Soil Contamination and its Uptake in the Crops of Urban Agricultural Yields.

Abstract

Food deserts impact millions of Americans and some see urban agriculture as a means to alleviate this impact. Soil contamination is a nearly ubiquitous reality in the urban setting, posing a challenge for those interested in undertaking urban agriculture projects as possibly tainted crops stand to threaten those that are positioned to benefit from this effort. Understanding soil contamination and how certain food crops interact with these contaminants may reveal a safer path forward for those involved.

1 Introduction

1.1 Food Deserts and Equity

Food deserts are a region where a large amount of the local population, typically the lower income, lack adequate access to affordable and healthy food options [1]. Often, this inadequate access is due to one or more socio-economic factors such as the far location of retail grocery stores, the inability to travel to such stores, or the lack of means to purchase a healthy food option as depicted in Figure 1. According to the USDA, approximately 23.5 million people live in low-income areas more than one mile from a supermarket. When considering low-income rural communities, 1.1 million people are more than 10 miles from a supermarket [2]. Providing all families access to nutritious diets is imperative to improving their health and lowering their rates of chronic disease.

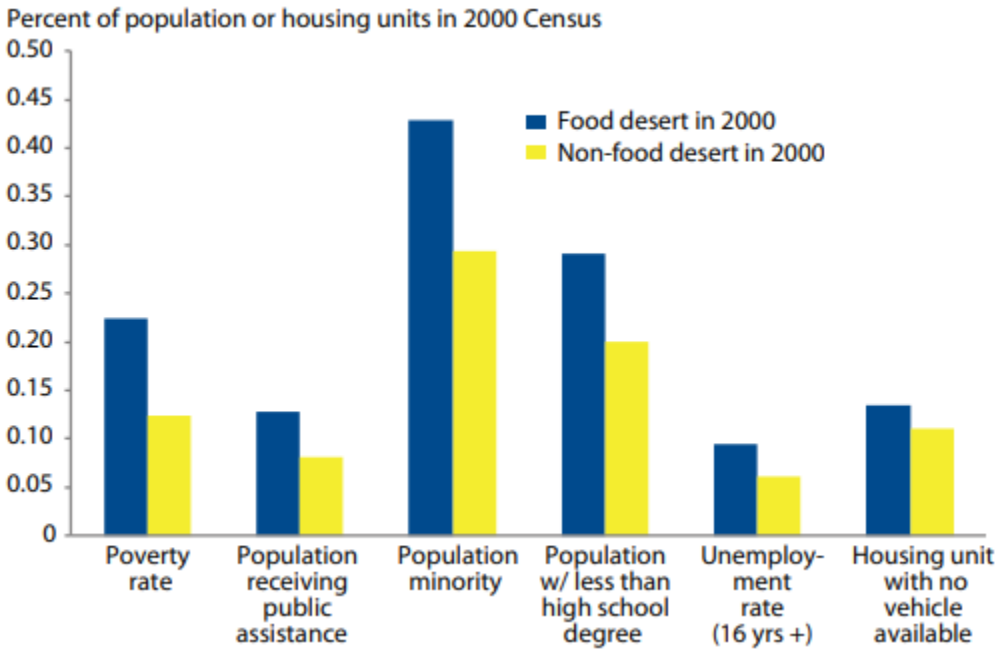

Figure 1. *Mean Characteristics of Food Deserts Versus Other Tracts, Census 2000[1].*

Research by the USDA's "Food Atlas" program, including a tool designed to help community leaders identify food deserts in their area, shows that while the number of retail grocery stores is increasing food insecurity in the U.S. is also increasing [3].

Several factors including discrimination-based zoning and redlining—a discriminatory practice that involved denying financial services to neighborhoods with large populations of racial and ethnic minorities—can help explain why more retail grocery stores being built is not leading to more access for certain communities resulting in non-white and lower income communities more often impacted by food deserts.

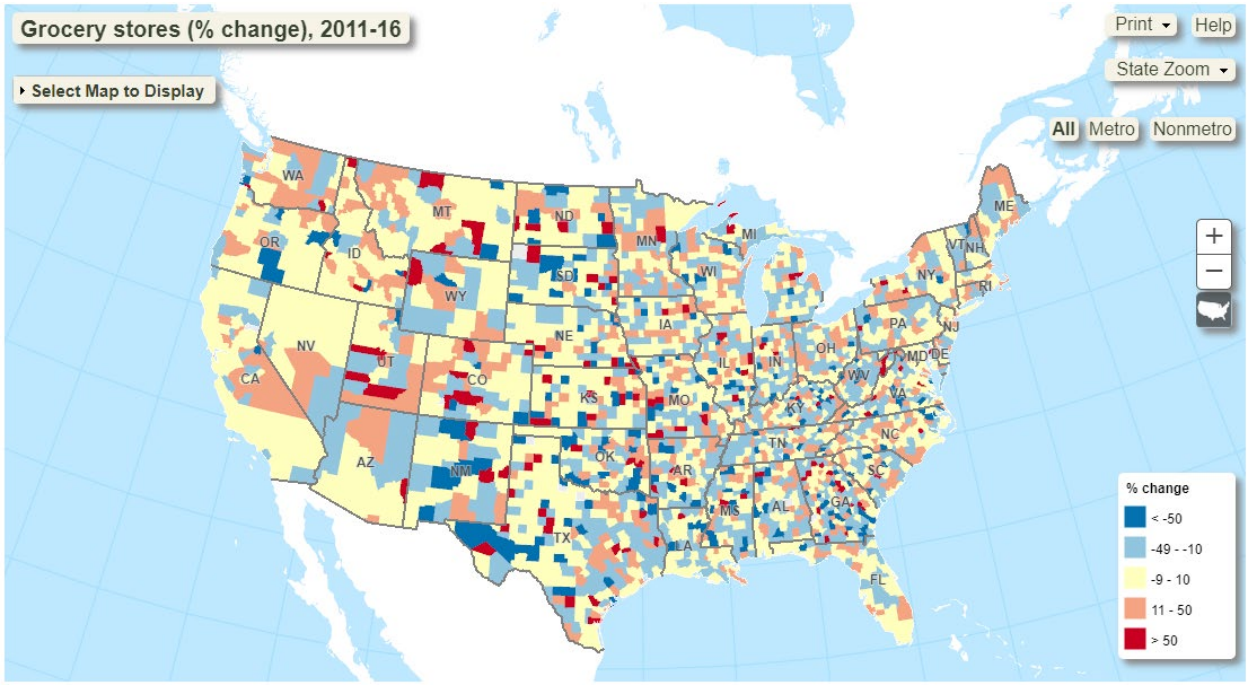

Figure 2 *(top). Number of Food Store Types by Year. All store types saw an increase in number, except specialized food stores [3].* ***Figure 3*** *(bottom). Grocery stores (% change 2011-16) [2].*

1.2 Urban Agriculture as a Solution to Food Deserts

While government agencies have acted to reduce the impact of discriminatory policies resulting in food deserts, it is clear that more must be done to alleviate the inadequate food access, and case studies have found that urban agriculture can positively impact fruit and vegetable availability[4]. Urban agriculture can be one solution to food deserts which may utilize government funding, but can also be achieved by smaller organizations and individuals often characterized by grassroots movements and populations historically discriminated against.

1.3 Soil Contamination Related to Historic and Poorer Neighborhoods

Proper care must be taken prior to considering starting a new urban agriculture project at any location. The higher probability of contaminated topsoil in urban settings demands further investigation of each proposed site to prevent dire adverse health effects. Toxic metals—including Cr, Cu, Ni, Pb, and Zn—are commonly deposited in urban environments via anthropogenic activities.

1.4 Crop Uptake of Contaminants Poses a Threat to Urban Agriculture and Those That Consume its Yields

If urban agriculture is to be employed to alleviate food deserts, soil health must be rigorously considered. Urban soils typically contain contaminants like lead, zinc, cadmium, copper, and barium (Pb, Zn, Cd, Cu, and Ba) at higher rates than environmental background soils. Additionally, in historically urban and impoverished communities rates are higher for these contaminants. Even more consideration must be given to the types of crops grown in these community gardens. Different food stuffs and vegetable crops uptake

common contaminants at different rates. Unfortunately, some of the worst vegetables to grow in contaminated soils often top the list of community garden yields.

2. Discussion

2.1 Government Action and the Need to Support Urban Agriculture

Governmental agencies have mobilized to place grocery stores in targeted communities for the specific purpose of combating food deserts. One early example of this includes the Pennsylvania Fresh Food Financing Initiative which was received well enough to inspire the Obama administration's $400 million version called the Healthy Food Financing Initiative in 2010, to later establish the HFFI at the USDA in 2014, and additional funding in 2016 [5]. In addition to efforts like these, the USDA added the Office of Urban Agriculture and Innovative Production (OUAIP) [6]. Sharing roots within the Farm Bill; a law promoting sustainable farms, rural businesses, and communities around the country; the OUAIP has been authorized $57 million since 2020 to supports projects like the Urban Agriculture and Innovative Production Competitive Grants. The office finds itself underfunded as 78% of the requests for grants have been rejected.

2.2 Soil Contamination in Urban and Historic Neighborhoods

Numerous studies have demonstrated the link between intense anthropogenic activities and its effect on historic urban soils. While some potentially toxic elements may be more evenly distributed across urban and rural (or even natural) landscapes (Al, Ca, Fe, K, Mg, Na, P, S, Ti), others (Ag, As, Au, Ba, Be, Cd, Co, Cr, Cu, Hg, Mn, Mo, Ni, Pb, Pd, Pt, Rh, Sb, Sn, Tl, V, and Zn) are found in higher concentrations in urban sites. Industrial, residential, and transportation land uses are responsible for varying amounts of these PTEs.

2.2.1 Case Studies

A study of urban soil contamination in Salerno, Italy revealed some PTEs to be highly concentrated in urban sites. For at least 10% of sampled sites concentrations of Be (0.5-11.8 mg/kg), Cu (6.4-710 mg/kg), Pb (8.3-1306 mg/kg), Tl (0.13-1.79 mg/kg), Sn (0.5-125.6 mg/kg), and Zn (19.5-1682 mg/kg) exceeded local legal limits, and the highly toxic Pb and Zn were at concentrations over ten times higher than legally allowable limits.[7]

One study by Kelly et al. analyzed these impacts on topsoils of a London, UK residential neighborhood and an industrial city near Birmingham, UK [8]. Topsoils in the residential neighborhood were found to have significantly higher concentrations of heavy metals in developed locations compared to less utilized spaces. Table 1 highlights how heavy metals concentrations increase within the boundaries of the urban sprawl according to proximity to residential housing units. Concentrations of Pb (>1000 µg/g) could be found in areas close to large road junctions and (~500 µg/g) near older housing at least 100 years old. Industrialized areas revealed mainly elevated levels of Zn rather than Pb due to the nature of the industrial activity.

Table 1. Concentration of Metals in Topsoils (0-15cm) relating to land-use in London Borough of Richmond-upon-Thames (µg/g) [8].

	Pb range (g.m)[1]	Zn range (g.m)	Cd range (g.m)	Cu range (g.m)	*N*
Residential[2]	34–1840 (271)	36.6–1810 (179)	<0.2–11.1 (<0.2)	13.1–1130 (48)	106
Recreational[3]	20–1210 (93)	11.4–657 (66)	<0.2–1.2 (<0.2)	3.8–164 (19)	108

[1]Geometric mean.
[2]Refers to samples taken in back gardens.
[3]Refers to samples taken elsewhere, i.e. parks and sports grounds.

2.3 Crop uptake of PTEs in common urban agriculture crops

Moving forward with the assumption that all urban soils are unfit for agricultural uses would be the safest option to preserve human health, but it would bring the urban agricultural movement to a grinding halt. While it is true that many urban soils are contaminated with potentially toxic elements there is potential for current and future best management practices to result in a healthy and beneficial outcome. One such method would take into consideration which vegetable crops have lower uptake of these PTEs which may be found in the soils they are to be cultivated in.

One such case study of vegetables and heavy metal (Pb, Cd, Cu, Zn, and As) uptake by Zhou et al. choose a contaminated traditional farmland site [9]. Impacted by a failed mine tailing dam the farmland continues to produce foodstuffs and vegetables consumed by the farmers and sold at markets to urban residents. The researchers selected the crops commonly grown in the area for the study and assessed their heavy metal uptake against the target hazard quotient (THQ) described by the United States Environmental Protection Agency and against the tolerance limit set by the China National Standards (GB 2762-2012). The difference of Pb (0.004-2.361mg/kg), Cd (0.002-2.918mg/kg), and As (0.014-1.780 mg/kg) concentrations between the highest and lowest vegetables studied was as high as a thousand times different, while Cu (0.155-3.125 mg/kg) and Zn (1.151-54.65 mg/kg) ranged only a few times the lowest, providing clear evidence for consideration when selecting crops to grow in a potentially contaminated soil. They suggest vegetables to be cultivated in contaminated soils from most suitable to least suitable in order: legume/melon, stalk/root/solanaceous, leafy. To make a statement on which heavy metals

studied pose the most health risk, the researchers concluded Pb and Cd had the highest THQ values of all heavy metals in the study.

Another study used controlled spiked soils with Cd, Cu, Pb, and Zn to cultivate six common vegetables (spinach, carrot, French bean, pea, onion, lettuce) to determine PTE uptake [10]. The researchers mention Cd and Pb to be the most dangerous to human health of the PTEs studied and produced the following results; for vegetables studied regarding Cd and Pb revealed that Cd accumulated the most in lettuce (8.6 mg/kg) and spinach (5.8 mg.kg), and Pb in lettuce (14.6 mg/kg) and onion (7.5 mg/kg).

Following a different format, a study in Berlin, Germany considered three major components (use of contaminated soils for cultivation, crop irrigation with wastewater, and airborne pollution by traffic or industrial emissions) relating to crop uptake of heavy metals in an inner city. Of the three components the researchers studied traffic emissions, its effect on cultivation of different crops near highly traveled roads and assessed different management practices to reduce uptake of heavy metals [11]. Ultimately, the researchers suggest traffic burden and the presence of barriers had a great impact on the Pb content of crops raised. The results showed that of the trace metals studied (Pb, Cd, Cr, Ni, and Cu) all were elevated in the crops (tomato, green bean, carrot, potato, kohlrabi, white cabbage, nasturtium, parsley, chard, basil, mint, thyme) grown in the inner city versus the samples from the supermarket. 52% of all samples analyzed in the study failed European Union limits for Pb in food crops; tomato, kohlrabi, green beans, and white cabbage exceeding the limit only 33% of samples; and no basil nor nasturtium samples failed for Pb.

2.4 Most Commonly Cultivated Urban Agricultural Crops

To provide a more effortless transition, information regarding crops which uptake less potentially toxic elements becomes more useful when cross referenced with which crops are already being commonly cultivated by urban agriculture programs.

Table 2: Ten Most Prolific Community Garden Crops, New York, NY -2010 and 2011 (Pounds). Sixty-seven gardens (2010) and thirty-five gardens (2011) [12].

2010		2011	
Crop	**Pounds**	**Crop**	**Pounds**
Tomatoes	29,628	Tomatoes	4,116
Cucumbers	8,322	Cucumbers	1,452
Sweet Peppers	7,843	Summer Squash	1,357
Swiss Chard	5,505	Cilantro	635
Collard Greens	5,002	Cherry Tomatoes	611
Summer Squash	4,305	Eggplant	575
Eggplant	3,838	Cabbage	478
Winter Squash	3,003	Sweet Peppers	444
Hot Peppers	2,518	Calaloo	433
Cabbage	2,319	Hot Peppers	352

Table 2 shows yield in a number of community gardens in New York, USA. Comparing this to the research presented in the previous section regarding suitable crops to cultivate in contaminated soils one can make a more informed decision when considering which crops to raise. The food stuffs and vegetables most likely to be cultivated while also being the safest to cultivate include tomato and cucumber, while the least safe include Swiss chard, collard greens, and cabbage.

3 Conclusion

It is clear soil contamination demands consideration when planning a new or current urban agriculture project. If urban agriculture continues to be utilized to help alleviate food deserts and inequity it is not enough to simply select a favorite crop or one with the best yields. Due to the environment that these crops are likely to be grown in there are potentially a few paths forward. One may choose to relocate a project, follow certain best management practices to mitigate soil contamination (heavy metals like Cd and Pb), test soils or products for contamination, or select certain crop varieties (tomatoes, cucumbers, legumes, melons) to mitigate potentially harmful contamination of product. If one or all these measures are taken, then surely the manager of the urban agriculture project can know that they have made an effort to protect those that they set out to serve when beginning the project in the first place.

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