagnosed with brain cancer before 5 years of age, compared to living more than a mile from a facility.[214] However, like many previous studies of hazardous waste sites, we do not have a direct measure of exposure or the toxins that individuals were exposed to. Hence, estimates cannot be used to identify the precise pathways or toxins through which proximity harms health.[213]

In addition to TRI-specific studies, other research on chemical exposures reveals that human health is vulnerable to the types of chemicals and methods of release from TRI facilities.[227] We know that TRI releases include arsenic, cadmium, hexavalent chromium, nickel, formaldehyde, and others and these chemicals may be linked to cardiovascular and respiratory disease and cancer.[202, 232]

There are also equity issues related to the proximity of households and TRI facilities. A study in Oregon found that more than 20% of the TRI facilities (51 sites) showed a statistically significant greater percentage of Blacks living within the county in which the facilities were located, and Blacks were more than twice as likely as Whites to live within 1 mile of a TRI facility.[232] Fricker studied the distribution of TRI facilities in New York City and found that the relationship between race/ethnicity and proximity to sites vary greatly by borough.[233] They found that the Hispanic population is significantly associated with environmentally undesirable sites, so that an increase in the percentage of Hispanics in a census tract is associated with an increase in the expected number of sites in Brooklyn, Bronx and Queens boroughs. They also found a positive association between percent African-American and the number of sites in the Bronx and Queens boroughs. A study in Ohio found that census tracts which contain no TRI facilities in or adjacent to the tract had a higher median household income than tract that contain at least one TRI[235]. A study in Atlanta found that there were 4.7% more residents of color in census tracts where TRI facilities were located.[234] Finally, another study found census tracts with higher proportions of non-White residents and people living in poverty were more likely to be closer to TRI facilities.[58]

Traffic-Related Health Exposures

Traffic activity, wind speed, and direction can have a big influence on pollutant concentrations.[236] Generally, the more traffic, the higher the emissions; however, certain activities like congestion, stop-and-go movement or high-speed operations can increase emission of certain pollutants.[236] With more than 45 million people in the US living within 300 feet of a major transportation facility or infrastructure, there is concern about the potential health impacts from air pollutants emitted from cars.[236] Some people are known to be at greater risk of experiencing adverse health effects from air pollution, including those with asthma and other respiratory diseases.[238] Children, older adults, people with preexisting cardiopulmonary disease, and people of low socioeconomic status (SES) are also among those at higher risk for health impacts from some air pollutants associated with traffic emissions.[239]

The Environmental Integrity Project (EIP) found that on-road vehicles are likely the largest contributor to the air pollution people breathe in Baltimore.[237] This is because there is significant traffic congestion in the area and because vehicle tailpipes do not disperse pollution as widely as taller smokestacks.[237] The center of the city, which is exposed to pollution from the I-83 highway in addition to traffic congestion on non-highway roads, is the most exposed to relatively high pollution levels, with additional areas of high pollution in Northwest Baltimore, East Baltimore, and Southwest Baltimore.[237]

Emissions from road transport such as noise, particles and gases have been associated with issues of environmental justice in urban areas.[240] Previous research suggests that non-White and lower income individuals may be exposed to higher levels of traffic-related air pollution and that disparities vary with social gradients associated with higher susceptibility to pollution.[241 – 245] For example, Houston found racial/ethnic disparities in traffic and vehicle PM exposure in a major goods movement corridor, after controlling for factors associated with traffic generation. A higher percentage of nearby Black residents were associated with higher exposures for all exposures measured, a higher percentage of nearby Asian/Pacific Islander residents was associated with higher vehicle miles traveled and vehicle PM exposure, and a higher percentage of nearby Hispanics was associated with higher vehicle PM exposure.[243] Another study in New Zealand found that mean exposure to pollution is highest in the areas with the lowest-income and have greater proportions of non-European residents.[246]

Residential proximity is also a potential proxy for exposure to traffic-related pollution.[247] Several studies have found that living near highly trafficked roads is related to an increased risk of adverse health outcomes.[248 – 257] Both short and long-term traffic-related air pollution exposure has been associated with adverse health effects, particularly for vulnerable populations such as pregnant women and children.[258 – 259] Children are more vulnerable to the effects of air pollution because they breathe more air per unit of body weight than adults[260] and spend more time outdoors.[491] Residential proximity to busy roads has been associated with respiratory symptoms,[261 – 263] asthma hospitalizations[264] and decreased lung function in children.[265] A study in San Diego, California found increased risks for medical visits for asthmatic children associated with residences near at least one busy street.[266] English reported that the odds of residing in high traffic-flow areas were significantly higher for children experiencing more than 1 asthma hospitalization per year than for children having only 1 incident.[266] Some studies have found associations between proximity to traffic and childhood cancer.[267]

There is also compelling evidence in the US and other countries for an association between air pollution exposure during pregnancy and several health outcomes in the offspring, including low birth weight and small for gestational age.[268 – 272] Pregnancy may constitute a period of special vulnerability to environmental toxicants because it is a time of great change and growth.[278] Since development, cell proliferation and changing capability of fetal metabolism have a specific sequence, the timing of exposure to ambient toxicants could play a key role, even more important than the magnitude of dose.[279] Additional studies found an increased risk for low birth weight and preterm births for mothers who resided near highways[247] and in areas with high traffic density.[268, 273]

Numerous studies have also looked at environmental inequality, exposure to air pollution and adverse birth outcomes.[280 – 282] For example, a study evaluated the effects on birth outcomes of prenatal exposure to airborne PAHs monitored during pregnancy by personal air sampling, along with biomarker analysis for environmental tobacco smoke exposure. Among African Americans, they found high exposure to PAHs was associated with lower birth weights and smaller head circumference.[282] Another study assessed whether mothers with lower educational attainment and mothers in various race/ethnic groups were more likely to live in areas with higher aggregate levels of air pollution.[281] They found that Hispanic, African-American, and Asian mothers experienced higher mean levels of air pollution and were more than twice as likely to live in the most polluted counties in the US, whereas educational attainment was not associated with living in counties with higher pollution.[281]

Metals and Human Health Risks

Many species of plants have been successful in absorbing contaminants such as lead, cadmium, chromium, and arsenic from soils.[283] Plants absorb elements from soils based upon element properties, soil properties (i.e., pH, element level in soil, organic matter, cation exchange, capacity, and level of other elements in the soil) and plant properties (i.e., plant age, species, type of crop, edible portion)[284 – 287]. Some elements are easily absorbed and translocated to food chain plant tissues, while others are not.[288]

The consumption of metal contaminated vegetables is one of the most important pathways for metal exposure to humans.[289] However, there has not been much research on community garden produce and personal levels of exposure to heavy metals, even though evidence suggests that produce grown in contaminated environments may contain some of the harmful toxicants from the soil.[290 – 291] The toxicity of heavy metals is recognized as major human health risks and researchers have developed toxicological reference values to help characterize the risk of ingestion exposure. Many studies use the target hazard quotient (THQ), developed by the US EPA, to evaluate potential non-cancer health risks associated with long-term exposure to chemical pollutants in foodstuffs.[292] However, not all researchers use this reference value and it is important to recognize these differences when comparing risk estimates between studies.[293]

Lead is a naturally occurring toxic metal found in the Earth's crust. Its widespread use has resulted in extensive environmental contamination, human exposure and significant public health problems globally.[294] Because of widespread use of leaded paint before the mid-1970s and leaded gasoline before the mid-1980s, as well as contamination from industrial sources, urban soils often have lead concentrations much greater than normal background levels.[295] Soils adjacent to heavy traffic volume areas in cities and busy roadways also have high concentrations of lead.[295] Soil lead can transfer to humans through soil ingestion, consumption of Pb-contaminated foods, and inhalation of Pb-containing soil particles.[291] The most significant pathway is soil ingestion.[291] Lead is a cumulative toxicant that affects multiple organ systems and is particularly harmful to children.[294] Lead in the body is distributed to the brain, liver, kidney and bones. It is stored in the teeth and bones, where it accumulates over time. Lead in bone is released into blood during pregnancy and becomes a source of exposure to the developing fetus.[294]

Few US studies have examined the health impacts of urban vegetables consumption grown in soil contaminated with lead. Most indicate a variability in soil lead and lead concentrations in vegetables.[64, 197, 296 – 297] Studies have shown that most of the absorbed lead (Pb) remains in roots,[298] yet it is still unknown how this element goes into the root tissue and a critical point of exposure to lead is via food.[299] One study assessed the associated potential health risks for adults and children through consumption of home-grown vegetables and ingestion of soil particles living near a former lead smelter.[300] For adults, THQ for Pb via consumption and soil ingestion was less than 1.0, suggesting that both pathways were not a risk. For children, the THQ was greater than 1.0 for soil particle ingestion, indicating this pathway could be a health risk for children.[300] Another study found blood lead concentrations were related to the consumption of home grown produce. Residents with the highest consumptions had blood lead concentrations that were 28% higher than those who consumed no locally grown vegetables.[66] The study did not evaluate health effects of exposure. Cherfi evaluated the levels and potential health risks of various heavy metals in fruits and vegetables consumed. For all foodstuffs, the estimated daily intake and the target hazard quotient were below the threshold values, except for Pb, indicating a health risk over a lifetime of exposure.[301] Antoine assessed the potential health risks associated with heavy metals, including lead, in selected fruits and vegetables. They found each food type had a THQ below 1.0, indicating no undue non-carcinogenic risk from exposure to a single or multiple combination of metals tested.[296] Another study in Vietnam assessed heavy metal concentration in soil, irrigation water, and vegetables near mining activities and found that the average THQ across all vegetable specie samples was higher than the safety threshold of 1.0, which indicates a health risk.[292]

At high levels of digestive exposure, lead attacks the brain and central nervous system to cause coma, convulsions and even death.[294] High blood lead levels greater than 15µg/dl are associated with cardiovascular effects, nerve disorders, decreased kidney function, and fertility problems, including delayed conception and lower sperm counts and motility.[302] Blood lead levels below 10µg/dl are associated with decreased kidney function and increases in blood pressure, hypertension, and incidence of essential tremor.[302] Frank anemia may occur at 80µg/dl, while reduced hemoglobin production may occur at lower blood-lead levels (above 50µg/dl lead in blood in adults and 40µg/dl in children.[303] Neurotoxicity and chronic kidney toxicity are the main concerns for adults with excess exposure to lead.[304] Lead associated deficits have been documented in verbal intelligence quotient (IQ), performance IQ, academic skills, such as reading and mathematics, visual/spatial skills, and problem-solving skills. Meta-analysis has indicated that children's IQ scores decline 2 – 3 points per 10µg/dl increase in blood lead level and identified no threshold for the effects of lead on IQ.[160]

Children are more adversely affected because of their very high (~50%) intestinal absorption rates of ingested Pb compared with adults (5-10%).[303] There is no identified threshold or "safe" blood lead level below which no risk of poor development or intellectual function is expected.[302] Lead inhibits the bodies of growing children from absorbing iron, zinc, and calcium, minerals essential to proper brain and nerve development.[302] Adverse health effects occur in children at blood lead levels <5µg/dl, the most common include attention-related behavioral problems, decreased cognitive performance, and greater incidence of problem behaviors.[305] Researchers studied 162 middle class children from Denmark and found significant associations between lead and IQ scores and a significant increase in the risk for learning disabilities.[306] More recent studies looked at larger samples and children of higher socioeconomic status. A study investigated 579 New Zealand children at age 11 with a mean blood level of 11.1µg/dl.[307] Significant associations were found between log blood lead and children's reading, spelling, and behavior.[308]

Arsenic is released into the environment from both natural and anthropogenic sources.[309] The accumulation and resistance of arsenic varies between plant species due to genetic differences, diversity in detoxification processes and the amount of external As.[309] The primary routes of arsenic exposure are via ingestion and inhalation.[492] Also, lumber used to construct raised garden beds is often treated with chromated copper arsenate (CCA) and can diffuse into soil and be a source of arsenic exposure.[310] A study found that the closer soil was to CCA-treated lumber, the greater amount of arsenic availability was found in the soil.[310]

Arsenic is highly toxic in its inorganic form.[115] The International Agency for Research on Cancer (IARC) has classified arsenic and arsenic compounds as carcinogenic to humans.[115] Understanding the spatial distribution, uptake and health risks associated with arsenic exposure and consumption of vegetables is crucial to protect human health.[290] A study was done to assess arsenic exposure dose and risk via ingestion of home garden vegetables.[290] They found that vegetables grown in soils neighboring mine waste, on average accumulated more arsenic than store bought vegetables and several produce items were reported to have concentrations of arsenic greater than what was found in the US FDA Market Basket Study.[290] Outside of the US, studies of daily arsenic intake due to the consumption of homegrown vegetables for residents living near contaminated sites show variable results.[293] This is expected given both the differences in methodology for assessing metal exposure and the types of vegetables studied.[293] An assessment was performed on health risks associated with arsenic exposure via consumption of homegrown vegetables near contaminated glasswork sites. Researchers found the reasonable maximum exposure corresponded to a cancer incidence 20 times higher than the Swedish tolerance limit of 0.006 µg/kg/day in soil and in crops.[293] In Pakistan, researchers found that arsenic concentrations exceeded the safe maximum allowable limit set by WHO/FAO in 75% of vegetables sampled in selected districts, however, results indicated a low cancer risk from ingestion of edible portions of tested vegetables.[311] An additional study in Iran calculated a hazard quotient greater than 1.0 for adults and children of crops grown in contaminated rural areas, signifying that exposed adults and children are potentially at risk of health effects, including cancer.[309]

Arsenic in drinking water has been documented worldwide.[312] Low to moderate levels of arsenic exposure through drinking water has adverse effects such as skin lesions, circulatory disorders, neurological complications, diabetes, respiratory complications, hepatic and renal dysfunction including mortality due to chronic disease.[313] Depending on the type of arsenic exposure (i.e. acute or chronic) development of clinical symptoms varies.[314] However, symptoms of acute exposure develop much quicker, whereas clinical symptoms of chronic exposure develop over a prolonged period of exposure.[314] Various health effects including dermatological, cardiovascular, pulmonary disorders, reproductive effects, and neurological effects have been reported in adults and children due to arsenic exposure specifically via drinking water.[315 – 320] Acute exposure to arsenic can lead to nausea, diarrhea, encephalopathy, and neuropathy.[290] Chronic low-level exposure has been linked to diabetes, hypopigmentation/hyperkeratosis, and a probable role in promoting cancer of the bladder, lung, skin, and prostate.[321 – 322] Skin abnormalities are a key characteristic of chronic exposure in adults.[311] However, skin lesions usually develop 5 – 10 years after the exposure.[323]

Cadmium (Cd) is a naturally occurring metal. Human exposure pathways to cadmium may be direct ingestion of water and accidentally soil, consumption of food grown in contaminated fields, inhalation of dust, and dermal contact of soil and water.[324] In the US, most Cd is extracted as a byproduct during zinc production.[325] There is a higher risk of exposure for those who are involved in smelting and electroplating processes.[325] For the average American, low levels of Cd exposure occur through diet,[325] however, another significant source of Cd is smoking. With an estimated elimination half-life of 10 – 30 years and leaves the human body very slowly. Thus, once this metal gets absorbed by humans, it will accumulate inside the body throughout life.[327] The US Department of Health and Human Services (DHHS) and IARC have determined that cadmium and cadmium compounds are known human carcinogens.[327] The EPA has determined that cadmium is a probable human carcinogen.[327]

Similar studies have been performed on the health risks associated with cadmium exposure via consumption of vegetables. In Bangladesh, researchers found that cadmium exhibited relatively higher THQ compared to all other metals in the study area.[289] Thus, potential health risks from exposure is of some concern.[289] The health effects of dietary exposure to cadmium are kidney and bones disorders, prostate and breast cancer, disturbances of male fertility as well as disorders of pregnancy.[328] Smokers get exposed to significantly higher cadmium levels than non-smokers.[329] Severe damage to the lungs may occur through breathing high levels of cadmium.[325] Ingesting very high levels severely irritates the stomach, leading to vomit and diarrhea. Long-term exposure to lower levels leads to a buildup in the kidneys and possible kidney disease, lung damage, and fragile bones.[326] In the kidneys, cadmium accumulates and is the critical target organ.[330] This accumulation may lead to renal tubular dysfunction, which results in increased excretion of low molecular weight proteins in the urine. High intake of cadmium can lead to disturbances in calcium metabolism and the formation of kidney stones.[330] For those working and/or living in cadmium-contaminated areas, softening of the bones and osteoporosis may occur.[330] High inhalation exposure to cadmium oxide fume results in acute pneumonitis with pulmonary edema, which may be deadly.[330] Long-term, high-level occupational exposure is associated with lung changes, primarily characterized by chronic obstructive airway disease.[330]

Many studies have revealed the kidney was one of the primary sites of injury after Cd exposure.[331 – 333] Cohort studies showed that the carcinogenic effects of Cd appeared to occur at exposure levels below the levels associated with kidney effects. In addition, adverse effects on bones were found in patients owing to exposure to Cd.[334 – 336] It was also seen that Cd exposure was associated with diabetes, hypertension, and peripheral artery disease.[337] A high risk of diabetes incidence was found when comparing the highest versus the lowest Cd exposure categories. Cd has also been found to be significantly associated with hypertension and impaired kidney function.[324]

Chromium is a common heavy-metal contaminant in soil.[301] Usually, Cr occurs in two forms: Cr (III) and Cr (VI).[301] Cr III is biologically important to the human body in which it influences sugar and lipid metabolism.[338] Low levels of Cr (III) occur naturally in a variety of foods, such as fruits, vegetables, nuts, beverages, and meats.[339] Plants vary in their ability to accumulate chromium.[340] Uptake by Cr by plants depends on soil-based (e.g., total metal content, pH, organic matter) and plant (e.g., plant species).[341 – 342] Researchers reported that crops from the Brassicaceae family (cauliflower, kale, cabbage) can uptake more Cr than other plant species without presenting symptoms of toxicity to the plant.[299]

There have been cases of large-scale environmental pollution with Cr (VI).[343 – 344] Additionally, hundreds of Superfund sites contain Cr as a major contaminant.[345] Cr (VI) is highly toxic and has been determined to be a human carcinogen by inhalation by the IARC.[345] However, the general population is most likely to be exposed to trace levels of chromium VI in the food that is eaten.[346] The main health problems seen in animals following ingestion of chromium (VI) compounds are to the stomach and small intestine (irritation and ulcer) and the blood (anemia).[345]

Health risk assessments have found a potential for adverse health effects associated with consumption of vegetables contaminated with chromium from soil, with mixed results.[301, 347 – 349] Cherfi evaluated the levels of chromium, lead, zinc, and copper content in fruits and vegetables and found that among the metals, the Pb's THQ is largely the highest. The THQ of Cu, Zn, and Cr were less than 1.0 for the vegetables examined, indicating there is no risk for an adverse health effect when consuming these vegetables.[298] Qureshi examined the total health risk associated with the consumption of vegetables grown with treated wastewater and found the THQ values for Cr in all vegetables were far higher than the safe limit of 1.0, with lettuce taking a significant lead over other vegetables.[348] Additionally, Liao analyzed the transfer and potential health risks of chromium in soil to vegetables in areas near manufacturing plant in Hunan province, China and found the estimated total daily intake of chromium substantially exceeds the dietary allowable value, which may pose health risks to local populations.[349] It is important to note that some of these studies involved wastewater irrigation were the risk of chromium exposure could be more pronounced, and also local populations may rely more heavily on vegetables for consumption, placing them at a higher risk for exceeding daily intake of chromium.

It has long been established that inhalation of chromium in particular Cr (VI), can cause human lung cancer.[350] Yet, limited studies have been done to investigate Cr VI carcinogenicity via ingestion. Recently, researchers have investigated health risks associated with ingestion of chromium in drinking water.[351 – 353] A study by Zhang and Li reported increased mortality from stomach cancers among rural residents in the Liaoning Province of China where drinking water was heavily contaminated with Cr (VI).[354] One recent analysis of this study confirmed the originally reported association between Cr (VI) contamination and cancer mortality,[351] while another study using a smaller control population did not.[355] A meta-analysis of studies among chromate workers did not find a link between inhalation exposures to Cr (VI) and cancers outside the respiratory system.[356] Also, it is important to consider the limitations of ecological studies for their inability to control for confounders. This is especially important for the analysis for stomach tumors in China because of its well-known high incidence of stomach cancer.[357]

Mercury is a naturally occurring element that is found in air, water and soil.[358] Mercury is released into the environment from volcanic activity, weathering of rocks and as a result of human activity.[358] It exists in various forms: elemental (or metallic), inorganic, and organic.[359] Methylmercury, which is known to be the most poisonous among the mercury compounds, is created when inorganic mercury circulating in the general environment is dissolved into freshwater and seawater.[360] The consumption of MeHg contaminated food and soil are the main channel for human exposure to MeHg[362]. Seafood consumption, especially the consumption of fish, is the main source of humans' exposure to MeHg.[359] Plants can absorb mercury that is deposited on leaf surfaces.[361 – 363] Plants can also uptake mercury from water and soil via roots.[364] The majority of mercury accumulated locally in the plant with little mobility.[365] Most uptake tends to accumulate moderate amounts in the shoots,[366] either due to translocation or direct absorption of the vapor form[359]. Furthermore, it is difficult to excrete MeHg, therefore MeHg can bioaccumulate in the human body.[168]

Studies outside the US have assessed mercury concentrations in vegetables cultivated near various sources of mercury pollution, including near zinc plants,[367] fluorescent lamp factories,[368] industrial zones,[369] oil zones,[370] and coal-fired plants.[371] Wu discussed potential health risks associated with vegetable consumption near a coal-fired plant and found leafy vegetables contained the highest mercury concentration.[362] They also noted that local residents who largely rely on locally produced vegetables and rice may have potential health risks associated with consumption because their totally weekly mercury intake is several-fold high than the provisional tolerable weekly intake (PTWI)[371]. Additionally, Zheng investigated the health risk of Hg to the inhabitants around a zinc plant via consumption of vegetables and found a THQ for Hg over 1.0, indicating that there are health risks to inhabitants who live close to the Zinc plant and consume vegetables grown nearby.[367]

The central nervous system is most severely affected by MeHg exposure, which causes various symptoms such as ataxia, dysarthria, auditory disturbances and tremors.[372] Recently, researchers have found that MeHg exposure may cause cardiovascular disease and damage the reproductive system and immune system.[373 – 374] Studies have also linked MeHg exposure and deficit in visual and cognitive functions.[375] Neurotoxicity of MeHg is of major concern for fetal and postnatal brain development. Pregnant women and children are particularly sensitive to the harmful effects of mercury on the nervous system before they are born, and in the early months after birth.[376] Fetuses are a high-risk group because the developing brain is particularly susceptible to the harmful effects of MeHG exposure.[377] The effects on mercury exposure may be subtle or more pronounced, depending on the dose and frequency of exposure.[376] In cases in which the exposure was relatively small, some effects might not be apparent, such as small decreases in IQ or effects on the brain that may only be determined through very sensitive neuropsychological testing.[376] In instances in which the exposure is great, the effects may be more serious, such as intellectual and developmental disabilities, incoordination and inability to move.[376]

CHAPTER 3: STUDY 1

INTRODUCTION

The relationship between poverty and food security is well-documented. Lack of discretionary income affects food choices and ultimately nutritional status.[375] Obesity, cardiovascular disease, and diabetes disproportionately affect low-income urban communities.[375] In New York City, researchers found higher rates of obesity in low-income and people of color neighborhoods than in more affluent and predominantly white neighborhoods. The prevalence of obesity in one of New York City's wealthiest neighborhoods, was 9% in 2006, while prevalence ranged from 21% to 30% among adults living in some of the City's lowest income neighborhoods.[45] In Baltimore, 43% or predominantly black neighborhoods and 46% of lower-income neighborhoods were in the lowest tertial of healthy food availability versus 4% and 13%, respectively, in predominantly White and higher-income neighborhoods.[29] These poor and people of color communities are often characterized by limited access to healthy food and high access to unhealthy food and have thus been labeled "food deserts"[376].

The USDA defines food deserts as 'parts of the country vapid of fresh fruit, vegetables, and other healthful whole foods, usually found in impoverished areas'.[120] According to Feeding America, about 23% of Baltimoreans, including more than 30,000 children, experience food insecurity – that is they lack access, at times, to enough food for an active, healthy life for all household members, and limited or uncertain availability of nutritionally adequate foods[46]. A food swamp is a place where unhealthy foods are more readily available than healthy foods.[377] Food swamps typically exist in food deserts, where there are limited options for purchasing healthy foods.[377] Food deserts offer residents few, if any, high-quality, full-service supermarkets or grocery stores, but many corner stores and fast food restaurants. Communities with no or distant grocery stores, or with an imbalance of healthy food options, will likely have higher rates of premature death and chronic health conditions, such as cancer, cardiovascular disease, diabetes, obesity, and hypertension.[16, 92, 265, 378] Consumption of inexpensive and readily available fast food results in a risk of heart disease that is 50% higher for poor African-Americans compared to more affluent African-Americans.[376] However, urban communities have been embracing urban agriculture as an alternative method to access healthy food.[379]

Urban agriculture practices have been defined as the "growing, processing, and distribution of food and non-food plant and tree crops in farmlands that are mainly located on the fringe of an urban area".[380] Institutional efforts to accommodate and promote urban agriculture within U.S. cities are gaining momentum.[379] Land inventories are being employed by municipal governments to support urban agriculture projects[381 – 382] and several cities have revised policies and zoning ordinances to accommodate the changing land-use.[383] Non-profits and municipal governments in cities are creating food policy councils, many of which include elements to strengthen urban agriculture.[384 – 385] The American Planning Association reports that urban agriculture continues to grow as a planning priority, with several cities and counties including local food elements and UA in their comprehensive plans.[386]

Urban agriculture can serve to provide alternative food options for communities living in food deserts and/or food swamps. There are many benefits of urban agriculture, including sociocultural,[387 – 392] environmental sustainability,[393] public health and food security implications,[49, 52] and economic developmental outcomes.[136] Growing evidence suggests that incorporating urban agriculture into the urban environment will greatly improve the sustainability of cities.[380] It can increase biodiversity and green space, attracting native plants, pollinators, and a variety of small animals.[115] They also facilitate drainage of water and reduce the urban heat island effect.[115] Urban farms provide public health benefits by providing greater access to fresh, organic produce,[69, 394] a space for recreation,[52, 395] and mental health and therapeutic benefits.[49, 137 – 138, 395]

Despite growing interest in urban gardens, concern about the presence of real or perceived contamination persists.[170, 173, 179, 287, 396] Urban environments are variably contaminated with metals and persistent organic pollutants due to human activities including transportation, construction, manufacturing, fossil fuel combustion, and incinerator emissions.[59, 397 – 398] Urban garden soils can be contaminated with lead (Pb), cadmium (Cd), and mercury (Hg)[59, 178]. Urban soils are notorious sinks for heavy metal contaminants due to industrial and historic traffic emissions, waste incineration, and use of lead-based paint for residential and industrial purposes.[399] For example, in Charleston, South Carolina, researchers found a high concentration of trace metals in areas near heavily trafficked roadways, an incinerator, Superfund sites, and metal recyclers.[221]

The limitations of urban agriculture include health risks to growers and consumers from soil contaminants if adequate preventive measures to reduce exposures are not taken.[115] Previous studies have shown that food crops grown on contaminated urban soils contain higher concentrations of trace metals than those grown on uncontaminated soil,[59, 400 – 401] and therefore dietary intake of certain contaminants in food consumed by urban communities may exceed acceptable limits.[402 – 406] There is concern that food safety, human nutrition and the social developmental benefits of urban agriculture may be undermined by accompanying health hazards arising from contamination from industrial and municipal sources.[160, 174, 407]

The city of Baltimore is an urban area with a history of contamination due to legacy pollution from industrial hazards and prior uses of lead. Most of the housing stock was built prior to 1950 when lead-based paint was used ubiquitously.[408] Between 1950 and 2016, the city's population fell from 949,708 to 614,664[409]. The depopulation of Baltimore has resulted in approximately 16,000 vacant buildings and 14,000 vacant lots in Baltimore,[410] resulting in proxy exposure to lead-based paint.

Roads in urban areas can be sources of several soil contaminants, including metals, such as Pb, Zn, Cu, V and Mo from vehicle exhausts, tire particles, corrosion of vehicle body work and road markings, and brake and clutch dust.[59] Research has shown that the city center is most exposed to traffic pollution due to pollution from I-83 highway and nearby neighborhoods with condensed traffic activity.[237] In addition, there are legacy pollution sites such as Toxic Release Inventory (TRI) facilities, land restoration sites (LRPs), and Superfund sites that can contribute to environmental contamination in the presence of urban agriculture.

Due to the presence of TRI facilities, Superfund sites, LRPs, and traffic, neighborhoods that host urban farms may have soil contamination. For instance, heavy metal contamination of soil and urban-grown produce may pose exposure and health risks for populations who reside near these locations or consume the produce. Most metals do not undergo microbial or chemical degradation and their total concentration in soils persists for a long time after their introduction.[175] Two key processes which allow human exposure to metal pollution through gardening are plant uptake where the plant is human food, and soil ingestion. Plant uptake includes both adsorption of air pollutants on plant surfaces, and uptake by the roots with translocation to edible plant tissues. Soil ingestion includes pica, the intentional ingestion of nonfood, inadvertent soil ingestion during hand-to-mouth play, and improperly washing produce.[178]

The aim of this study was to investigate the spatial distribution among LRPs, TRI facilities, Superfund sites, and traffic with urban farms alongside the sociodemographic composition in the City of Baltimore. We mapped all LRPs, Superfund sites, and TRI facilities to examine proximity of contamination and burden disparities near urban farms. Additionally, we evaluated whether or not the LRPs, Superfund sites, and TRI facilities had the presence of mercury, lead, arsenic, cadmium, and chromium contamination. If sites were determined to contain mercury, lead, arsenic, cadmium, or chromium, they were regarded as 'known heavy metals' sites.

METHODS

Regulated Sites with Unknown Environmental Contamination

We identified all active LRPs, as mentioned by the Maryland Department of the Environment (MDE), TRI facilities and Superfund sites for unknown environmental contamination. The purpose of this analysis was to identify all sites in Baltimore City that may have unknown contaminants and to understand their location in relation to urban farms. There were a total of 225 active LRP sites, 19 TRI facilities and 2 Superfund sites in Baltimore City. The maps in Figures 1 – 9 illustrate the total number of LRPs, TRI facilities and Superfund sites in Baltimore City.

Regulated Sites with Known Heavy Metals

To assess the distribution of brownfields known to have the presence of heavy metals in Baltimore City, we downloaded data from the MDE Brownfield Master Inventory (BMI) Report. The BMI report data is updated quarterly. The data used was from 1/2/2018. There was a total of 351 active brownfields in Baltimore City identified in the BMI report. We screened for sites that had explanatory factsheets which mentioned lead, mercury, arsenic, cadmium, or chromium to be a known pollutant investigated at the site. These factsheets are important because they identify site location, site history, environmental investigations, and current status. After completing the word search, we identified 35 brownfields in Baltimore City with factsheets that identified contamination of lead, mercury, arsenic, cadmium, or chromium.

We also mapped all LRPs, as identified by MDE. These sites included closed and archived sites. There were a total of 1711 LRP sites in Baltimore City. We first screened for sites indicating whether metals in the groundwater were a concern, which limited our search to 82. Next, we identified sites indicating whether metals in the groundwater were a concern and had a fact sheet available, leaving 80 sites. We then screened for sites indicated whether metals in the soil were a concern and found 187 sites. Of the 187 sites indicating metals in the soil are a concern, 31 did not have fact sheets and we limited our search to 121 sites. We next screened for sites that indicated whether metals in the sediment were a concern and found 12 sites, 2 sites not have factsheets and we limited our search to 10 sites. Of the 211 sites, 45 were duplicates, and we thus limited our search to 166 sites which indicated that metals were a concern in the groundwater, soil, or sediment. After completing a word search of 'lead, mercury, arsenic, cadmium, or chromium' in the factsheets, we identified 43 sites that had factsheets indicating that lead, mercury, arsenic, cadmium, or chromium metals were a concern. Because MDE considers land restoration sites brownfields, we joined the count of brownfields and land restoration sites and mapped them as a total count of LRP sites.

Finally, we downloaded 2016 data from EPA's TRI database, and filtered for facilities with category 1 metals in Baltimore City. Category 1 elemental metals include lead, mercury, arsenic, chromium, and cadmium. We excluded other metals in our analysis because more research has been done on the five metals in urban soil environments. We identified 14 TRI sites in Baltimore City that were known to release lead, mercury, arsenic, chromium, or cadmium to the air, water, and/or soil. The depiction of hazards with the presence of heavy metals may be seen in Figure 13 and table 1. Although screening for heavy metals provides information about what contaminants are present at certain sites, we have not conducted any exposure and/or risk assessments. Thus, this analysis discusses proximity to environmental hazards and heavy methods as a proxy of exposure.

Urban Farms

We identified urban farms as 'farms that grow food in and around urban areas'. They differ from community gardens, as the food is grown for sale, not personal consumption. These farms range in size and by type of products produced, and by farming practices' (CLF Food System Map). We identified 24 urban farms that met this definition and analyzed those urban farms for proximity to all regulated sites, regulated sites with known heavy metal contamination, and regulated sites with unknown heavy metal contamination.

Sociodemographic (SOD) Measures

Sociodemographic measures included in our study were: 1) percent African-American, 2) percent unemployment rate (percent of the population ages 16 years and over who are unemployed), 3) percent with less than a high school education (ages 18 - 24), 4) median household income, 5) estimate of owner-occupied housing units, and 6) percent receiving SNAP (Supplemental Nutrition Assistance Program). All variables were calculated using the 2016 American Community Survey (ACS) 5-year estimates. Percent African-American, median household income, and educational attainment were applied to the census tract level to build our maps.

RESULTS

Figure 1: Median Household Income and Urban Farms

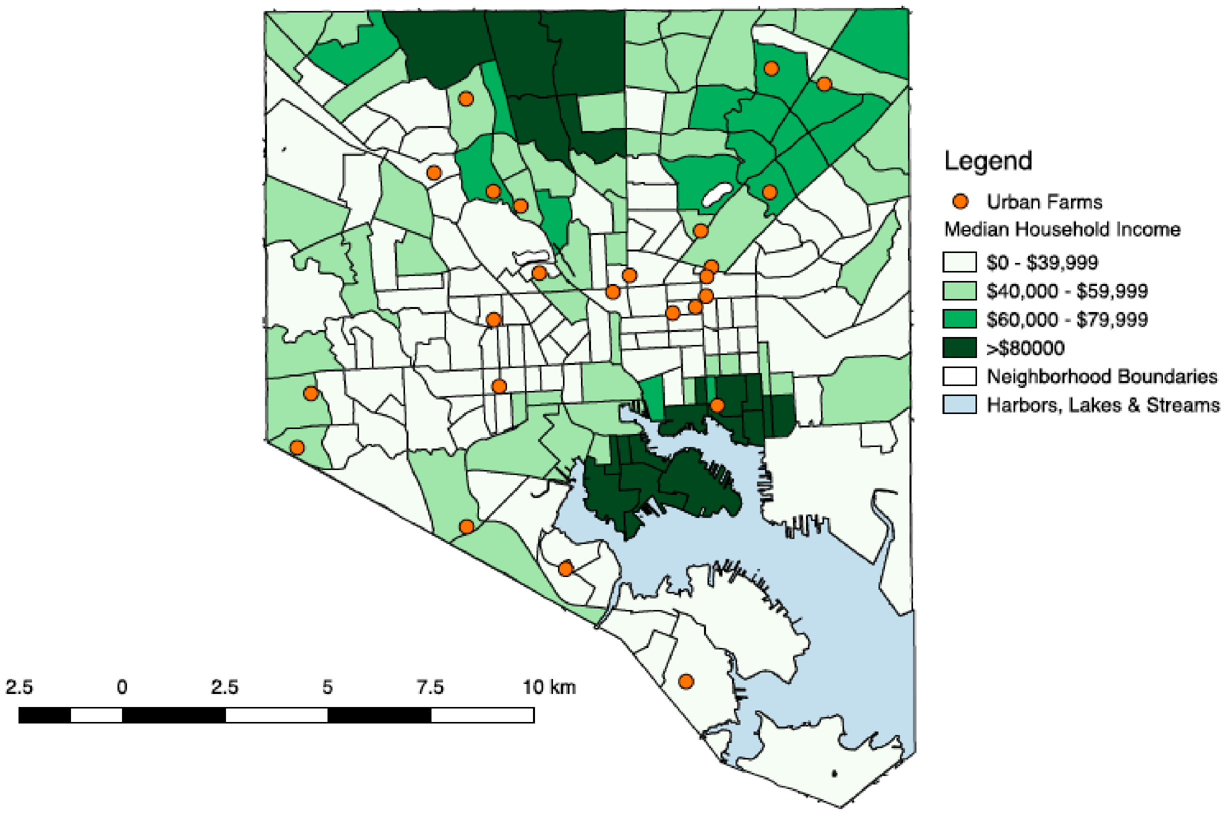


Figure 1 depicts median household income and the locations of urban farms in the City. Census tracts with the highest median income level were found in north-central and south-central areas of the city. Only one farm was located on a tract with an income of over $80,000. Four farms were in tracts with an income of $60,000 - $80,000. Most farms were located within $0 - $60,000 tracts.

Figure 2: Median Household Income, Urban Farms, and Environmental Hazards

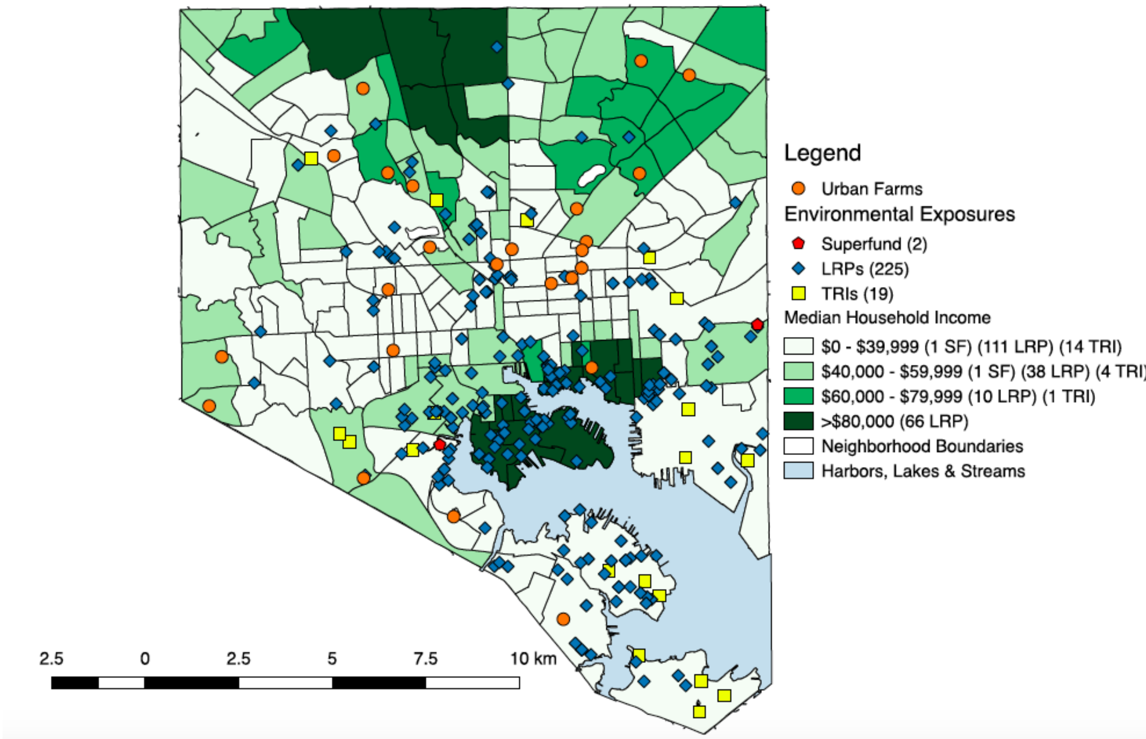


Figure 2 identifies median household income, urban farm locations, and environmental hazards. There were two major clusters of environmental hazards, one was in the center of the inner harbor and the other was the southern perimeter of the inner harbor. Overall, most Superfund sites, TRI facilities, and LRPs were located around the perimeter of the inner harbor and the historical industrial zones south of the city. The center inner harbor was also a region of higher median household income. Most of the TRI facilities and LRPs were found in tracts within a $0 - $39,999 median household income, while the income group of $40,000 - $59,999 had the fewest number of hazards. On the west and east ends of the city, median household income was within $0 - $39,999 and there was a greater dispersion of hazards. Finally, on the southwest area of the inner harbor, there was a cluster of LRPs and TRI facilities, located in a low-income tract, with few urban farms.

Figure 3: Median Household Income, Urban Farms, Environmental Hazards and Healthy Food Priority Areas

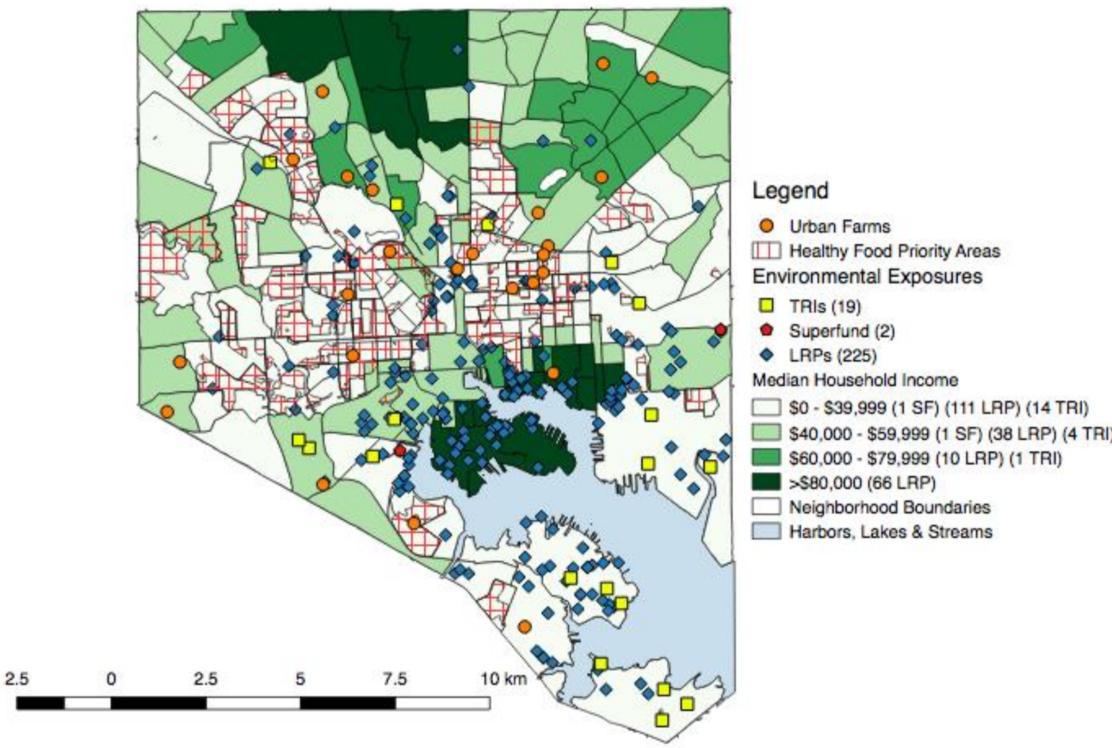


Figure 3 shows median household income, urban farm locations, environmental hazards, and healthy food priority areas. This figure shows that 9 urban farms were located within healthy food priority areas. Healthy food priority areas were located in census tracts with a median household income between $0 - $39,999 and a number of environmental hazards.

Figure 4: Percent African-American and Urban Farms

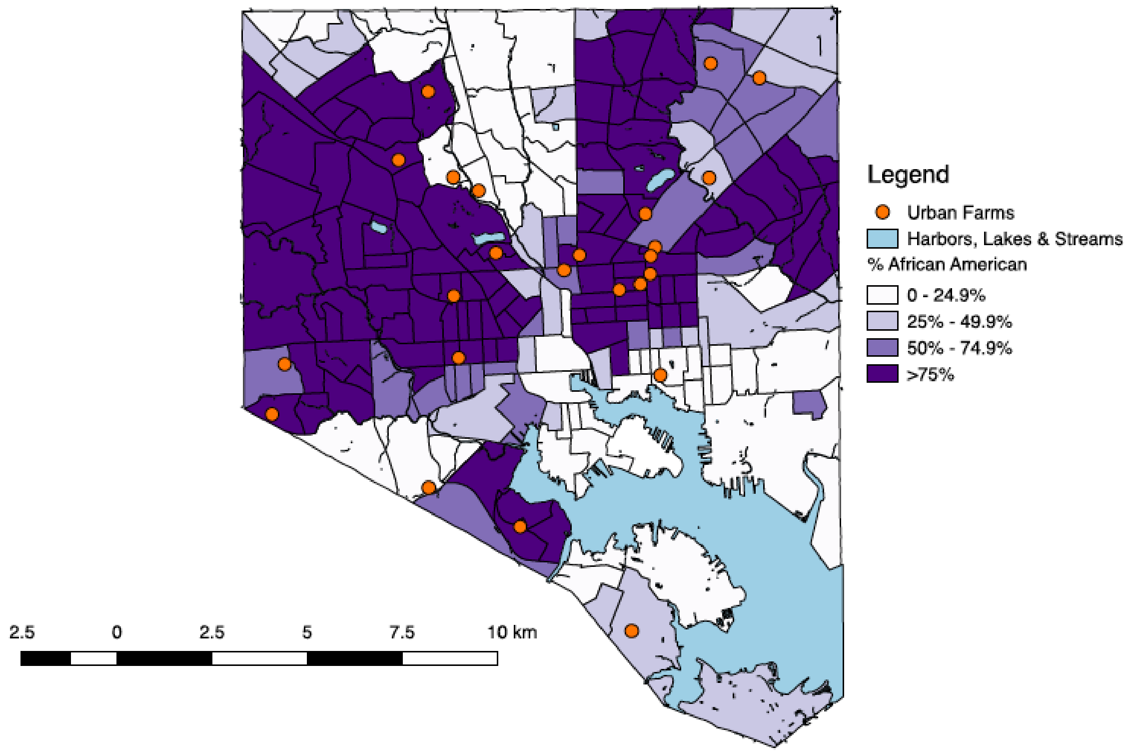
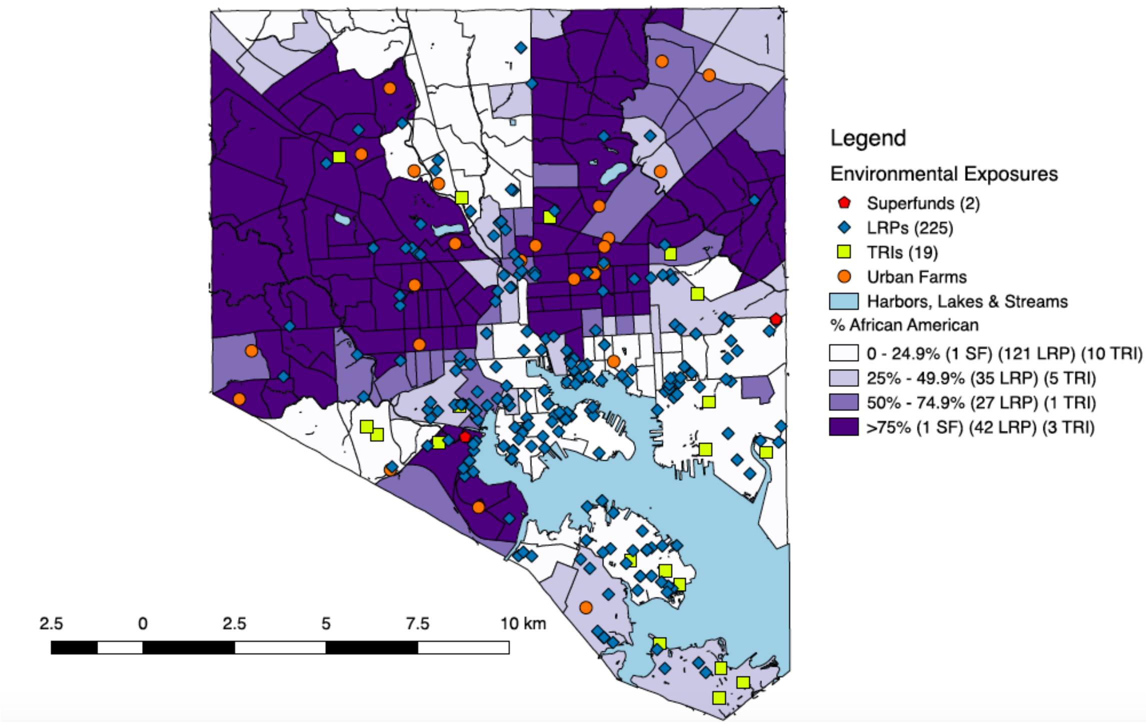


Figure 4 depicts percent African-American and urban farm locations. Most farms were located in tracts that were over 75% African-American. Three farms were located in tracts with 50 - 75% African-American and 2 farms with 25% - 50% African-American. Finally, 4 farms were located in tracts with a 0 - 25% African-American population. From figure 1, we can gather that the same census tracts with the highest median household income (>$80,000), have 0 – 24.9% of residents that were African-American and the census tracts with a lower median household income (0 - $39,999), have a higher percentage of African-American residents.

Figure 5: Percent African-American, Urban Farms and Environmental Hazards



There were a cluster of environmental hazards in the southern region of the city, located in tracts with a 0 - 25% African-American population. There were also hazards on the east and west sides of the city, where the African-American population is >75%. Most clusters of environmental hazards were located in tracts with 0 to 49.9% African-American population. We identified more LRPs and TRI facilities in tracts with 0 – 24.9% of African-American residents and fewer hazards in tracts with 50 – 74.9% of African-American residents.

Figure 6: Percent African-American, Urban Farms, Environmental Hazards, and Healthy Food Priority Areas

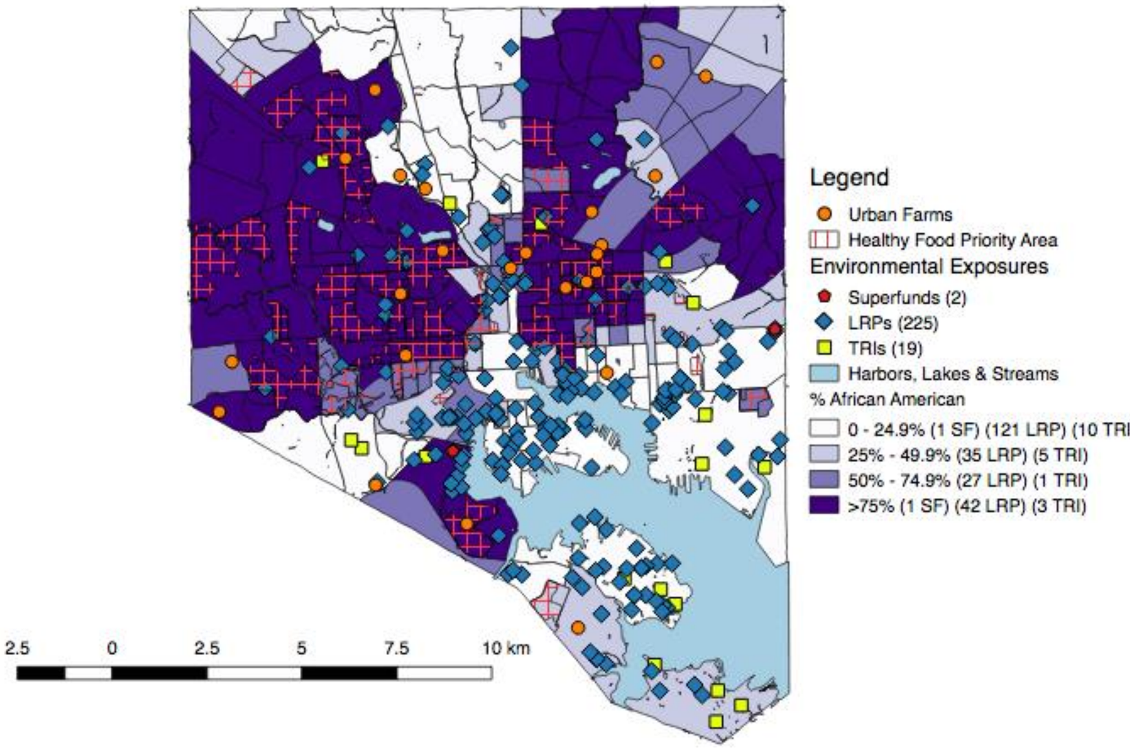
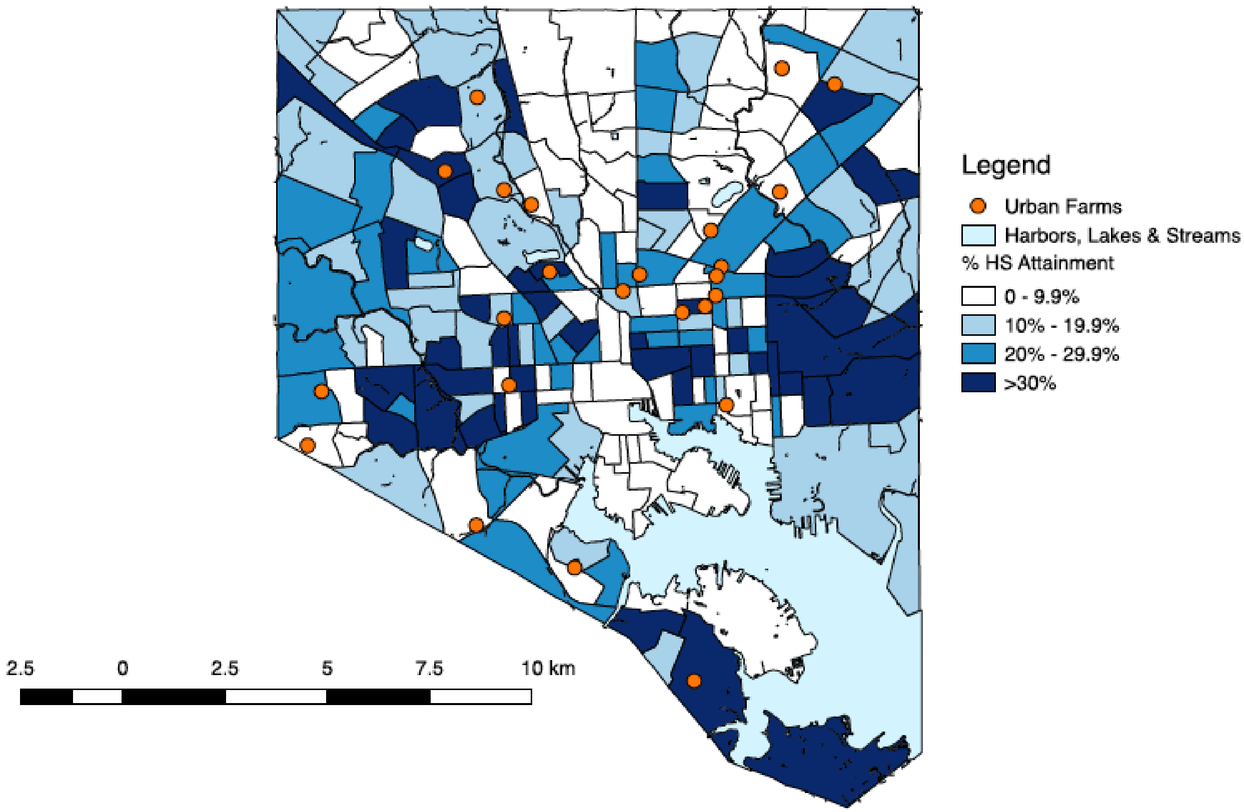


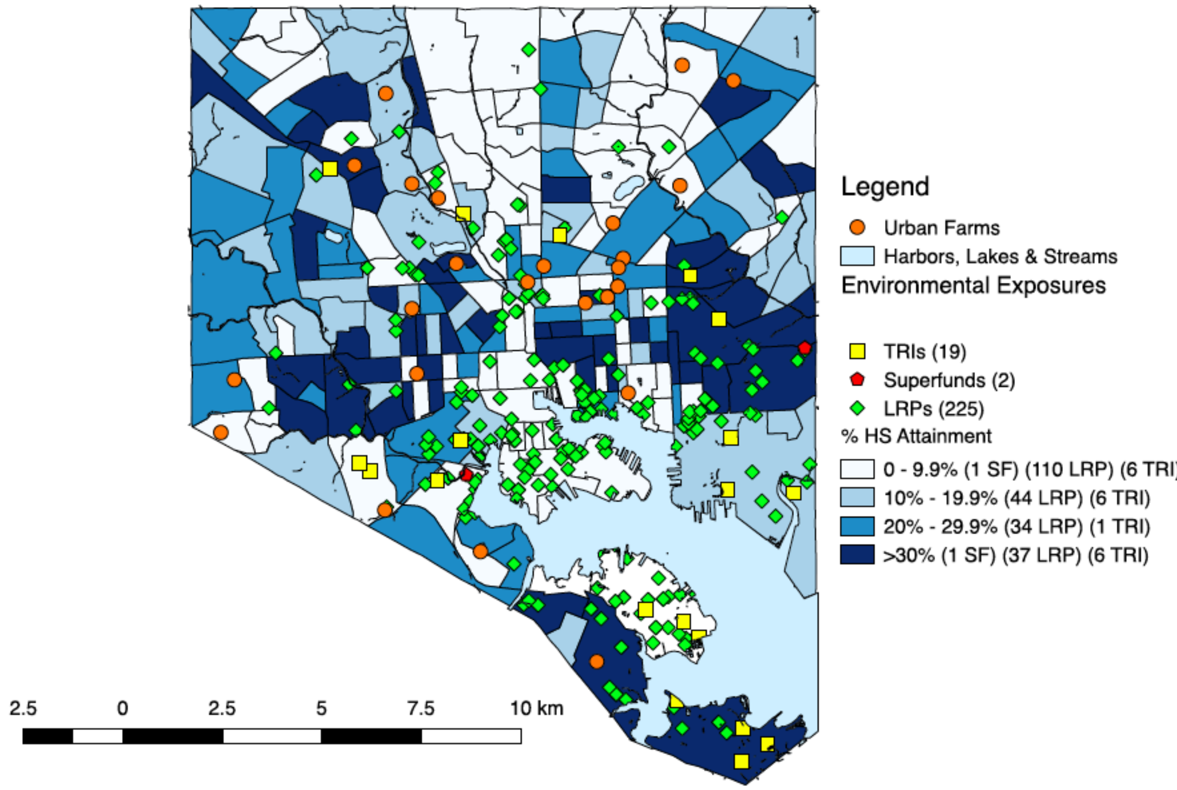
Figure 6 illustrates healthy food priority areas, percent African-American, environmental hazards, and urban farm locations. This map shows that most of the healthy food priority areas are located in census tracts with over 75% African-American population. As noted previously, 9 urban farms were located in healthy food priority areas and more LRPs and TRI facilities in tracts with 0 – 24.9% of African-American residents.

Figure 7: Percent with less than a High School diploma and Urban Farms



Educational attainment follows a similar pattern as seen with percent African-American; census tracts that had a higher percentage of African-American residents had a higher percentage of residents with less than a high school diploma. Areas on the east and west sides of the city had the highest percentage of residents with less than a high school diploma, while areas north and south had a lower percentage with less than a high school diploma. Some areas on the east side of the city had a lower African-American percentage (0 – 24.9%) and a higher percentage of residents with less than a high school diploma. Urban farms were mostly located in tracts with a high percentage of less than a high school diploma (10% - 30%). About 5 farms were located in tracts with 0 – 9.9% of residents have less than a high school diploma.

Figure 8: Percent with less than a High School diploma, Urban Farms and Environmental Hazards



Environmental hazards were mostly found in tracts with low educational attainment (0 – 9.9%). Specifically, most LRPs were found within 0 – 9.9% of individuals without a high school education. The following quartiles, 10% – 19.9%, 20% - 29.9%, and >30%, had a similar number of LRPs. Additionally, hazards were present in tracts with over 30% of residents with less than a high school diploma, as seen on the eastern end of the city. Few LRP sites were located in tracts with a low percentage of individuals with less than a HS diploma, as seen in the northern parts of the city.

Figure 9: Percent with less than a High School diploma, Urban Farms, Environmental Hazards and Healthy Food Priority Areas

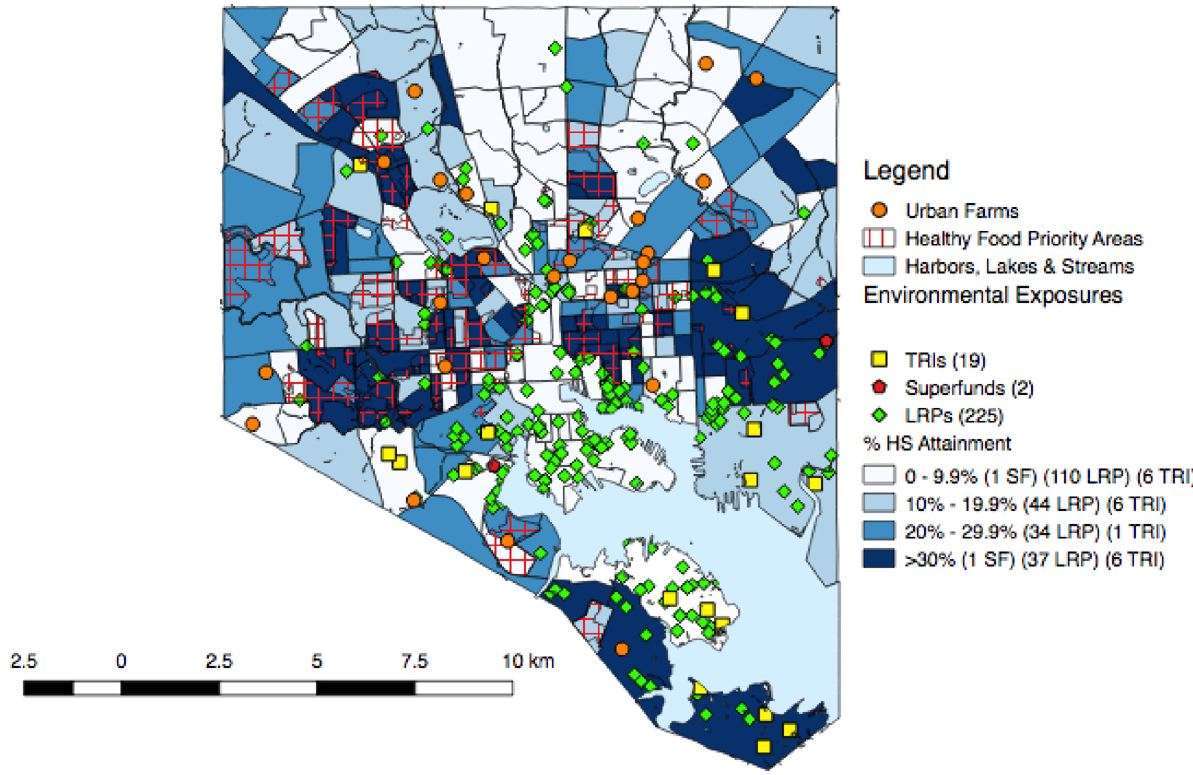


Figure 9 shows healthy food priority areas, percentage with less than a high school diploma, environmental hazards, and urban farm locations. Figures 3 and 6 illustrate how healthy food priority areas were located in tracts with low median household income ($0 – $39,999) and a high percent African-American population (>75%). Figure 9; however, displays more spatial variation with the locations of healthy food priority areas and % less than a high school diploma, meaning priority areas are found in tracts with populations having differing levels of educational attainment.

Figure 10: Intersection of Streets and Urban Farms

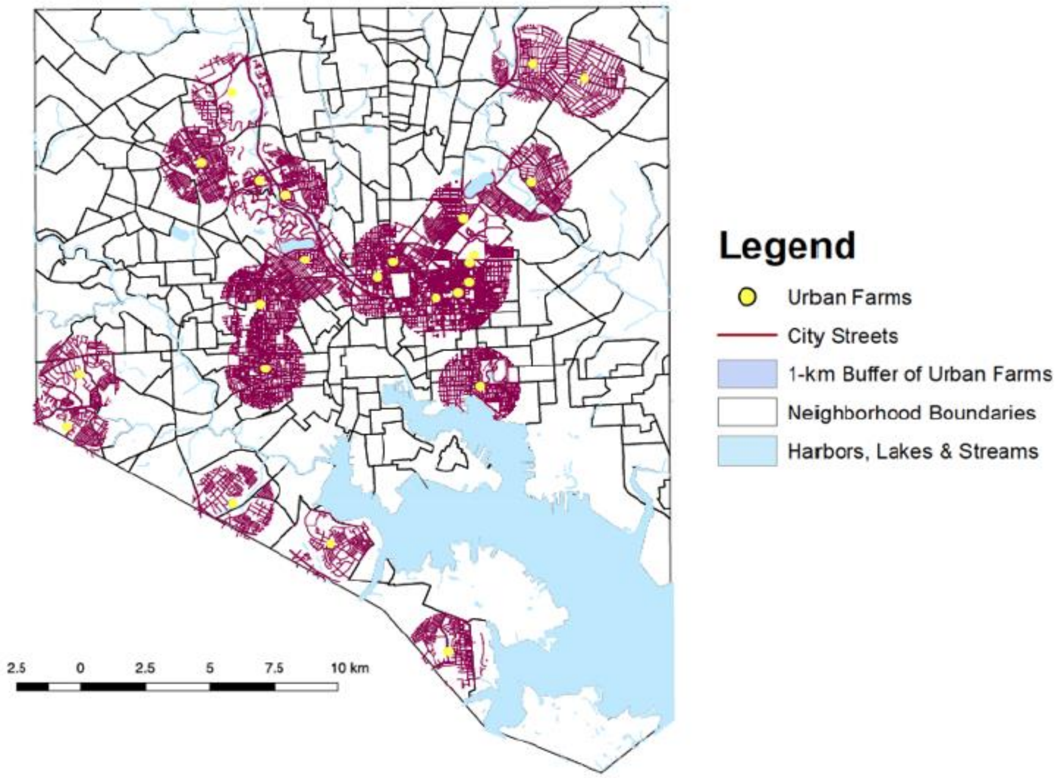
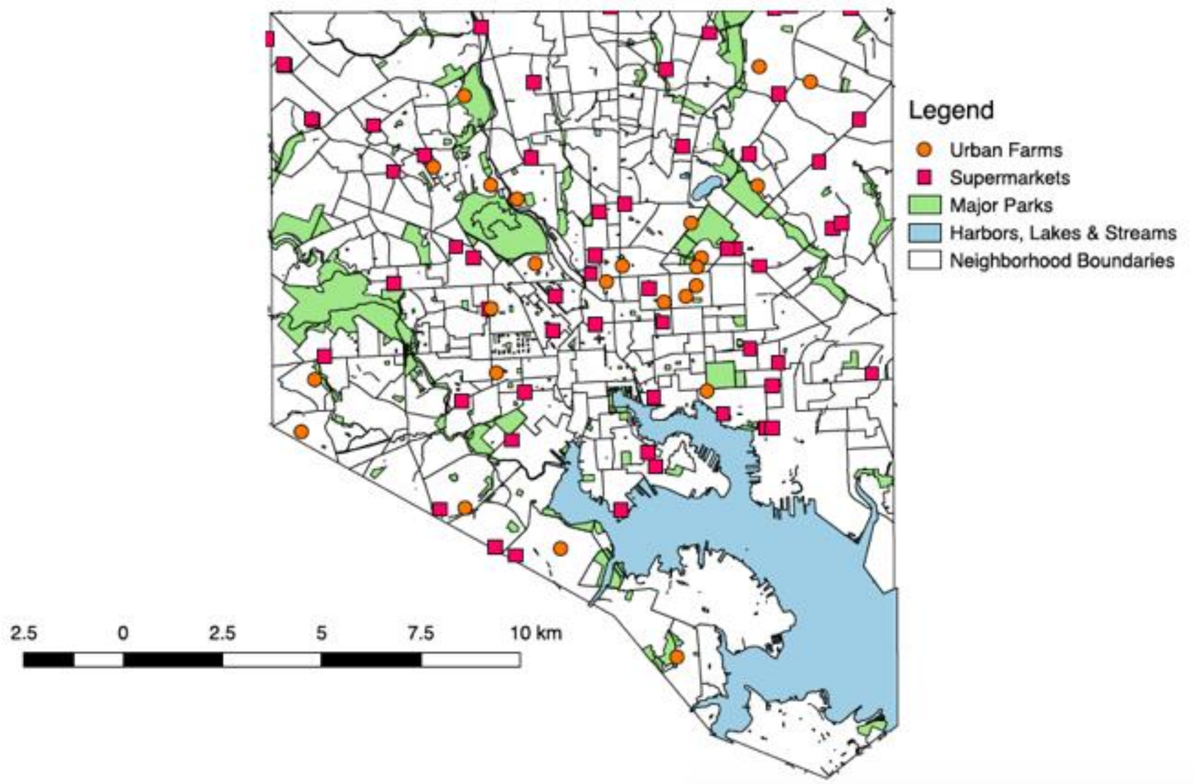


Figure 10 shows the intersection of streets and urban farms. All farms show a concentration of streets; however, the densest concentrations of streets were in the City center.

Figure 11: Supermarkets and Urban Farms



We identified the locations of urban farms and supermarkets in Figure 11. There were more supermarkets than urban farms and clusters of both supermarkets and urban farms were mostly found in the City center.

Figure 12: Presence of Environmental Contamination in Baltimore City

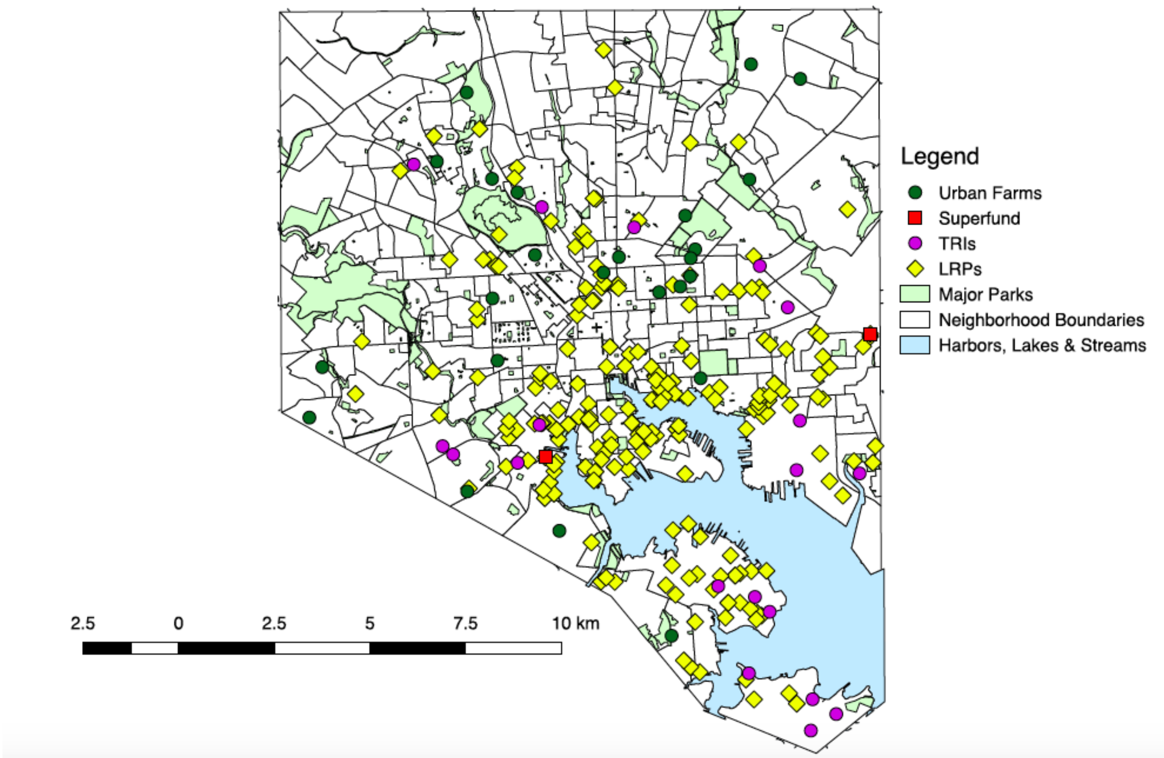
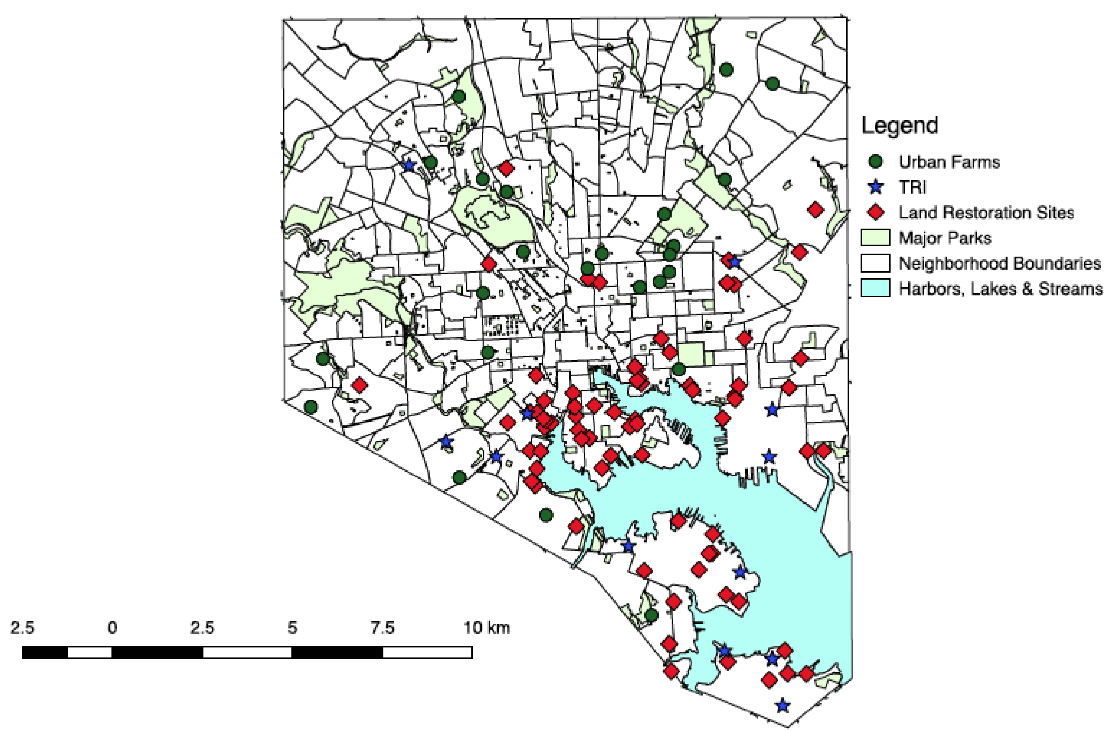


Figure 13: Hazards with the Presence of Heavy Metals in Baltimore City



We mapped the presence of sites with known heavy metal contamination and unknown environmental contamination in figures 12 and 13. There were more LRP sites that had undefined environmental contamination than sites containing lead, mercury, arsenic, cadmium, or chromium. Two Superfund sites were identified with unknown environmental contamination, while 14 TRI facilities were mapped to contain lead, mercury, arsenic, cadmium, or chromium. However, a total of 19 TRI facilities were identified in Baltimore City. There were 166 LRPs identified with heavy metals and 225 total LRPs in the City. Most of the LRPs were located in the historic, industrial areas of the inner harbor.

Table 1: Count of Presence of Heavy Metal Sites and Unknown Contamination Sites within 1-km, 2-km, and 5-km of urban farms

	1km			**2-km**			**5-km**		
	LRP	TRI	Superfund	LRP	TRI	Superfund	LRP	TRI	Superfund
Heavy Metal Contamination	12	1		36	3		422	40	
Unknown Environmental Contamination	46	3	0	168	11	1	1324	75	4

Within a 1-km, 2km and 5-km buffer of an urban farm, there were more sites hosting unknown environmental contamination than sites with the presence of heavy metals. Most contaminated sites were LRPs. There was an observed increase of LRP sites from 1-km to 5-km and a similar pattern was found for TRI facilities and Superfund sites.

Table 2: Mean Distribution of sociodemographic measures by urban farm and TRI facility buffer zones in Baltimore City

	Host		Host 1-km - 2-km	
Sociodemographic	**TRI**	**Non-TRI**	**TRI**	**Non-TRI**
# census tracts	3	21	9	15
%Black	48	72.5	68	70.3
%Unemployment	19.1	16	19.2	14.6
%<HS Education	30.1	17.9	24	17.4
Median HH Income	34,987	46,755	35,423	50,214
%Receiving SNAP	30.9	31.1	30.4	31.4
% Owner-Occupied	51.5	51.6	48.5	53.4

Host defined as a census tract that hosts at least one urban farm.

Table 3: Mean Distribution of sociodemographic measures by non-urban farms and TRI facility buffer zones in Baltimore City

	Non-Host	Non-Host
Sociodemographic	**TRI**	**Non-TRI**
# census tracts	170	8
%Black	64	52
%Unemployment	12.3	15
%<HS Education	19	18.9
Median HH Income	47,119	36,730
%Receiving SNAP	30	35.2
% Owner-Occupied	45.3	40.1

Non-host defined as a census tract that does not host an urban farm.

Tables 2 and 3 illustrate that there were more tracts that hosted an urban farm but did not host a TRI site, compared to tracts that hosted an urban farm and a TRI site. There was a higher percentage of African-American residents, a higher median household income, a higher percent of owner-occupied homes, and a higher percentage of resident receiving SNAP, also called food stamps in the census tracts hosting an urban farm but no TRI facility. Tracts that hosted an urban farm and did not host a TRI site and tracts that hosted an urban farm within a 1-km through 2-km buffer, and did not host a TRI site, both had higher median household incomes than tracts that hosted an urban farm and a

TRI site. The percentage of African-American residents increased for both tracts that hosted an urban farm and did not host a TRI facility and tracts that hosted an urban farm within a 1-km to 2-km buffer and did not host a TRI facility. The percentage of residents who received SNAP benefits remained mostly the same across all comparisons, at about 30%, except for tracts that did not host an urban farm or a TRI facility, receiving about 35% of SNAP benefits. Within a 1-km - 2 km buffer of an urban farm, there were 9 tracts that hosted TRI facilities and 15 tracts that did not host TRI facilities. Similarly, tracts that hosted an urban farm but did not host a TRI had a higher percentage of African-American residents, a higher median household income and a higher percent of the population receiving SNAP benefits.

Table 3 identifies more tracts that did not host an urban farm but hosted a TRI facility, compared to tracts that did not host an urban farm or a TRI facility. These tracts also had a higher percentage of African-American residents, a higher median household income, and a higher rate of homeownership. Additionally, we evaluated the distribution of supermarkets by urban farms and found that most census tract host an urban farm, but do not hard a supermarket. Only four census tracts host an urban farm and a supermarket. Thirty-nine census tracts did not host an urban farm but hosted a supermarket and 18 tracts did not host either an urban farm or a supermarket.

Tables 2 and 3 primarily indicate that more people were unemployed, had less than a high school diploma and had a lower median household income in tracts that hosted an urban farm and TRI facility compared to tracts that hosted an urban farm without a TRI facility. However, we witnessed a higher percentage of African-American residents in tracts without a TRI facility. Urban farms that were located in tracts with TRI facilities had about a $15,000 lower median household income than tracts without a TRI facility. For tracts that did not host an urban farm or a TRI facility, their median household income was similar to tracts who hosted both; however, for tracts that did not host a farm but hosted a TRI facility, they had a median HH income which was $15,000 greater. This may also be seen in Figure 2, where median household income is higher in tracts without an urban farm and a cluster of TRI facilities are located in tracts with a higher income level.

Figures 3, 6 and 9 showcase how healthy food priority areas are predominantly located in tracts with low median household income ($0 - $40,000) a higher percentage of African-American residents (>75% Black), and a higher percentage of residents with less than a high school diploma (>30%). However, these areas do not have as many clusters of environmental hazards than the southern, more industrial areas of the city. Environmental hazard clusters, specifically LRPs, were located in areas with a higher median household income (>$80,000), a lower percentage of African-American residents (0 - 25%), and a lower percentage of residents with less than a high school diploma (0 – 9.9%).

DISCUSSION

Urban agriculture provides access to fresh fruits and vegetables in food deprived areas but presents a potential problem for health because of proximity to legacy pollution sites and traffic. Nine urban farms were located in Healthy Food Priority Areas; however, 46 LRPs and 3 TRI facilities were located within 1-km buffer of an urban farm. We also identified more LRPs than TRI facilities or Superfund sites and these LRPs were concentrated near the perimeter of the Inner Harbor.

We found the distribution of LRPs near the Inner Harbor, in the eastern and southern peripheries of the city. In this study, we found that more people were unemployed, had less than a high school diploma and had a lower median household income in census tracts that hosted an urban farm and a TRI facility. Conversely, we found that census tracts that host an urban farm but do not host a TRI facility had a higher median household income, a higher percentage of African-American residents, and a higher rate of homeownership. Additionally, we found census tracts who host an urban farm without a TRI facility had over a $10,000 higher average median household income. The opposite was seen in census tracts that did not host an urban farm, with a $10,000 higher average median household income observed in tracts with a TRI facility. Census tracts who do not host an urban farm had higher averages of median household income compared to tracts who do host.

We identified a cluster of LRPs in the southern, industrial perimeter of the city in a high-income census tract (>$80,000). We also identified a cluster of TRI facilities and LRPs on the south, east end of the Inner Harbor in a low-income tract of $0 - $39,999. In the high-income cluster of LRPs, we found a low percentage of African-American residents (0 – 24.9%) and a low percentage of less than a high school diploma (0 – 9.9%). However, in the low-income cluster of LRPs and TRI facilities, we found a higher percentage of African-American residents (25 – 49.9%) and a higher percentage of less than a high school diploma (>30%).

Within a 1-km buffer of an urban farm, we identified 47 LRPs with the presence of unknown environmental contamination and 12 LRPs with the presence of heavy metal contamination. Three TRI facilities were within the 1-km buffer of an urban farm, while one TRI facility with the presence of heavy metal contamination was located within the 1-km buffer. Finally, no Superfund sites were located within a 1-km buffer of an urban farm. We also located urban farms in tracts with a lower median household income ($0 – $39,999), more African-American residents (>75%) and a higher percentage of residents with less than a high school diploma (>30%).

Boone evaluated the distribution of TRI facilities in Baltimore City and found those census tracts with a TRI site tend to have more Whites than Blacks, fewer people with college experience, and slightly lower family incomes.[225] In our study, we found that TRI facilities are mostly located in tracts with a lower median household income ($0 - $39,999), have a lower percent of African-American residents (0 – 24.9%), and in tracts with a variety of educational attainment levels. About 12 TRI facilities are located in tracts that have 0% - 19.9% with less than a high school diploma, while about 7 TRI facilities are located in tracts with 20% to over 30% of residents without a high school diploma. Our results are similar to Boone's, in that we found more white residents with a lower median household income living near TRI facilities. However, we found a variety of educational attainment levels for residents living near a TRI. We also evaluated the distribution of LRPs in Baltimore. We found most LRPs are located in tracts with a high median household income (>$80,000), less African-American residents (0 – 24.9%), and fewer residents with less than a high school diploma (0 – 9.9%).

Prior research has found that low socioeconomic status (SES) populations and non-white residents in some areas reside in communities with a disproportionate burden of locally unwanted land use (LULUs).[221 – 223] One study in South Carolina found burden disparities in the location of Superfund sites for Non-White and low-income populations at the block and census tract levels in South Carolina.[221] They also found that Black and White populations living in poverty, populations with a home built before 1950, and Black and White populations with less than a high school education were more likely to live in a Superfund host tract. Only two Superfund sites are found in Baltimore City, and we did not conduct a sociodemographic analysis of tracts that hosted a Superfund site.

In all comparisons measured, we found tracts who hosted both an urban farm and a TRI facility, had populations with the highest percentage of less than a high school education and the lowest median household income. For the state of Maryland, Wilson found that tracts with higher proportions of non-white residents and people living in poverty were more likely to live closer to TRI facilities.[58] In Baltimore City, we found that tracts that do not host an urban farm but host a TRI have a higher percentage of Black residents compared to tracts that do not host a TRI facility. However, tracts that do not host a TRI but host an urban farm, have a higher percent of Black residents.

Studies have shown that low-income persons and populations of color have a disproportionate burden of residing in communities with LULUs, including TRI facilities,[410 – 411] landfills,[412] incinerators,[412] hazardous waste sites,[410, 233] sewer and water infrastructure treatment plants,[3, 233, 413 – 414] coal-fired plants,[412] industrial animal operations[415] and Superfund sites.[416] This disproportionate burden can to increased exposure to harmful pollutants,[417 – 420] which exacerbates the risk of poor health and well-being. For instance, Litt found communities in Southeast Baltimore who lived near more brownfields experienced statistically higher mortality rates due to cancer (27% excess), lung cancer (33% excess), respiratory disease (39%), excess, and the major causes of death (index of liver, diabetes, stroke, COPD, heart disease, cancer, injury, and influenza and pneumonia; 20% excess), than communities in the same area who lived near fewer brownfields.[201] In Baltimore, Yesilonis found that urban soils had concentrations that were elevated above-background levels, with a large proportion of locations exceeding EPA soil screening levels.[177] Pouyat also found that concentrations for Cu, Pb, and Zn were higher in the more urbanized areas of the Baltimore-Washington region than the background concentrations expected for soils in the study area.[407] Additionally, Pouyat identified that elevated concentrations of Cu, Pb, Zn, and to a lesser extent, As and Cd, located in older and more urbanized areas suggest that people living in these areas have a greater risk of exposure to these metals.[407]

There are possible reasons for the distribution of environmental hazards including LRPs in Baltimore. Residential segregation and income inequality plays a role in shaping environmental inequality.[421] Restrictive housing policies forced Blacks to concentrate in neighborhoods away from the old industrial centers of the city, while White workers lived and owned homes closer to the industrial city[422]. For the last 40 years, the density of polluting facilities has been higher in white than black neighborhoods.[225] Boone's analysis supports earlier studies on Baltimore that show that percent white is a key variable in explaining the presence of toxic industry.[421, 423 – 424] Downey studied the relative pollution burden experienced by Hispanics, Blacks and Whites in US-metropolitan cities. In Baltimore, they found that high segregation levels did not result in

Black/White environmental inequality and Hispanics were more highly exposed to RSEI air pollutants than Blacks, even though Hispanic/White segregation levels were lower than Black/White segregation levels. Baltimore's Hispanic population is a bit more residentially dispersed than Baltimore's Black population, as result, Hispanics are more likely than Blacks to live in polluted neighborhoods.[421] However, neither Blacks or Hispanics were as residentially dispersed or as highly concentrated in Baltimore's high-pollution neighborhoods than Whites.[421] Thus, Baltimore's Black population is segregated into neighborhoods with relatively few TRI facilities.[421]

This study has several limitations. We did not collect any biomarkers, soil samples, or air samples for analysis of toxicants. Our GIS research identified proximity to hazards as a proxy for exposure to contamination. For TRI data, not all companies are required to report toxic releases, only those with more than 10 employees that produce or process over 25,000 pounds or use more than 10,000 of a chemical listed on the TRI.[422] Not all chemicals that may have negative impacts on the environment have been reported. Over time, the number has increased but is still a fraction of possibly harmful chemicals.[422] Acute releases of chemicals may be more harmful than chronic releases, may not be reported if thresholds are not surpassed.[422] At the same time, total releases over a year may mark a number of acute releases.[422]

The real constraint in using GIS for health and equity research is not software; however, but data deficiencies.[425] Incomplete, inaccurate, and nonexistent information does not necessarily reflect our state of knowledge about the issues but may be merely an indication of our society's informational (and funding) priorities.[425] Not all environmental sites in Baltimore City are shown in Figures 19 and 20. All LRP sites in

Baltimore City, as identified by MDE were mapped; however, active and/or closed brownfields that were not identified as LRPs were not mapped. This was done to reduce duplication of sites. Also, an additional grocery store was introduced to Baltimore by the Salvation Army in March of 2018, which will impact the designated Healthy Food Priority Areas. Finally, we identified 24 urban farms using Johns Hopkins definition of 'farms that grow food in and around urban areas'. To clarify, two farms strictly grew honey and one farm grew herbs.

Finally, different protective measures are featured in our sample of 24 urban farms, making it difficult to understand and quantify proxy for exposure to contamination. Out of 24 farms, 18 farms grow food outside, in the site's soil, if below the soil safety standards, or remediated soil. Out of the 18 farms which grew food outside, two farms had additional hoop houses, which is a structure used as a greenhouse or a season extender, typically made from steel and covered in polythene, usually semi-circular, square or elongated in shape, on site from which they grow food in.[426] Finally, three farms grew only in hoop houses and one farm used an indoor, controlled environment. This farm utilized hydroponics, the cultivation of plants by placing the roots in liquid nutrient solutions rather than in soil, to sustain their food-growing practice indoors and growing technology to increase environmental efficiency.[493] Thus, it is difficult to understand contamination risks with different protective measures on urban farms.

Future studies should consider plume modeling, to better understand the dispersion of contaminants from legacy sites and traffic and their relation to urban farms. Also, site-specific analysis on soil characteristics and air samples in and near urban farms should be conducted. This analysis can provide more information on the types of contaminants on each farm and identify the best protective features for each site. Finally, future studies should investigate how to quantify the amount of protection seen on various urban agriculture projects (i.e., raised beds, hoop houses and greenhouses), to evaluate the benefits of each measure and encourage gardeners and policymakers to invest in these features.

CONCLUSION

Urban agriculture offers a means of obtaining healthy food while making use of vacant land in cities.[160] Much of this vacant land is located within or nearby food deserts.[62] However, heavy metal soil contamination in urban areas is a major concern for human health and food safety.[160, 294, 427] Legacy sites such as brownfields, Superfund sites, and TRI facilities may contribute to soil contamination from the emission of environmental contaminants. Contaminants, like heavy metals, can linger in the environment and adhere to the plants surface. Gardening can increase the potential for adults and children to be exposed to soil contaminants through incidental soil ingestion, soil resuspension and subsequent exposure.[428] This research helps to identify areas in the City where there is a greater concentration of environmental hazards. This information may be useful for gardeners and urban agriculture advocates when initiating new projects, by reconsidering sites or adding protective features and soil remediation strategies for urban agriculture sites.

CHAPTER 4: STUDY 2

INTRODUCTION

There is growing awareness of urban gardening's approach to increase the availability and intake of fruits and vegetables for urban residents.[31, 53, 91, 429] However, urban soils are often close to pollution sources, such as industrial areas and heavily trafficked roads.[62, 430] Soil and water pollution from these nearby industries and highways can contain heavy metals, and toxic organic industrial wastes, and other pollutants.[62, 138, 178] These contaminants can settle on garden soil, plant leaves, and fruits.[138] For example, plants grown in lead contaminated soil can accumulate lead from the adherence of dust and translocation into the plant tissue.[63] The amount of contamination depends on distance from road, crop species, time exposed before harvest, and recent rainfall.[176] Heavy metal contamination of fruits and vegetables may occur by uptake in roots from contaminated soils and irrigation water as well as from deposits on parts of the plants exposed to the air from polluted environments.[431 – 433] High deposition and accumulation of trace metals in the edible part of root and leafy crops has been reported in studies.[64] Vegetables are capable of accumulating trace metals from polluted soil and from surface deposition into their shoots in polluted environments.[406] Trace metals in the air have been reported to significantly influence total metal concentration of vegetable plants, especially when washing is not thoroughly done.[168]

Food is an important pathway of exposure for several metals. The uptake and bio accessibility of heavy metals has been reviewed, yet, limited research has been done on indirect soil-plant-human transfer, whereby trace elements can enter the human system and cause potential harm.[434] One study, based in Wales, United Kingdom, found a direct association between ingestion of homegrown produce and blood lead levels in women of childbearing age.[66] To wash produce, the U.S. Food and Drug Administration (FDA) recommends that consumers use a vegetable brush to scrub firm-skinned produce while holding it under running water and wash less firm-skinned produce by rubbing or rinsing under running water.[435] The lack of proper cleaning procedures, especially for root and low-growing plants, can be a cause of concern.[434] When not properly washed before eaten, plants can expose consumers to contamination.[138] Children, pregnant women, and adults with compromised metabolic systems may be especially vulnerable in this regard.[138]

Most studies have evaluated the efficacy of household washing urban-grown vegetables, in relation to limiting exposure to lead.[63, 288, 434, 436 – 437] Limited studies have been done to evaluate the effectiveness of other heavy metals. However, one study assessed the effectiveness of washing on mercury contents on vegetables. They found between a 19 – 63% reduction in mercury contents of water-rinsed vegetables.[437] Another study found the concentration of Cr to be greater in unwashed, than in washed, vegetables in contaminated sites in Kampala City, Uganda but found no significant difference in Cd concentration between washed and unwashed vegetable shoots.[495]

Another study evaluated transfer of Pb in vegetables with three cleaning protocols. Generally, the lab-cleaning procedure was more effective in reducing Pb concentrations in the vegetables. Peeled carrots had significantly lower Pb concentrations than tap-water washed carrots, indicating that the impact of the removal of surface contamination through peeling was greater than the concentrating effect due to peeling.[434] However, other studies have reported an increase in carrot root Pb concentrations when roots were peeled before analysis.[436] A similar study was done to evaluate soil-plant transfer of Pb and the effects of vegetables cleaning techniques. Swiss chard cleaned with the tap water contained 2.6 to 4.6 times greater Pb concentrations than cleaned with the lab method. Similarly, tap water cleaned tomatoes had 3.0 times greater Pb concentrations than lab-cleaned tomatoes. In contrast, cleaning methods and peeling did not significantly impact Pb concentrations in carrots. Discrepancies in Pb concentrations in carrots from the studies above may be attributed to the soil type and varietal differences in carrots.[288] Another study evaluated the effects of washing with detergent and water on plants grown in residential gardens contaminated by lead.[63] Both washing techniques removed lead concentrations to a degree, however, 50% of water-washed leafy edibles and 28% of detergent-washed samples showed lead detection.[63] Researchers concluded that the risk of lead from leafy and root edibles is a result of both lead contaminated dust attached to the plant surface and direct uptake of lead into the plant tissue.[63]

Although leaded gasoline has been banned in many developed countries, it is still used in developing countries.[288] A study found higher Pb concentrations in vegetables grown along major highways in in Kampala City, Uganda.[61] Furthermore, they observed a significant difference in Pb concentrations in unwashed and washed leafy vegetables grown in urban gardens. They observed a 35% decrease in Pb concentrations in washed leafy vegetables versus unwashed leafy vegetables grown in urban gardens.[61] It is important to understand how consumers perceive urban agriculture to identify preferences in underlying food values and help improve communication and policymaking.[438]

Research has been performed to address the increasing consumer demand for locally produced food and to understand their attitudes and purchase decisions.[439] Studies have found that consumers place a greater importance on purchasing local rather than organic food, and they perceive that local foods are better for society.[143, 440] Yet, limited studies have been done regarding consumer's perception or urban-grown foods. Grebitus surveyed student's perceptions of the benefits of urban agriculture and showed that consumers think there are health benefits affiliated with consuming urban agriculture. Furthermore, they thought urban agriculture was associated with community building and sustainability. They also identified a contrary economic perspective that urban agriculture provides "better quality but more expensive".[141] Another survey reported that about 60% of respondents felt that locally grown produce had superior food safety level than conventional produce.[146] Another study revealed that consumers perceived locally grown produce as safer and carried less risk than produce grown elsewhere because of the shorter distance traveled to farmers' markets versus other markets.[147] An additional study found that consumers generally hold a positive food safety perception of food from farmers' markets, which may be in contrast to actual microbial safety of produce obtained from these markets.[150]

However, gardening in urban settings and consuming urban-grown produce may present health risks, including exposure to heavy metals that may be present in urban soils.[140, 441] Contaminated urban soils can pose significant direct risks to human health through direct ingestion of soil particles, inhalation of dust, and consumption of food plants grown in metal-contaminated soils.[442] If not properly washed, plants can expose consumers to heavy metal contamination.[61, 288, 434]

The aim of this study was to understand use of and behavior in-relation to urban grown food and provide insight into food handling behaviors of consumers of urban-grown food. We investigated the frequency of consumption and washing practices of urban-grown kale, bell peppers, any squash, tomatoes, and carrots. It is important to understand food handling behaviors of urban-grown produce because thorough cleaning of soil/dust particles deposited on vegetables has been shown to further reduce food chain transfer of soil contaminants to humans.[288, 441, 434]

METHODS

Questionnaire and Produce Selection

To access the consumption quantity and food handling behaviors of the studied fruits and vegetables, a questionnaire-based survey was performed. Produce items were selected based on the Safe Urban Harvest farmers and gardeners survey and the Food Commodity Intake Database (FCID). The Safe Urban Harvest project surveyed Baltimore farm managers and community garden leaders and asked them to list their top five items grown at the farm/garden (by area in production) and the FCID database lists the size of the portion (in grams) eaten by commodity eaters of the chosen product. We selected tomatoes, carrots, kale, bell peppers and squash for the survey because: 1) they are popular vegetables grown by farmers/gardeners in Baltimore City, and 2) they are vegetables most commonly consumed. Tomatoes, kale, bell peppers, and squash had the highest number of mentions identified by Baltimore City farmers as items they most often grew. While carrots had fewer mentions, the FCID database showed that 25% of the US population consumes carrots. The database also showed a high consumption rate of

16% or greater for the other produce items surveyed. Thus, these five items were selected based off what farmers typically grew and what consumers typically ate. We collected information on demographics, dietary consumption, and washing practicing using surveys. However, we lacked a food diary and/or food frequency questionnaire to better capture diet. The University of Maryland IRB approved the survey and consent forms.

Participants and Procedures

We recruited Baltimore City residents who have consumed urban-grown produce to participate in the survey through social media, Food PAC, the Waverly farmers' market, and food courts. We conducted a convenience sampling approach and attended the Waverly Farmers' Market and R-House to distribute the survey. The survey was distributed through Facebook for Food PAC members. Food PAC was developed by the Baltimore Food Policy Initiative and members work actively to improve food access and the food system. Food PAC has over 60 members, representing nonprofits, universities, farms, businesses, hospitals, and residents. Based on our review of previous studies,[111, 140, 287] we recruited a total of 71 residents to participate in our food handling survey from February to April 2018. Participants were first asked if they have ever consumed produce grown in Baltimore City. If they answered 'yes', they were then asked to read the consent form and voluntarily agree to participate in the research study. We utilized a convenience sampling technique to reach all participants. All surveys were completed anonymously, and no personal identifiers were used when analyzing data.

RESULTS

Table 1: Sociodemographic Characteristics of Participants (N=71)

Sociodemographic Characteristics	Percent (%)
Gender	
Male	29.6 (n=21)
Female	64.8 (n=46)
Non-Binary	1.4 (n=1)
Prefer not to answer	4.2 (n=3)
Race	
Black	11.3 (n=8)
Latino (a)	1.4 (n=1)
Asian/Asian American	4.2 (n=3)
White	66.2 (n=47)
Multiracial	5.6 (n=4)
Other	2.8 (n=2)
Prefer not to answer	8.5 (n=6)
Age	
18 – 24	9.9 (n=7)
25 – 29	45.1 (n=32)
30 – 34	15.5 (n=11)
35 – 44	14.1 (n=10)
45 – 54	4.2 (n=3)
55 – 64	2.8 (n=2)
65>	1.4 (n=1)
Prefer not to answer	7 (n=5)
Education	
<HS	1.4 (n=1)
HS Graduate	0 (n=0)
Some College	9.9 (n=7)
College Degree or >	83.1 (n=59)
Prefer not to answer	5.6 (n=4)
Household Income	
<$20,000	18.3 (n=13)
$20,000 – $34,999	14.1 (n=10)
$35,000 - $49,999	19.7 (n=14)
$50,000 - $74,999	16.9 (n=12)
$75,000 - $99,999	7 (n=5)
Over $100,000	14.1 (n=10)
Prefer not to answer	9.9 (n=7)
Years of total urban-produce consumption	
More than 10 years	8.5 (n=6)
Between 7 and 9 years	8.5 (n=6)
Between 4 and 6 years	12.7 (n=9)
Between 1 and 5 years	32.4 (n=23)
Less than 1 year	16.9 (n=12)
Don’t know	16.9 (n=12)
Refused	4.1 (n=3)

Table 1 shows the sociodemographic characteristics of the survey participants. Most participants were female (65%), white (66%), were between ages 25 – 29 and had a college degree or greater. Years of total urban-produce consumption had more diverse responses. The most common consumption rate among participants was between 1 and 5 years (32%), followed by less than 1 year of urban produce consumption (17%), and 17% of responses did not know how long they have been consuming urban-grown produce. Median household income had the most variation of responses. All income responses were between 14 – 20%, except $75,000 - $99,999 and 'prefer not to answer'.

Table 2: 'For each of the purchasing locations, please circle whether you have, have not, don't know if you have, or refuse to indicate whether or not you have purchased produce from the following places?'

Location	**Yes (%)**	**No (%)**	**Refused (%)**	**DN (%)**	**Total**
Farmer's Market	86.4 (n=57)	7.6 (n=5)	1.5 (n=1)	5 (n=3)	66
CSA	34.3 (n=23)	55.2 (n=37)	3 (n=2)	7.5 (n=5)	67
Urban Farm Stand	38.8 (n=26)	47.8 (n=32)	1.5 (n=1)	11.9 (n=8)	67
Mobile Market	16.4 (n=11)	70.2 (n=47)	1.5 (n=1)	11.9 (n=8)	67
Home Garden	41.2 (n=28)	50 (n=34)	1.5 (n=1)	7.4 (n=5)	68
School Garden	10.6 (n=7)	77.3 (n=51)	1.5 (n=1)	10.6 (n=7)	66
Avenue Market	26.9 (n=18)	58.2 (n=39)	1.5 (n=1)	13.4 (n=9)	67

** DN – Don't know

In this sample, participants identified local farmers markets (86%) as the most common purchasing location for urban-grown produce, followed by a home garden (41%). Many participants also had purchased from an urban farm stand or were a community supported agriculture (CSA) member. Most individuals also did not purchase food from a school garden (77%) or mobile market (70%).

Table 3: 'How often do you eat produce grown in Baltimore City, when local produce is abundant (i.e. summer)?' (N = 68)

Answer	Percent (%)
Once a week or more	48.5 (n=33)
Between 4 and 8 servings a month	13.2 (n=9)
Once a month	5.9 (n=4)
Once every 3 months	4.4 (n=3)
Once every 6 months	5.9 (n=4)
Don't Know	19.1 (n=13)
Prefer not to answer	3 (n=2)

About half of participants stated they consumed urban-grown food at least once a week or more, when local produce is abundant. Also, 19% of participants stated they were unsure of how often they consumed urban-grown produce.

Table 4: 'When it is seasonally abundant, how many times per month do you generally consume carrots, tomatoes, kale, bell peppers, or any squash that are city-grown?' (N=68)

Answer	Carrots (%)	Tomatoes (%)	Kale (%)	Bell Peppers (%)	Any Squash (%)
Zero	17.7 (n=12)	14.7 (n=10)	16.2 (n=11)	17.7 (n=12)	14.7 (n=10)
Once	48.5 (n=33)	36.8 (n=25)	35.3 (n=24)	41.2 (n=28)	44.1 (n=30)
Twice	11.8 (n=8)	13.2 (n=9)	20.6 (n=14)	11.8 (n=8)	14.7 (n=10)
3 – 5 times	17.7 (n=12)	14.8 (n=10)	13.2 (n=9)	13.2 (n=9)	10.3 (n=7)
6 – 10 times	0 (n=0)	7.4 (n=5)	4.4 (n=3)	7.4 (n=5)	13.2 (n=9)
More than 10 times	4.3 (n=3)	13.1 (n=9)	10.3 (n=7)	8.7 (n=6)	3 (n=2)

Across all produce items, the most common amount participants consumed carrots, tomatoes, kale, bell peppers or any squash was about once a month, which was about 35 – 49%. Between 15 – 18% of participants stated they did not eat carrots, tomatoes, kale, bell peppers, or squash at any time during a seasonally abundant month.

Table 5: 'Which method of communication would you prefer to receive information about your urban grown food?' by various sociodemographic factors (N = 71)

Answer	Percent (%)	Female (%)	White (%)
Printed Information (brochure, factsheet, mail)	40.8 (n=29)	58.6 (n=17)	62 (n=18)
Media (social media, television, email, radio)	32.4 (n=23)	78 (n=18)	70 (n=16)
Personal contact with expert	16.9 (n=12)	75 (n=9)	75 (n=9)
Don't know	7.1 (n=5)		
Refused	2.8 (n=2)		

Out of 71 participants, 41% state they preferred to receive information about their urban-grown food via printed information (brochure, factsheet, or mail), followed by 32% who prefer receiving information via the media (social media, television, email, radio). Finally, 17% of participants stated they preferred to communicate with an expert on information on their urban-grown food. Across all socio demographic groups, all participants were mostly female and white, between the ages of 25 – 29 and had at least a college degree or greater. However, we observed a difference in household income, with individuals who earn less than $20,000 prefer social media, television, email or radio as a way to receive information and individuals who make within $35,000 - $49,999 prefer printed information.

Table 6: Willingness and confidence of participants to wash produce (N = 39)

Question	Response	Percent (%)
How confident are you that you are able to wash produce?	Extremely Very Moderately Not so Unconfident	46.2 (n=18) 23.1 (n=9) 18 (n=7) 5 (n=2) 7.7 (n=3)
How willing are you to wash produce?	Extremely Very Moderately Not so Unconfident	61.5 (n=24) 10.3 (n=4) 20.5 (n=8) 5.1 (n=2) 2.6 (n=1)

Tables 6 and 7 were developed after receiving initial feedback for the survey in February. The number of individuals who participated in the second survey was 39. Table 6 discusses willingness and confidence of these participants to wash produce. Most were both extremely confident and extremely willing to wash produce, 46% and 62%, respectively. Followed by 23% of participants were very confident in their ability to wash produce and 21% were moderately willing to wash produce.

Table 7: 'Do you make purchase options based on concerns about the safety of food production in general?' by various sociodemographic factors (N = 39)

Answer	Number (%)	Female (%)	White (%)
Always	18 (n=7)	57 (n=4)	42.8 (n=3)
Mostly	35.9 (n=14)	50 (n=7)	42.8 (n=6)
Sometimes	33.3 (n=13)	84.6 (n=11)	53.8 (n=7)
Never	7.8 (n=3)		
Don't know	2.6 (n=1)		
Refused	2.6 (n=1)		

We asked participants if they base purchase options on the concern about the safety of food, with 36% and 33% stated they mostly and sometimes base purchases on concerns of food safety. We found that older individuals, ages 30 – 34 most often chose that they 'sometimes' make purchases based on concerns about food safety. Half of respondents in this category also had a household income of less than $20,000 or $50,000 - $74,999. Finally, most of the individuals in each category obtained a college degree or greater.

Table 8. Local produce consumption and washing practices by demographic variables

			'Always Washing'				
	Total (N)	**consume local produce once a week or more (%)**	**Carrots (%)**	**Tomatoes (%)**	**Kale (%)**	**Bell Peppers (%)**	**Any Squash (%)**
Age category (y)							
18 – 24	7	57.1 (n=4)	85.7 (n=6)	66.7 (n=4)	100 (n=4)	80 (n=4)	100 (n=4)
25 – 29	32	37.5 (n=12)	50 (n=13)	56 (n=14)	56.5 (n=13)	70.8 (n=17)	56.5 (n=13)
30 – 34	11	72.7 (n=8)	77.8 (n=7)	60 (n=6)	66.7 (n=6)	60 (n=6)	55.5 (n=5)
35 – 44	10	50 (n=5)	100 (n=10)	100 (n=8)	88.9 (n=8)	87.5 (n=7)	85.7 (n=6)
45 – 54	3	33.3 (n=1)	100 (n=2)	33.3 (n=1)	50 (n=1)	50 (n=1)	100 (n=2)
55 – 64	2	0 (n=0)	50 (n=1)	100 (n=2)	100 (n=2)	100 (n=2)	100 (n=2)
65>	1	100 (n=1)	100 (n=1)	100 (n=1)	100 (n=1)	100 (n=1)	100 (n=1)
Gender							
Female	46	47.8 (n=22)	70.3 (n=26)	64.9 (n=24)	69.7 (n=23)	74.3 (n=26)	61.3 (n=19)
Male	21	42.9 (n=9)	77.8 (n=14)	68.4 (n=13)	75 (n=12)	76.4 (n=13)	72.2 (n=13)
Race							
African American	8	37.5 (n=3)	66.7 (n=4)	100 (n=6)	75 (n=3)	100 (n=6)	80 (n=4)
White	47	46.8 (n=22)	73.7 (n=28)	59.5 (n=22)	68.4 (n=26)	70.2 (n=26)	58.3 (n=21)
Latino (a) or Hispanic	1	100 (n=1)	100 (n=1)	100 (n=1)	100 (n=1)		100 (n=1)
Asian/Asian American	3	33.3 (n=1)	100 (n=3)	66.6 (n=2)	100 (n=2)	100 (n=3)	100 (n=3)
Multiracial	4	75 (n=3)	33.3 (n=1)	50 (n=2)	50 (n=1)	50 (n=2)	100 (n=1)
Education							
<HS	1	100 (n=1)		0 (n=0)	0 (n=0)	0 (n=0)	
HS Graduate							
Some College	7	71.4 (n=5)	100 (n=5)	83.3 (n=5)	80 (n=4)	60 (n=3)	100 (n=5)
College Degree or >	59	44.1 (n=26)	69.4 (n=34)	64.6 (n=31)	71.4 (n=30)	73 (n=35)	62 (n=26)
Household Income							
<$20,000	13	46.1 (n=6)	88.9 (n=8)	80 (n=8)	62.5 (n=5)	77.8 (n=7)	77.8 (n=7)
$20,000 - $34,000	10	30 (n=3)	62.5 (n=5)	25 (n=2)	62.5 (n=5)	57.1 (n=4)	37.5 (n=3)
$35,000 - $49,000	14	50 (n=7)	69.2 (n=9)	69.2 (n=9)	77.8 (n=7)	75 (n=9)	58.3 (n=7)
$50,000 - $74,000	12	58.3 (n=7)	62.5 (n=5)	80 (n=8)	70 (n=7)	10 (n=7)	66.7 (n=6)
$75,000 - $99,999	5	60 (n=3)	60 (n=3)	25 (n=1)	33.3 (n=1)	50 (n=2)	75 (n=3)
>$100,000	10	60 (n=6)	77.8 (n=7)	75 (n=6)	80 (n=8)	88.9 (n=8)	57.1 (n=4)

* 'Always washing' represents number out of those who consume produce item

Table 8 shows local produce consumption and washing practices by various sociodemographic variables. Within the 25 – 29 age category, 37.5% of participants state they consume local produce once a week or more when it is seasonally abundant. More than half of these participants also state they always wash carrots, tomatoes, kale, bell peppers, or any squash; with bell peppers most often, always washed by participants at 71%.

When seasonally abundant, about 50% of females consumed local produce at least once a week or more. Out of all categories analyzed, males were the lowest percent who consumed local produce. Although there were less males surveyed, males 'always washed' carrots, tomatoes, kale, bell peppers, and squash more often than females. Most participants surveyed were also white and about half consumed local produce once a week or more. 16 participants surveyed were non-white. More than half of all white participants always washed all produce items surveyed, with the highest percent stating they 'always washed' carrots. Similarly, more than half of all black participants surveyed state they always washed all produce items and a 100% of participants state they always washed tomatoes and bell peppers.

Most participants had at least a college degree or greater, of these participants, about 44% consumed local produce once a week or more. Between 62% - 73% of these participants always washed the produce items analyzed, with bell peppers always washed the most. There was greatest variation between participants' household income, ranging from less than $20,000 to over $100,000. Income categories of between $75,000 and over $100,000 were the highest group to consume local produce once a week or more. The income group of less than $20,000 had the lowest percent, 46%, of consuming local produce once a week or more.

Out of all categories measured with at least 10 participants, incomes between $20,000 and $34,999 had a lower percent of 'always washing' squash versus other produce items measured. Individuals between 25 – 29 were found to 'always' wash the produce items asked less frequently than other age groups. All categories measured, except two income and one race category, have over 50% of participants always washing the five produce items analyzed.

Table 9: 'Please provide an explanation or list of reasons why you would sometimes wash or rinse city-grown carrots, tomatoes, kale, bell peppers, or squash' N = 68

'Dirt' (%)	'Pesticides' (%)	'Dirt and/or Pesticide' (%)	'Taught, Accustomed, Raised, Habit' (%)	None
33.8 (n=23)	10.3 (n=7)	7.4 (n=5)	14.7 (n=10)	17.6 (n=12)

We also conducted a topic word search for the question 'please provide an explanation or list of reasons why you would sometimes wash or rinse city-grown carrots, tomatoes, kale, bell peppers, and/or squash'. 33% of respondents said they sometimes washed these items to remove dirt, 18% stated to remove pesticides, and 7% stated it was what they were taught to do.

Table 10: 'If sometimes or always, what methods do you typically use to wash or rinse city-grown carrots, tomatoes, kale, bell peppers, and any squash'

	Carrots (%)	Tomatoes (%)	Kale (%)	Bell Peppers (%)	Squash (%)
Rinse under running water	32.9 (n=23)	50 (n=35)	50.9 (n=28)	53 (n=35)	49.1 (n=27)
Rub with hands under running water	44.3 (n=31)	37.1 (n=26)	30.9 (n=17)	36.4 (n=24)	41.8 (n=23)
Scrub brush under running water	17.1 (n=12)	7.1 (n=5)	1.8 (n=1)	7.6 (n=5)	7.3 (n=4)
Soak in container of water	2.9 (n=2)	4.3 (n=3)	12.7 (n=7)	1.5 (n=1)	0 (n=0)
Wash with something other than water (e.g. produce spray, vegetable wash)	2.9 (n=2)	1.4 (n=1)	3.6 (n=2)	1.5 (n=1)	1.8 (n=1)
Total	70	70	55	66	55

Table 10 shows different methods of washing carrots, tomatoes, kale, bell peppers, or squash. Most participants either rinsed these items or rubbed these items under running water. Also, fewer participants consumed kale and squash, then bell peppers, tomatoes, and carrots. Very few participants stated they soaked these produce items in a container of water or washed with something other than water.

DISCUSSION

Urban agriculture presents benefits and challenges for environmental health. Studies have shown that urban agriculture sites increase the intake of fruits and vegetables among participants.[111 – 114] However, there is concern regarding the contamination of heavy metals in agricultural soils and its impact on human health.[443] Metals in urban soils can be transferred into humans through ingestion and can pose a health risk to urban residents.[288, 444 – 445] The actual health risks of metals in ingested soil depend strongly on the fraction that is soluble in the gastrointestinal tract available for absorption, so that only a fraction of the total soil metals is human accessible.[446 – 447] There are various heavy metal exposure reduction strategies for both gardeners and consumers, such as using raised beds with clean, imported soil and washing produce.[20] Traditional rinsing should be used in conjunction with other methods to reduce exposure. Water washes off most soil particles and washing crops before eating reduces the potential for transferring heavy metals in soil to humans.[288, 434]

In our study, we found that those who consume urban-grown produce were mostly young, white, had a college degree or greater and consumed the items asked at least once a month. These participants also stated they most often purchased from a farmers' market and mostly 'always' washed their urban-grown produce. Across all sociodemographic groups, we found that more than half of all individuals 'always' washed the produce items surveyed. Additionally, 33% and 36% of participants stated they 'sometimes' and 'mostly', respectively, made purchase decisions based on concerns of food safety, and most respondents felt extremely confident and willing to wash produce.

Studies have found that most urban agriculture initiatives have been led mostly by young, white residents.[50, 56, 107, 118, 395, 448] We found similar results, in that most participants who consumed urban-grown produce were female, white and young (between 25 – 29). Most had at least a college degree or greater, however, there was variation in household incomes among all participants. Additional studies found that many urban gardeners were female and white. A study interviewed 67 people in 29 garden sites in Denver, Colorado and found that most participants were female, white and the average age was 46.8 years.[395] Another study interviewed 8 garden volunteers, 7 of whom were white, however, all had different socioeconomic backgrounds.[50] A study in Flint found that more females participated in a community garden than males and these participants were also mostly white and were a high school graduate.[111]

Where individuals purchase urban-grown produce is important to understand food-purchasing patterns and develop marketing strategies. In our study, an overwhelming number of participants purchased food from a farmers' market. These results reflect the growing popularity of farmers' markets nationwide from 1,775 markets in 1994 and 8,669 markets in 2016. More consumers are deciding to purchase from farmers' markets as a more wholesome food outlet than their retail supermarket.[438] Also, about a third of participants purchased food from an urban farm stand or from a community supported agriculture stand. These results indicate a potential to increase purchasing from these two locations.

For consumer washing practices, studies have found that a higher percent of consumers wash produce compared to those who do no wash.[435, 449] We found that more than half of all individuals, across all socio demographic groups stated they 'always' washed the produce surveyed. The exception is only for one individual, highlighted in table 8. We also found 34% of participants washed produce to remove dirt, followed by 18% of participants who provided no explanation, and 15% of those who wash because it was how they were raised, accustomed to do doing, or out of habit. Verrill found the most common reasons to wash fresh produce were to remove dirt (93%), followed by removal of pesticides (79%) and bacteria or germs (60%).

We found consumers most often rinsed under running water or rubbed the produce item with hands under running water. Only carrots reported a higher frequency of participants rubbing with hands under running water verses rinsing under running water. Carrots have a harder exterior rind, which may encourage consumers to rub with hands while washing. Very few participants reported other methods of washing produce, such as scrubbing with a brush, soaking in a container of water, of washing with something other than water (e.g. produce spray). A previous study found a higher percentage of consumers washed strawberries and tomatoes than cantaloupes and pre-cut, bagged lettuce and concluded that one of the main findings was that consumers reported different rates of washing vegetables and fruits depending on the type of produce.[435]

Consumers obtain information about food safety from various sources and their attitudes toward information on safe produce handling differed by sex, income, education, and age (450 – 451). In our study, we found that most respondents (41%), stated they preferred printed information (i.e. brochure, factsheets, mail); followed by 32% who prefer the media (i.e. social media, television, email), and 17% preferred a consultation with an expert. Across all sociodemographic groups, we observed a difference in household income, with individuals who earn less than $20,00 prefer social media, television, email or radio to receive information and individuals who make between $35,000 - $49,999 prefer printed information. Studies have shown that people with different sociodemographic characteristics perceive food risks in different ways and have different preferences of methods to receive food safety information.[452 – 454]

Food safety risk perceptions and attitudes are related to socioeconomic factors, experiences and culture, and trust in various sources of information.[455] Understanding consumer perceptions of food risk is critical when assessing the actual level of risk to which consumers are exposed when they handle foods[456]. When asked whether consumers made food purchasing decisions based on concerns about the safety of food production in general, most stated they sometimes or mostly make decisions based on concerns about food safety. We identified that fewer participants always make food purchasing decisions based on concerns about food safety and a need for greater food safety education. We also found that older individuals, most often chose that they 'sometime' make purchases based on concerns about food safety. Half of respondents in this category also had a household income of less than $20,000 or $50,000 - $74,999. Researchers have found that consumers generally have a positive food safety perception of urban-grown food.[141, 150] Other research on food safety have found that consumer trust in information about food risks are potential determinants of their food-related behavior.[457] In addition, research has found that personal and indirect food safety experiences substantially affect risk perceptions.[455]

Self-efficacy is the belief in one's own ability to perform tasks and affect outcomes[458] and can predict subsequent motivation and performance[459] relative to specific tasks. Limited studies have been done regarding consumers' confidence and willingness of produce washing. We asked participants about both and found that more than half of all participants stated they are extremely willing to wash produce (62%), and, about 46% stated they are extremely confident in their ability to wash produce, with 23% stating they are very confident. Richards measured self-efficacy of food safety among adolescent populations and found that adolescents feel confident in their ability of personal hygiene (i.e. hand washing), while cross-contamination and cooking/cooling temperatures were areas of lowest self-efficacy.[460] Another study found that young adults especially engage in unsafe food-handling practices[461 – 464] and lacks vital food safety knowledge.[461, 464 – 466] Most of our participants were between ages 25 – 29, thus these previous results could be applied to our study.

Our study had several limitations. We distributed our survey from February through April, a time when there is likely no produce available from urban farms. However, the questions specified whether respondents consumed produce in summertime when produce is seasonally abundant. Thus, our participants could suffer from recall bias. We used convenience sampling approach because it was inexpensive, and participants were readily available. However, convenience sampling is not representative of the entire population, and could thus lead to over-or-under sampling and biased results. We also experienced a disconnect between the locations of survey respondents and the farms where the food was grown. We did not survey participants at other urban produce purchasing locations, such as urban farm food stands, mobile markets, or community supported agriculture locations and limited our sampling location to one farmer's market.

In addition, we did not conduct a pilot study of the survey, which impacts the validity and rigor of the study. Pilot studies represent a fundamental phase of the research process.[467] The purpose of conducting a pilot study is to examine the feasibility of an approach that is intended to be used in a larger scale study.[467] Because we did not conduct a pilot study, there is a lack of standardization for certain survey questions. For example, fewer participants answered questions regarding willingness and confidence of washing produce.

The issues of perception bias, recall bias, interview, bias, and selection bias are other limitations of this study. Perception bias is the tendency to be subjective about people and events, causing biased information to be collected in a study or biased interpretation of the study's results.[468] This affected our study because the interviewer recruited individuals at farmer's markets who had free time to complete the survey, thus limiting the persons involved in the study. Recall bias occurs when participants do not remember previous events or experiences accurately or exclude details. Recall bias is an issue when participants have to self-report, as seen in surveys. Additionally, we encountered selection bias via convenience sampling. We only recruited individuals who were affiliated with urban agriculture initiatives and/or consumed urban-grown produce to take part in the project. Finally, our study was limited to interviewer bias. When we surveyed our first wave of respondents, our risk perception questions may have influenced respondents to continue to answer the survey in a certain matter. Thus, the remainder of our survey questions included in our analysis may have been tainted from the structure of our previous, discarded risk perception questions.

In Baltimore, future studies should be performed to understand the effect of produce washing on urban-grown produce. Several studies have been done in heavily contaminated environments and researchers would benefit from a better understanding of the effects of washing in different environmental backgrounds. In addition, conducting biomarker analysis for specific heavy metals, to understand and quantify the exposure associated with consuming urban-grown produce is needed. Finally, a cohort study for gardeners and consumers of urban-grown produce should be considered to understand latency effect, temporal sequence, and examine multiple effects associated with exposure to urban-grown produce.

CONCLUSION

We surveyed consumers of urban-grown produce on their washing practices, frequency of consumption, communication preferences, and food safety handling. In this sample, most respondents were young, female and white. Respondents stated they 'always' washed the produce items asked, across all sociodemographic groups. Although, we observed a difference in income and communication preferences, with respondents with a higher income preferring printed information and those with a lower income preferring media as a method to receive information of urban-grown produce. We also found that middle-aged persons most often chose that they 'sometimes' make purchase decisions based on concerns of food safety, indicating these individuals may need targeted food safety education interventions. These results could help to identify and create more targeted food education programs and enhance risk communication among growers to consumers.

CHAPTER 5:

CONCLUSIONS

Our results primarily indicate that within a 1-km buffer, most urban farms experience above state average exposures to traffic, lead-based paint from pre-1960s housing, Superfund proximity, diesel particulate matter, and air toxic cancer risk. We found a presence of LRPs and TRI facilities within a 1-km buffer of an urban farm and identified that more residents were unemployed, had less than a high school diploma and had a lower median household income in census tracts that hosted an urban farm and a TRI facility compared to tracts who hosted an urban farm without a TRI facility. We also found that those who consume urban-grown produce were mostly young, white, had a college degree or greater and consumed the items asked at least once a month. These participants also stated they most often purchased from a farmers' market. Across all socio demographic groups, we found that more than half of all individuals 'always' washed the produce items surveyed. We did not find sociodemographic differences in the frequency of persons 'always' washing the items asked. Most participants either 'mostly' or 'sometimes' made purchase decisions based on concerns of food safety, while most respondents felt extremely confident and willing to wash produce.

In this study, we observed an increase in the number of LRPs, TRI facilities, and Superfund sites from a 1-km buffer within an urban farm to a 5-km buffer of an urban farm. We found an increase in Black/African-American residents in those census tracts that host an urban farm within 1-km to 2km buffer and a TRI facility; however, overall the percent of Black/African-American were greater in tracts that did not host a TRI facility. TRI facilities were mostly located in tracts with a lower median household income ($0 - $39,999), a lower percent of Black/African American residents (0 – 24.9%), and in tracts with a variety of educational attainment levels. The percent of individuals receiving SNAP benefits and percent homeownership remained fairly even across all distributions at about 31% and 51%, respectively.

We also found that healthy food priority areas are predominantly located in census tracts with low median household income ($0 - $40,000) and communities of color (>75% Black), and higher percentage of residents with less than a high school diploma (>30%). However, these areas do not have as many clusters of environmental hazards as the southern, more industrial areas of the city. Environmental hazard clusters, specifically LRPs, were located in areas with a higher median household income (>$80,000), a lower percentage of African-American residents (0 - 25%), and a lower percentage of residents with less than a high school diploma (0 – 9.9%).

Wilson found significant burden disparities where more TRI facilities were located in census tracts with higher non-white and low-income populations for the state of South Carolina and metropolitan Charleston.[58] In addition to this work, other researchers have documented similar racial and income disparities among communities hosting TRI facilities.[232, 470] Neumann discovered that TRI facilities were located disproportionately in people of color neighborhoods and in areas with lower incomes compared to those in the surrounding counties.[232] In Baltimore City, however, census tracts made up of White, working-class people are more likely to contain a TRI than primarily Black census tracts.[225] Numerous environmental justice studies conducted at the census tract or zip code level show that marginalized communities, including persons in poverty and people of color, are more likely to live near TRI facilities than Whites and higher-income residents.[58, 233 – 235, 471] Previous analyses and studies have demonstrated that a series of institutions effectively segregated white and black Baltimore and restricted heavy industry through zoning to areas near the harbor[225] and how the present distribution of TRI facilities is related to past land use.[472]

Previous research has found that exposure to mobile sources of air pollution through residential proximity to major roadways increased the risk of adverse health effects[245 – 254] and that persons of color and lower-income individuals may be exposed to higher levels of traffic-related air pollution.[239 – 243] We found the greatest concentration of roads surrounding urban farms to be in the city center. Research has shown that the local settings of urban farms affects trace metal contamination of vegetables crops, with Pb concentrations being higher in leafy vegetables, fruits and roots grown in gardens with higher traffic burdens,[473] even in places where the sale of leaded gasoline has long been banned.[436]

Studies have found that Baltimore's urban soils contain elevated levels of lead.[65, 177 – 178, 180] Root and green leafy vegetables are generally considered more prone to absorb and store lead and arsenic from contaminated soil.[176] Metals in urban soils can be transferred into humans through ingestion of contaminated vegetables and can pose a health risk to urban residents.[288, 444, 474] The lack of proper cleaning procedures, especially for root and low-growing plants, can be a cause of concern.[434] When not properly washed before eaten, plants can expose consumers to contamination.[138]

In our study, we found that most participants (34%) washed produce to remove dirt, followed by participants who provided no explanation (18%), and those who rinse because it was how they were raised, accustomed to do doing, or out of habit (15%). We also found that consumers most often rinsed or rubbed the produce item with hands under running water, and only carrots reported a higher frequency of participants rubbing with hands under running water verses rinsing under running water. Carrots have a harder exterior rind, which may encourage consumers to rub with hands while washing. Very few participants reported other methods of washing produce, such as scrubbing with a brush, soaking in a container of water, of washing with something other than water (e.g., produce spray).

We observed sociodemographic differences in responses to questions regarding communication preferences and food safety purchasing decisions. Individuals who earned less than $20,000 preferred social media, television, email or radio and individuals who make within $35,000 - $49,999 prefer printed information as the primary way to receive information about their urban-grown food. For purchasing decisions, older individuals, ages 30 – 34 most often ‘sometimes’ made purchases based on concerns about food safety, while younger individuals, ages 18 – 24, ‘always’ and ‘mostly’ made purchase decisions based on concerns about food safety. Sociodemographic differences were also found regarding produce consumption and washing practices. Males were found to consume less produce than females; however, fewer males were surveyed in this study. Income categories of between $75,000 and over $100,000 were the highest group to consume local produce once a week or more. The income group of less than $20,000 had the lowest percent of consuming local produce once a week or more. Additionally, incomes of less than $20,000 were observed to ‘always wash’ squash less often than other produce items measured. Individuals between 25 – 29 were found to ‘always’ wash the produce items asked less frequently than other age groups. All categories measured, except two income and one race category, have over 50% of participants always washing the five produce items analyzed.

Understanding consumer perceptions of food risk is important when assessing the actual level of risk to which consumers are exposed when they handle foods[456]. When asked whether consumers made food purchasing decisions based on concerns about the safety of food production in general, most stated they sometimes or mostly make decisions based on concerns about food safety. We identified that fewer participants always make food purchasing decisions based on concerns about food safety and a need for greater food safety education. Other research on food safety have found that consumer trust in information about food risks are potential determinants of their food-related behavior.[457, 475] Limited studies have been done regarding consumers' confidence and willingness of produce washing. We asked participants about both and found that more than half of all participants stated they are extremely willing to wash produce (62%), and, about 46% stated they are extremely confident in their ability to wash produce, with 23% stating they are very confident.

There are health consequences associated with the ingestion of urban-grown produce contaminated with heavy metals; however, this contribution is dependent on the percentage of the diet made up of lead-laden homegrown vegetables and the type of vegetable preparation (e.g., washing, peeling)[449]. The actual health risks of metals in ingested soil depend strongly on the fraction that is soluble in the gastrointestinal tract available for absorption, so that only a fraction of the total soil metals is human accessible.[444] In most cases, the toxicity of an ingested chemical depends, in part, on the magnitude to which it is absorbed from the gastrointestinal tract into the body.[476] Metals can exist in a variety of chemicals and physical forms and not all forms of a given metal are absorbed to the same extent.[476]

Specifically, adults absorb approximately 11% of ingested lead[477] and excrete approximately 50–60% of that ingested over the short term and an additional 25% over many months, with the excretion rate dependent on the total body burden of lead.[478] Children, however, can absorb anywhere from 30 to 75% of ingested lead[477] and an infant can excrete much less than adults.[479] Pregnant women who ingest contaminated foods can transfer lead to the fetus.[480] Also, for pregnant mothers, lead stored in bones is mobilized and made available to transfer to the fetus during pregnancy.[63] The consumption of lead contaminated root crops, leafy vegetables and herbs may contribute to the total body burden of lead.[63]

The evidence is clear that many communities – predominantly low-income, urban communities of color and rural areas – lack adequate access to healthy food, and the evidence also suggests that the lack of access negatively impacts the health of residents and neighborhoods.[33] These findings indicate that policy interventions to increase access to healthy food in ‘food deserts’ will help people eat a healthy diet, while contributing to community economic development.[33] Improving access to healthy food is a critical component of an agenda to build an equitable and sustainable food system[33]. Urban agriculture initiatives could reduce food insecurity and may improve dietary intake among urban residents.[69, 111 – 113, 138]

Baltimore City has urban agriculture policies to ensure soil safety guidelines. The soil safety policy requires for sites intended to grow food to test for lead, arsenic, cadmium, and chromium and to conduct a risk assessment to test for additional contaminants. The soil safety guidelines pertain specifically to lead and can be found in the appendix. Sites that test for lead levels at 400-999 ppm represents low to moderate risk and are not required to perform site remediation, but best practices must be followed. EPA recommends that soil lead levels less than 400 mg/kg are generally safe for residential use.[481] However; some researchers have recommended complete abstinence from consumption of vegetables grown in soils with Pb concentrations exceeding 400 ppm [63]. Finster recommended that soils with Pb levels from 400 to 1,000 ppm should not be used for gardening. Defoe recommended for urban gardens with Pb concentrations between 700 – 1,900 ppm, to cultivate vegetables in raised beds.[63] Because urban gardens may vary according to contamination source and complexity, soil physical/chemical characteristics, and the availability of remediation resources,[434] we encourage the use of site-specific risk assessments to determine any potential risk to human health.

Community gardens and urban agriculture have largely shown a benefit of urban farms for improving neighborhood aesthetics,[49] community development,[51, 57] social capital,[55, 57, 119] improving neighborhood property values,[136] and providing a safe area for community members to participate in a physical activity.[49] Furthermore, urban agriculture initiatives can offer affordable and convenient access to fresh produce, particularly for urban residents with limited access to supermarkets.[31, 53, 91, 111, 429] However, urban soils often have elevated concentrations of lead and other contaminants due to historic human activities.[174] Gardening and related activities can increase the potential for adults and children to be exposed to soil contaminants through incidental soil ingestion, produce consumption, and other pathways.[428] It is important to recognize environmental sources of heavy metal exposure, such as urban garden soil, in urban communities and take steps to minimize exposures.[176]

Community-based public health education interventions should be offered to gardeners and residents. Community garden leaders and neighborhood officials should offer resources about soil contamination to residents interested in community gardening.[156] Previous research suggests that local groups, such as agricultural extension offices, community gardening networks, or the city government offices are appropriate sources to disseminate information regarding soil contamination.[140] Training on best practices for growing and handling produce has also been shown to be beneficial for neighborhood residents, especially in minority urban areas.[156] Non-profit organizations have utilized training exercises to engage young people from urban, low-income and people of color neighborhoods to cultivate their own produce.[482] This strategy could encourage more people of color to participate in community gardening.[156] We encourage community-based organizations (CBOs) seeking to obtain information on the spatial distribution of LULUs to study the negative health impacts of these sites as part of a comprehensive community revitalization program.[221]

LIMITATIONS

With reference to specific aim #1, we used proximity as a measure of environmental contamination. No biomarker analysis, plume modeling, soil sampling or air sampling was conducted to identify and/or quantify exposure. Location has been used in epidemiological studies to explore associations between health effects and industrial pollution;[216] however, there are limitations. Exposure assessment emphasizes toxic and persistent pollutants, cumulative exposures from multiple sources (including non-point and mobile source emissions), and susceptible populations.[484] As a result, the source-receptor pathways that relate emissions to exposures are increasingly variable and complex.[484] There are many pathways, sources, locations and activities that influence exposures, so that exposure estimates based on location may be highly uncertain. [484] Future studies can better assess exposure by conducting biomarker analysis, to measure and evaluate specific toxins in the body.

With reference to specific aim #2, we were unable to plot the locations of community gardens and thus, we could not quantify nor map how many community gardens were in Baltimore City. Some gardens are listed online while others are not. To identify all community gardens, requires knowledge of local projects via networks and partnerships with community-based organizations. While some community gardens produce a significant amount of food, that food is usually grown for personal consumption or donation and is not typically sold to customers.[483] Also, there is difficulty when constructing the definition of a 'Healthy Food Priority Area' when using a cross-sectional study. Stores, especially small and independently owned, change ownership or go in and out of business frequently.[46] This could impact the development of the 'Healthy Food Priority Area' definition which includes the Healthy Food Availability Index (HFAI) score for supermarkets and corner stores. We were unable to conduct a statistical analysis to evaluate significant among the mean distributions Future studies should consider investigating the spatial distribution of community gardens in relation to environmental hazards.

Additionally, we may not have a complete dataset of TRI facilities or LRPs. Some LRPs encompass several acres in Baltimore City; however, we only represented their presence by a single point on the maps, which may be misleading. Also, the US EPA does not require smaller industrial facilities to report toxic releases.[485] Theoretically, cumulative effects of smaller non-TRI-reporting facilities might outweigh the individual effect of larger (but fewer) TRI-reporting facilities.[485] Also, the TRI database does not address environmental fate and transport of industry emissions using modeling and other analytical techniques.[485] We also lacked a statistical analysis to evaluate the significance of mean distribution of sociodemographic measures by urban farm and TRI facility buffer zones. Future studies should consider analyzing the spatial distribution of community gardens and farms by environmental hazards, to have a better understanding of the distribution of these hazards in relation to all urban agriculture projects.

With reference to specific aim #3, because of the cross-sectional nature of our study, causality between the association of consumption and exposure cannot be inferred. In addition, we experienced non-response bias for some survey questions. This impacted the validity and rigor of our survey because some questions had fewer responses than others. Additionally, survey questions which ask respondents to rate the degree to which they consume urban-grown produce, may not accurately measure consumers' real produce consumption frequency. Survey respondents may respond inaccurately or just guess their produce consumption frequencies. In addition, social desirability bias (i.e., the participants' tendency toward a perception of what is "correct" or socially acceptable) may affect variable means and cause misleading results when they self-report general food safety perception.[494] For instance, the question "How confident are you that you are able to wash produce?" is considered socially desirable as everyone should follow good food safety practices. Yet, some consumers may not actually utilize proper food safety practices, even though they are likely to respond favorable to this statement.[150] Our small population size did not allow our results to be generalizable to a larger population. We also used a convenience sampling approach that limited the representatives of our sample of African-American adults in Baltimore City.

Finally, there were barriers to constructing risk perception questions in relation to urban-grown produce handling behaviors. Thus, we were unable to explore how individuals perceive urban-grown food. Studies are needed to explore risk perception in relation to urban-grown food because individuals may view and handle this produce differently, which may result in improper food handling and cause adverse health effects. Furthermore, this type of research is especially important for vulnerable populations, such as children and pregnant women. We experienced a disconnect between those who were surveyed and those who consume urban-grown produce. We do not trace back who consumed what products and from which urban farm. Future studies should conduct better survey recruitment, by surveying consumers of urban-grown produce at urban farm stands, mobile markets, community supported agriculture stands, public markets, and additional farmers' markets. Currently, 13 farms sell at least one farmers market and 4 farms sell at more than one farmer's market. Two farms sell at one public market, two farms sell through a mobile market and six farms have a farm stand on site. Of the 19 food producing farms, there are approximately 262 community supported agriculture members. These locations can help connect researchers to their consumer of interest. There is also an issue of contamination uptake versus contamination settling of the outer layers of produce. It is difficult to assess how much of the contaminant is taken up by the produce item and how much of the contaminant is settled on the outer layers, and whether washing results in a significant reduction of contaminants. Future studies should consider risk assessments to examine the effect of washing on contaminant concentrations in different produce samples. Finally, future studies can better assess diet through food frequency questionnaires and/or food diaries. These tools will better capture consumption frequency.

RECOMMENDATIONS

Further community engagement and environmental health education interventions are needed at urban farms. Educating gardeners and participants of soil contaminants in urban soils will help make more informed decisions regarding exposure prevention and remediation strategies. Environmental health education programs must promote health literacy, by helping communities make informed choices to reduce hazardous exposures. Environmental health literacy (EHL) support individuals in making informed decisions that can reduce health risks and ultimately increase their quality of life.[166] Effective efforts to raise EHL must make risk messaging understandable and relevant to individuals, and they must provide not only the results of research but also address existing misinformation and misperceptions.[486] Community-engaged research approaches can enhance trust between community members and academic research institutions by incorporating community input to community-specific research efforts.[166]

Because community gardens are not growing food to be sold, they are not upheld to the same soil testing standards as urban farms. Regular soil testing at community gardens should be conducted to monitor the levels of contaminants. More research on potential exposures to soil contaminants from garden soils, in crop tissues, and on the surfaces of produce, and the effectiveness and feasibility of various soil remediation techniques. Additionally, physical measures may also be taken to reduce contamination exposure, such as utilizing raised beds with clean, imported soil, and regular testing of soil. Buffer strips may be used to filter storm water contaminants before reaching food production areas.[60] Certain cultivation methods, such as indoor or soil-free hydroponics operations, may also be used to avoid contaminant exposure.[115] Government support for conducting, interpreting, and funding such efforts could help ensure that the most vulnerable are not exposed to these risks and associated poor health outcomes.[115]

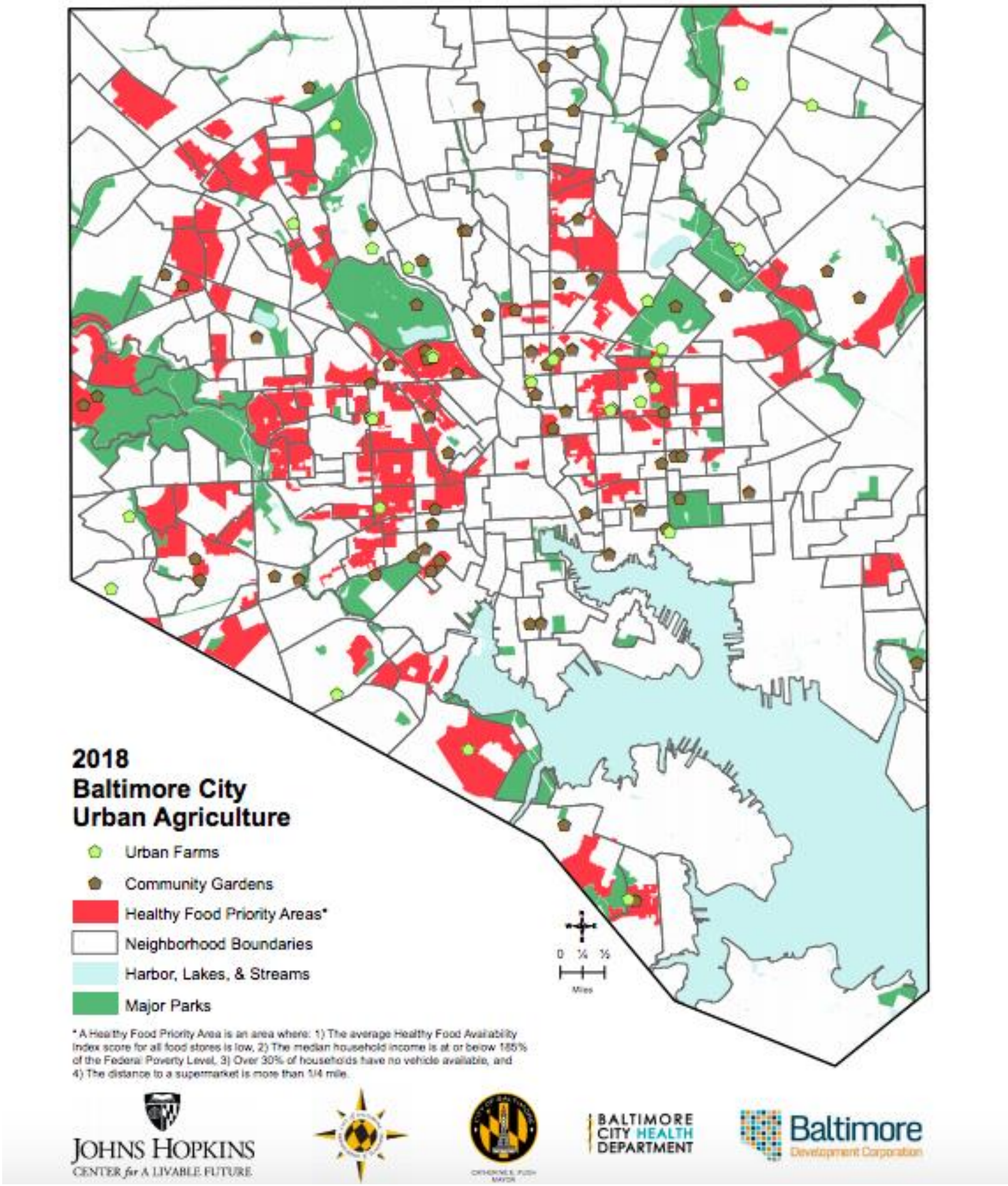
Finally, there are policy-related recommendations. The brownfields law, H.R. 2869, has a health-monitoring aspect that was enacted in January 2002[487]. The law allows a local government to spend up to 10% of a brownfield grant for, 'monitoring the health of populations exposed to one or more hazardous substances from a brownfield site; and monitoring and enforcement of any institutional control used to prevent human exposure to any hazardous substance from a brownfield site'.[196] Although the EPA encourages communities to conduct health-monitoring activities through brownfield funding, the number of communities that implement health-monitoring programs is still small.[487] In fiscal year 2009, less than 5% of brownfield applicants proposed community health monitoring in their funding proposals.[487] Developers in Baltimore should utilize the 10% of a brownfield grant for population health monitoring.

Site specific risk assessments need to be conducted in residential areas near TRI facilities, Superfund sites, or LRP sites where home and community gardens are located to identify substances of concern.[287] To establish potential human risk, comparisons with the EPA established soil screening levels for human ingestion of soil and the natural background soil metal concentrations for targeted urban agriculture sites should be investigated. By identifying priority substances of concern, public health officials and environmental regulators, together with affected communities, can develop strategies for biomonitoring or area monitoring if they deem it necessary to better understand population exposures.[201] Finally, enforcing stricter soil safety policies may be necessary for sites intended to grow food. Soil levels above 400 ppm are not required to perform remediation; however, caution should be used. The EPA has no consensus on a reference dose for lead, and soil levels above the 400 ppm could be a cause for concern for certain populations.

Systematic studies of soil contamination on vacant land are needed to protect the public from potential risks associated with urban agriculture.[62] A better understanding of soil contamination is warranted because many people congregate and spend time at these locations, including gardeners and the public of all ages. Environmental health tracking information can protect communities over the long term by setting standards for each urban farm.

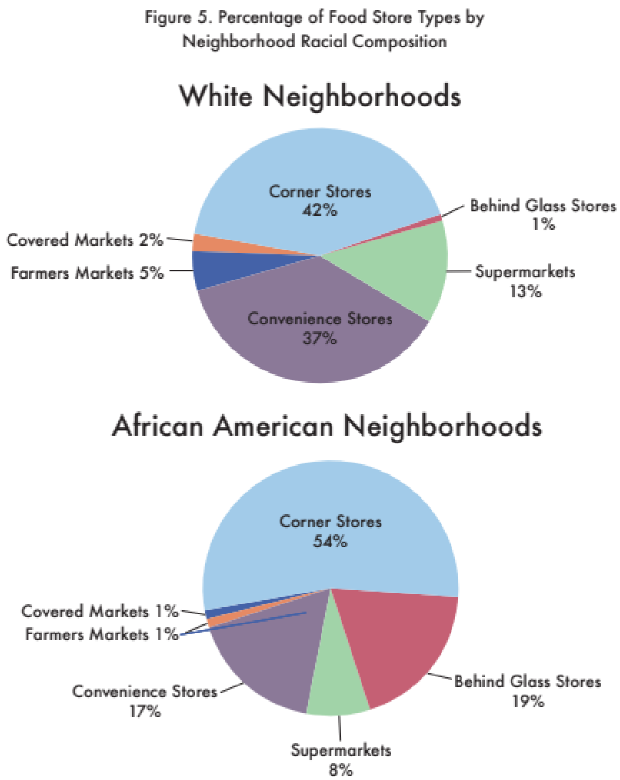
Appendix 1: Figures and Tables

Figure 1: 2018 Baltimore City Food Map



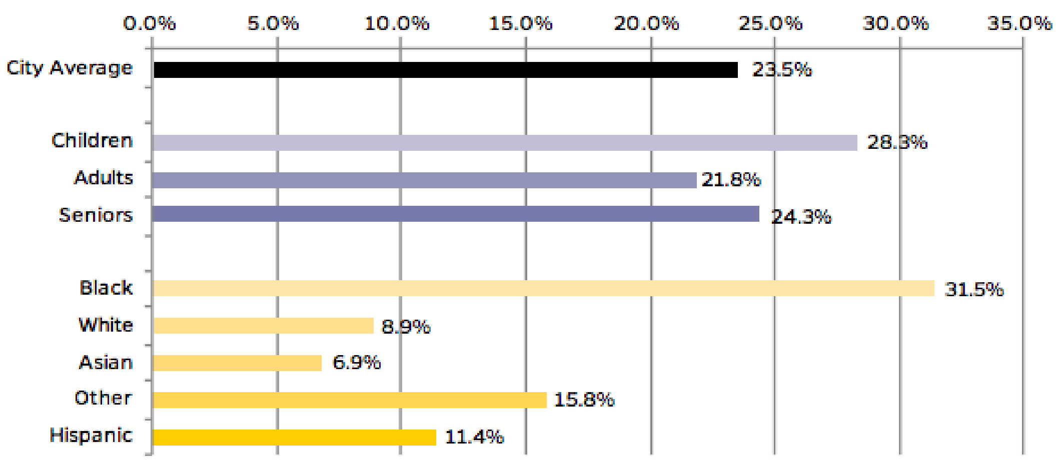
Actual Table
Source: Baltimore City Food Environment. 2018 Report (2018). Retrieved February 19, 2018, from https://planning.baltimorecity.gov/baltimore-food-policy-initiative/food-environment

Figure 2: Percentage of Food Store Types by Neighborhood Racial Composition



Actual Table
Source: Haering, S., Franco, M. (2010). The Baltimore City Food Environment. Johns Hopkins: Center for a Livable Future.

Figure 3: Percent of Population Group Living in a Healthy Food Priority Area



Actual Table
Source: Baltimore City Food Environment. 2018 Report (2018). Retrieved February 19, 2018, from https://planning.baltimorecity.gov/baltimore-food-policy-initiative/food-environment

Table 1: Store Types Located Inside and Outside of Healthy Food Priority Areas

	Stores located in Healthy Food Priority Areas		Stores located outside of Healthy Food Priority Areas	
	Number	Average HFAI	Number	Average HFAI
Supermarkets	N/A	N/A	47	27.7
Small Grocery and Corner Stores	103	7.5	422	9.5
Convenience Stores	6	8.8	177	9.3
Public Markets	0	0	6	14.0

Table 4: Store Types Located Inside and Outside of Healthy Food Priority Areas

Actual Table
Source: Baltimore City Food Environment. 2018 Report (2018). Retrieved February 19, 2018, from https://planning.baltimorecity.gov/baltimore-food-policy-initiative/food-environment

Table 2: Lead Guidelines

0-50 parts per million (ppm)	or below of lead is equivalent to background levels of lead in soils and is of negligible concern. No action is required in your Soil Safety Plan.
50-400 ppm	of lead represents low risk, and is suitable for food production. However, if children directly ingest soil, they may be at some risk. Consider following the best management practices described below, especially if children will be at the site. No action is required in your Soil Safety Plan.
400-999 ppm	ppm of lead represents low-moderate risk. Best practices must be followed, as described below, and must be listed in your Soil Safety Plan. Remediation is recommended but not required.
1,000-2,000 ppm	represents moderate-high risk. In addition to best management practices, your Soil Safety Plan must include remediation, as described below.
2,000 ppm or greater	is high risk. You must bring in clean soil from an outside source and maintain a strict plan to prevent that soil from becoming contaminated, as well as to prevent human exposure to the existing soil. These measures must be described in your Soil Safety Plan. You may also wish to consider using a different site.

Actual Table:
The City of Baltimore's Soil Safety Policy for Food Production. Retrieved June 11, 2018, from https://www.baltimoresustainability.org/projects/baltimore-food-policy-initiative/homegrown-baltimore/urban-agriculture-2

Appendix 2: EJ Screen Indicators and Environmental Contamination

EJSCREEN Indicators

EJSCREEN is an environmental justice screening and mapping tool developed by the US EPA and was first released to the public in the year 2015, replacing the tool EJView.[496] The tool consists of a nationally reliable dataset and an approach for combining environmental and demographic indicators.[496] EJ provides 12 indicators that can be grouped into three categories, potential exposure, proximity exposure, and hazard/risk.[496] They were calculated using US EPA, Department of Transportation (DOT), and Census/American Community Survey (ACS) data. In 2016, the second version of the tool was released to the public with the most recent data and with several new features. The tool provides demographic and environmental information for the user selected geographic areas. EJSCREEN has census block resolution and allows the user to report on a known geography by block group, tract, county, or city or select a location by drawing a site or entering coordinates.

We developed a 1-km, 2-km, and 5-km buffer with air toxics cancer risk, diesel particulate matter level in air, traffic proximity and volume, lead paint indicator, and proximity to National Priority List (NPL) sites around each urban farm in Baltimore City via EJSCREEN. We evaluated the values of five environmental indicators, in comparison to the Maryland state average to understand how Baltimore City compares to the rest of Maryland. Finally, we developed a 1-km box and whisker plots to display the distribution of the observed values of the five environmental indicators.

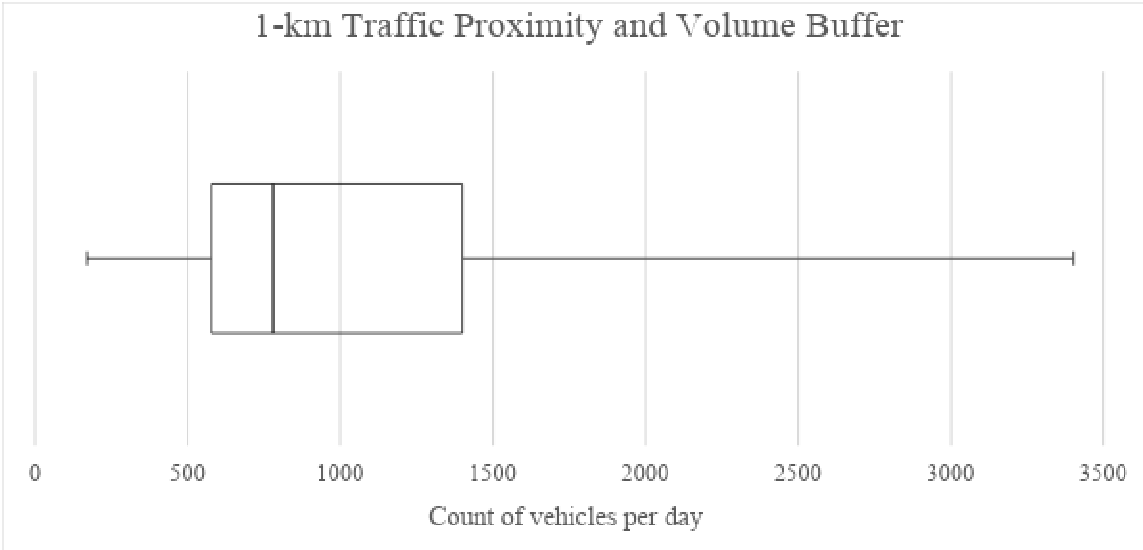
Table 1: Urban Farms and Traffic Proximity and Volume within 1-km, 2-km and 5-km buffer of an urban farm

	Count of Urban Farms		
Daily Traffic Count/Distance to Road	1-km	2-km	5-km
200– 580	6		
581 – 799	7	4	2
800 – 1200	3	7	6
1200>	8	13	16

Traffic proximity and volume is defined as the count of vehicles per day (average annual daily traffic) at major roads within 500 meters (or nearest one beyond 500 m), divided by distance in meters. Calculated from U.S. Department of Transportation National Transportation Atlas Database, Highway Performance Monitoring System, 2014, retrieved 4/2015.

All environmental indicators measured by EJ Screen were above the Maryland state average. The average daily traffic count within a 1-km buffer of an urban farm was almost double the Maryland state average at 1106 vehicles versus 580 vehicles per day. Eight out of twenty-four urban farms had an average daily traffic count of over 1200 vehicles within the 1-km buffer. Eighteen farms were above the Maryland state average within a 1-km buffer and all farms were above the state average within a 2-km and 5-km buffer. The average count of vehicles per day was about the same, 1263 and 1261, within a 2-km and 5-km buffer, respectively.

Figure 1: Box and Whisker plot of 1-km Traffic and Volume Buffer



Within a 1-km buffer of an urban farm, our lowest observation was about 200 vehicles per day. Quartile one, represents the median of the data points to the left of the median and is about 600 vehicles per day. The median is the mean of the middle two numbers, which is about 800 vehicles per day and the third quartile is the median of the data points to the right of the median, which is about 1400 vehicles per day. Finally, our highest observation was nearly 2400 vehicles per day. The figure above has a longer box, indicating a greater interquartile range. Most samples fell above the median of 800 vehicles per day within 1-km of an urban farm. Our box plot was skewed to the right, meaning the mean was greater than the median.

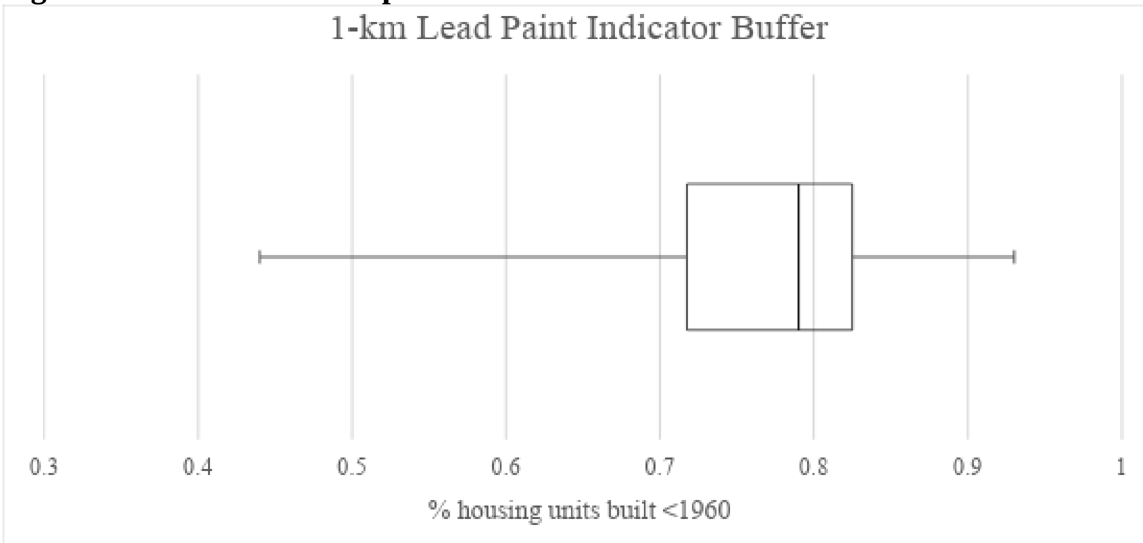
Table 2: Urban Farms and Lead Paint Indicator within 1-km, 2-km, and 5-km of an urban farm

	Count of Urban Farms		
% pre-1960s Housing	1-km	2-km	5-km
0 – 30%			
31 – 49%	1		
50 – 74%	10	10	12
>75%	13	14	12

Lead Paint Indicator is defined as the percent of housing units built before 1960, as indicator of potential exposure to lead paint. Calculated from the Census Bureau's American Community Survey 2011-2015.

Most urban farms within a 1-km buffer had an average of over 75% of housing built pre-1960s. Within a 1-km, 2-km, and 5-km buffer, all farms were above the Maryland state average of 30% of housing built before the 1960s. The average percentage of pre-1960s housing was almost the same at 75% for within a 1-km, 2-km and 5-km buffer of an urban farm.

Figure 2: Box and Whisker plot of 1-km Lead Paint Indicator Buffer



Within a 1-km buffer of an urban farm, our lowest observation was around 45% of housing units were built before 1960. This value was above the Maryland state average of 30% of housing units built before 1960. Quartile one, represents the median of the data points to the left of the median and was almost 72%. The median is the mean of the middle two numbers, which was about 78% and the third quartile is the median of the data points to the right of the median, which was about 83%. Finally, our highest observation was almost 93% of housing units were built before 1960 within a 1-km buffer of an urban farm. Both the traffic and lead paint box plots have longer whiskers, representing a greater range for the overall sample. The box for % housing units built before 1960 was small, meaning most data points fall within the interquartile range. Finally, our box was skewed left meaning the mean was less than the median.

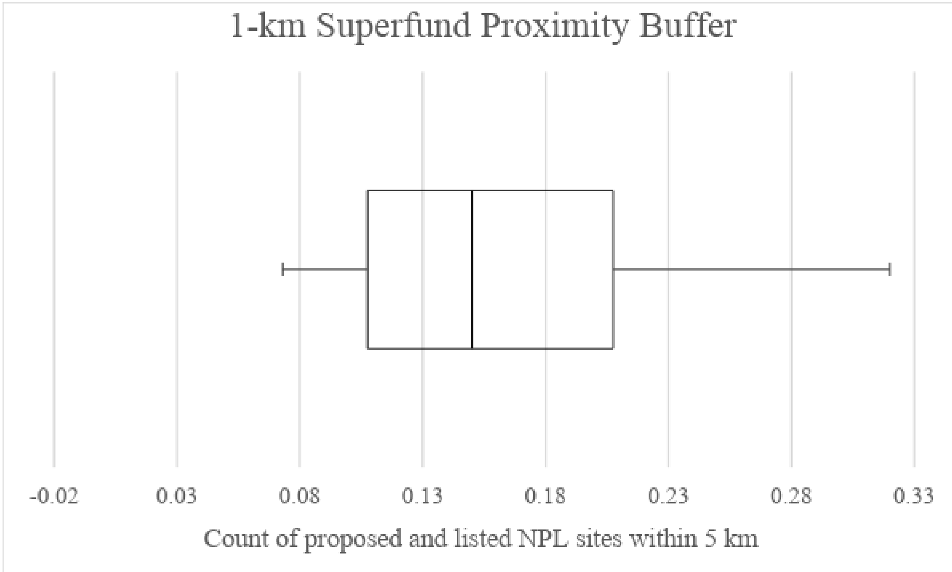
Table 3: Urban Farms and Superfund Proximity within 1-km, 2-km, and 5-km of an urban farm

	Count of Urban Farms		
Site count/km distance	1-km	2-km	5-km
0 – 0.13	10	10	10
0.14 – 0.19	7	6	2
0.2 – 0.29	6	6	10
0.3>	1	2	2

Superfund proximity is defined as the count of proposed and listed NPL sites within 5 km (or nearest one beyond 5 km), each divided by distance in km. Count excludes deleted sites. Source: Calculated from EPA CERCLIS database, retrieved 12/05/2016.

Fourteen urban farms were above the Maryland state average of Superfund proximity, defined as the count of proposed and listed NPL sites within 1-km, 2-km and 5-km. However, the average site count increased over the 1-km, 2-km and 5-km buffer, from 0.16 count of sites/km within a 1km buffer to 0.18 count of sites/km within a 5km buffer. Superfund proximity had the least number of urban farms above the state average within either a 1-km, 2-km or 5-km buffer, compared to the other environmental indicators.

Figure 3: Box and Whisker plot of 1-km Superfund Proximity Buffer



Within a 1-km buffer of an urban farm, our lowest observation was a count of 0.08 proposed and listed NPL sites within 5 km. Our distribution was slightly skewed to the right, meaning the mean was greater than the median. Our highest observation was about a 0.32 count. About half of our distributions fall below the median and the other half fall above the median.

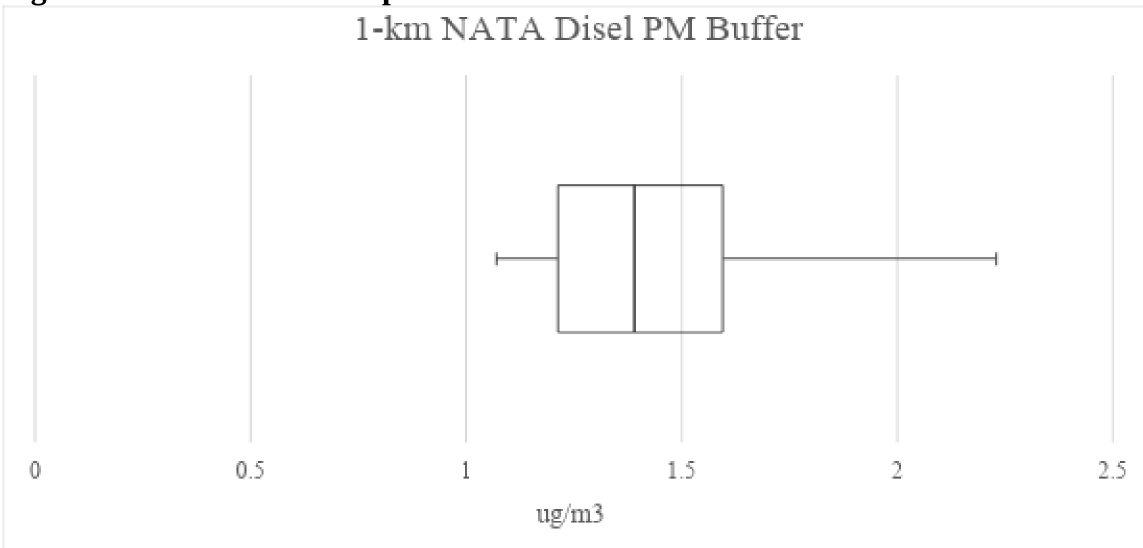
Table 4: Urban Farms and NATA Diesel PM within 1-km, 2-km, and 5-km of an urban farm

	Count of Urban Farms		
ug/m3	1-km	2-km	5-km
≤1.1	1	1	
1.2 – 1.39	12	7	7
1.4 – 1.59	5	9	14
1.6>	6	7	3

NATA diesel PM is defined as diesel particulate matter level in air in micrograms per cubic meter (ug/m^3). Source: EPA 2011 National Air Toxics Assessments.

The average diesel particulate matter level in air (ug/m^3) decreased as buffer distance increased. Within 1-km of an urban farm, most farms had between 1.2 – 1.39 ug/m^3 DPM. Most farms within a 5-km buffer had between 1.4 – 1.59 ug/m^3 DPM; however, less farms had higher levels of diesel particulate matter (1.6 ug/m^3>), compared to farms within a 2-km and 1-km buffer. Almost all urban farms were above the state average of 1.1 ug/m^3 within a 1-km and 2-km buffer and all farms were above the average within a 5-km buffer.

Figure 4: Box and Whisker plot of 1-km NATA Diesel PM Buffer



Our box plot was skewed to the right, meaning the mean was about greater than the median. Our highest observation of diesel particulate matter was about 2.3 ug/m^3. Half of our observations fell below the median and the other half fell above. Our lowest observation was about 1.0 ug/m^3.

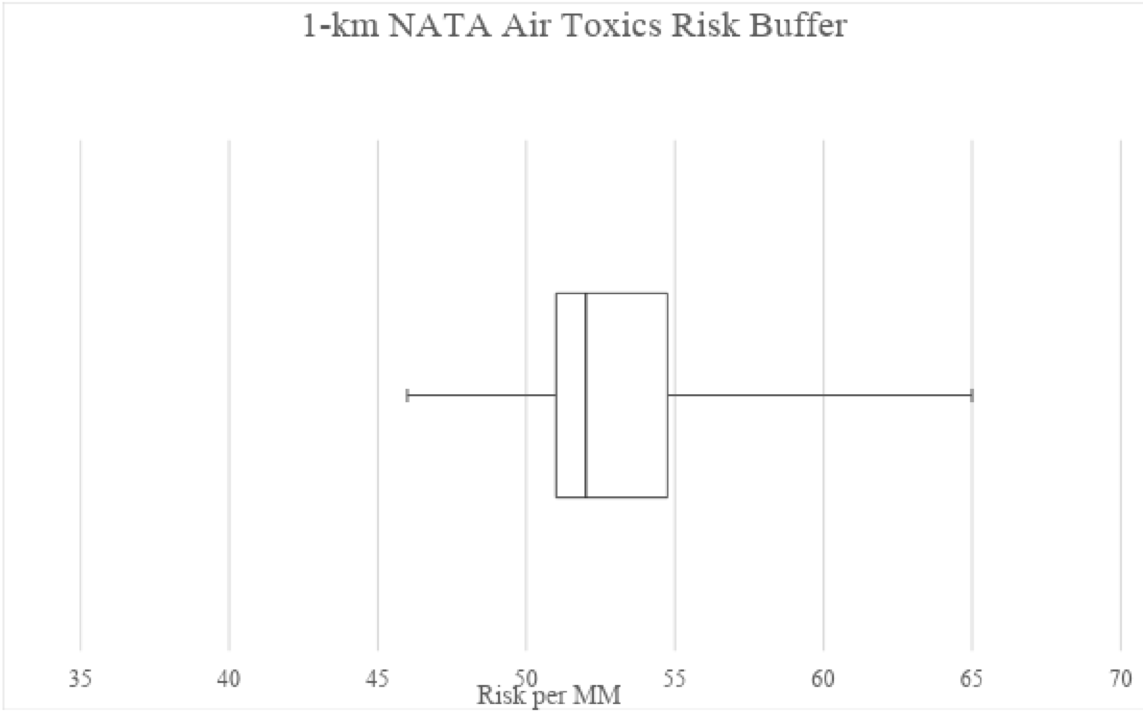
Table 5: Urban Farms and NATA Air Toxics Cancer Risk within 1-km, 2-km, and 5-km of an urban farm

	Count of Urban Farms		
risk per million	1-km	2-km	5-km
≤45			
46 – 51	8	6	4
52 – 57	12	17	20
57>	4	1	

NATA Air Toxics Cancer Risk is defined as lifetime cancer risk from inhalation of air toxics, as risk per lifetime per million people. Source: EPA 2011 National Air Toxics Assessment.

Within a 1-km, 2-km or 5-km buffer, all farms were observed to be above the Maryland state average for air toxics cancer risk. Most farms had an air toxics cancer risk between 52 – 57 per million people, while the Maryland state average is 45 per million people. The average risk was the same at 53 per million for all buffers.

Figure 5: Box and Whisker plot of 1-km NATA Air Toxics Cancer Risk



Our boxplot is tightly knit, meaning most data points fell within the interquartile range. It was slightly skewed to the right, indicating our mean was greater than our median. Quartile one, represents the median of the data points to the left of the median and has an average air toxic risk of 51 per million people. The median is the mean of the middle two numbers, which was about 52 per million people and the third quartile is the median of the data points to the right of the median, which was about 54 per million. Finally, our highest observation was an average air toxic risk of 65 per million people.

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