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SOIL NUTRIENT AND CONTAMINANT ASSESSMENT IN COMMUNITY GARDENS, LOUISVILLE, KENTUCKY

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ABSTRACT

SOIL NUTRIENT AND CONTAMINANT ASSESSMENT IN A COMMUNITY GARDENS, LOUISVILLE, KENTUCKY

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April 21, 2020

Urban population impact on environmental warming has inspired interest in vegetative coverage to mitigate human influence. Community gardens are proposed to increase green space and access to fresh food, improve health, and quality of life. The potential for soil contamination in post-industrial cities is high presenting a health risk for gardeners. Three Louisville, Kentucky community gardens were chosen for analysis of soil texture, pH, concentration of trace nutrients and metals using Mehlich 1 Extraction. In two community gardens, relative absence of heavy metals suggest they are currently safe for gardening. One garden had a concentration of copper and zinc over the World Health Organization (WHO) guidelines, and the presence of lead was identified. A soil testing schedule should include transverse sampling where metals are present. Environmental Protection Agency (EPA) best management practices should be used, and precautionary measures provided for gardeners.

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INTRODUCTION

The environmental impact of urban population growth and concerns about climate change have inspired focus on increasing vegetative coverage in urban areas (Wang and Wang, 2017, Stone et al., 2015). The U.S. Census defines urban as “any incorporated place or census designated place of at least 2,500 and less than 50,000 people” (United States Census Bureau, 2017). Community gardens have been proposed as a strategy to increase green space in urban communities (Corrigan 2011, Parece & Campbell, 2017). Additionally, gardens have social and public health impacts by contributing to food security, fostering healthy eating, improving physical and mental health, facilitating interaction between neighbors, and improving quality of life (Corrigan, Carney et al., 2012, Gray et al., 2014, Gregory et al., 2016).

While urban greening has proven benefits, risk of exposure to potentially harmful contaminants cannot be overlooked - especially in food production gardens (Varlamoff, 2016, Wong et al, 2017). Trace elements are naturally occurring but can occur in higher concentrations in urban areas. Urban soils often have low organic material and nutrient concentration due to erosion and compaction (USDA, 2018). Urban soils run the risk of contamination due to historic land use, proximity to pollution sources, and management practices (U.S.

EPA 2014, Varlamoff, 2016). These factors present a health risk for gardeners. Gardeners could be exposed to contaminants while manipulating the soil, inhaling aerosolized dust, if soil is accidentally consumed, and by eating produce that has been in close proximity to contaminants (Varlamoff, 2016).

The objective of this study is to answer the following questions: Are legacy contaminants present in Louisville, Kentucky's urban community gardens? Are observed soil amendments in garden plots improving soil nutrient concentration? H_0: Concentration of contaminants will not differ between community gardens. H_1: Contaminants will differ between community gardens. If contaminants are present, what strategies can be implemented to increase awareness and decrease risk to participants?

LITERATURE REVIEW

The urban population in the United States has steadily increased since 1960 (World Bank, 2018). In 2018, 82% of the U.S. population lived in urban areas (WB, 2018). Urban areas where minimal greenspace, socioeconomic disparity and built environment variations correlate with disparities in quality of life and increased health risk for residents (Parece, et al. 2017). Community gardens have been proposed as a solution to decrease food insecurity in communities identified as having “low-access” to fresh and healthy foods (Wang et al., 2014). Environmental history must be considered when sites are identified for community gardening as urban soils often contain higher concentrations of potentially dangerous contaminants than those outside the urban core (Silveira, 2016, McClintock, 2012, Clark, et al. 2008).

This chapter will explore previous studies on food insecurity, community gardens, and contamination associated with urban soil. Some contaminants such as lead, cadmium and arsenic are listed on the Agency for Toxic Substances and Disease Registry (ATSDR) 2017 Substance Priority list (CDC, 2007) as they are known to have significant impacts on human health. Soil is the leading exposure pathway of lead in children (Clark et al., 2007). Routes and implications of exposure, and strategies to decrease risk will be identified. This study will assess nutrient and contaminant concentration in urban community garden plots in Louisville, Kentucky.

Food insecurity

Food insecurity is defined by the U.S. Department of Agriculture as, “limited or uncertain availability of nutritionally adequate and safe foods or limited or uncertain ability to acquire acceptable foods in socially acceptable ways” (USDA, 2019). Food insecurity is a national concern - particularly in areas of high poverty and in households with children. A healthy diet is important for lifelong health. A diet low in fresh fruits and vegetables increases risk factors for cancer, heart disease, stroke, and diabetes, poor oral health, obesity, and infant mortality (Pryor et al., 2017). Urban areas with minimal greenspace, socioeconomic disparity, and significant hardscapes associated with the built environment variability reveal greater likelihood of disparities in quality of life and increased health risk for residents (Parece et al., 2017). Low income and communities of color often lack access to healthy, locally produced foods as supermarket locations are determined based on economic potential instead of community needs (Winne, 2008). In 2017 food insecurity affected 15.8% of Jefferson County residents: higher than the national average of 12.9% (Feeding America, 2016). Average poverty rate in Louisville is 16.6% (LOJIC 2018).

Food deserts are urban or rural areas with limited access to affordable and healthy food options that correlate with food insecurity. Food access challenges often include limited physical access and economic challenges to affording a healthy diet (Pryor, et al., 2017). The 2010 State of Food compiled by the Mayor’s Heathy Hometown Movement reported that West Louisville residents have limited access to grocery stores as well as limited transportation options (Food in Neighborhoods, 2010). Limited access drives residents to purchase food from the abundance of convenience and liquor stores present in the area. Locally produced food could contribute to food security, improve community health outcomes, and eliminate challenges related to both cost and access in neighborhoods without a nearby grocery.

Urban Agriculture and Community Gardens

Urban agriculture and community gardens have been promoted as a strategy to address food desert conditions (Corrigan 2011, Carney et al., 2012, Gray et al., 2014). The Food and Agriculture Organization of the United Nations (FAO) defines urban agriculture as “growing food and raising livestock animals in cities” (FAO, 2010). Community gardens can provide access to growing space, tools, and resources for communities. Community gardens were created as a response to emergency conditions such as war or food shortage (Birky and Strom, 2013). During World War I the United Sates government asked families to grow food in kitchen gardens as an act of patriotism. American women grew food for their families and communities, and during WWII it is reported that victory gardens produced as much as 40% of the fresh vegetables in the U.S. (Andreatta, 2015). Carney et al. focused on the impact a community garden project had on vegetable intake, food security, and family relationships within an immigrant population. An important function of these gardens was production of culturally relevant foods through which traditions found a place in a new country (Carney et al., 2012).

Community gardening today can be tied to social and environmental concerns as well as provision of fresh foods that make a meaningful contribution to family health (Buckingham, 2005). Community garden participants are engaged for a variety of reasons including increased environmental awareness, desire to connect with the community, benefits of physical activity, improved mental health, disillusionment with industrial agriculture, increasing transportation and food costs, and interest in environmental education (Birky and Strom, 2013).

The degree to which food production on this small scale impacts food insecurity is difficult to quantify, however studies have revealed that gardeners have increased access to high quality, diverse, and nutritious food (Kortright and Wakefield, 2011, Opitz et al., 2015). Diverse participants with varied motivations coupled with public support from local, regional, and governmental organizations create the potential for lasting movement. These studies suggest that community gardens have the potential to reduce food insecurity at a household level (Kortright and Wakefield, 2011, Opitz et al., 2015).

The Food in Louisville Neighborhoods Community Coalition website identifies 35 local food and community garden spaces in Louisville (Food in Neighborhoods, 2018). Of the identified gardens, 10 are allotment gardens managed by the Jefferson County Cooperative Extension Service where plots can be rented yearly for a small fee. Water and small equipment are available to gardeners at no additional charge (University of Kentucky, 2018). Nonprofit and religious organizations manage 15 community gardens, and community members manage 5 neighborhood gardens. Many of these gardens are in communities that have limited access to fresh food.

Urban Soils and Contamination

The most common soil contaminants are heavy metals. Heavy metal presence is usually due to anthropogenic pollution – a result of human activity - primarily fossil fuel burning, industrial effluents, and smoke and concentrated near buildings, roads, and industry (Taylor and Robertson, 2009). Metals have been useful to humans for centuries and do not degrade. While metals have relatively low mobility in situ, remobilization occurs when soil is disturbed. Researchers have identified methods to determine risk associated with soil contaminants by combining land use histories, soil testing, and implementation of appropriate remediation solutions (Varlamoff, 2016, Heinegg, 2002).

Soil concentration varies due to wind dispersion and human activity (Silveira et al., 2016). Historic use of lead paint and leaded gasoline has contributed to the presence of lead in urban soils (U.S. EPA, 2011). Industrial and commercial use of chemically treated wood, pesticides, solvents, and historic coal combustion (Table. 1) have contributed to the presence of contaminants in urban soil (Varlamoff, 2016).

General Source	**Previous Site Use**	**Specific Contaminants**
Paint (prior to 1978)	Old residential buildings, leather tanning, landfill operations,	Lead
High traffic area	Highways and roadways especially those built before leaded fuel was phased out (1996)	Lead, zinc, polycyclic aromatic hydrocarbons (PAHs)
Treated lumber	Lumber treatment facilities, presence of treated lumber	Arsenic, chromium, copper
Burning wastes	Landfills, historic burning of household waste	PAHs, dioxins
Sewage sludge	Sewage treatment plants, Combined Sewer Overflows (CSOs)	Cadmium, copper, zinc, lead, persistent bioaccumulative toxins (PBTs)
Petroleum spills	Gas stations residential/commercial/industrial uses (anywhere an aboveground or underground storage tank is or has been located)	PAHs, benzene, toluene, xylene, ethyl benzene
Pesticides	Pesticide use, formulation, packaging and shipping	Lead, arsenic, mercury, chlordane, other chlorinated pesticides
Commercial or industrial site use	PAHs, petroleum products, solvents, lead, other heavy metals (such as arsenic, cadmium, chromium, lead, mercury and zinc)	
Dry cleaners	Stoddard solvent and tetrachloroethene	

Table 1: Source : Heinegg, A., Maragos, P., Mason, E., Rabinowicz, J., Straccini, G. and Walsh, H. (2002) Urban Agriculture and Soil Contamination and ATSDR ToxGuides referenced November 20, 2018 https://www.atsdr.cdc.gov/toxguides/index.asp

While some elements are naturally occurring in the soil, concentration beyond safe levels identified by the EPA can be investigated through soil sampling. Any time there is a question regarding contaminants present in urban soils, soil should be tested. Contaminants at high levels can lead to classification of sites as brownfields, which is a lengthy and complex process. Brownfields are defined as properties where redevelopment or reuse may be complicated by the concentration of a hazardous substance, pollutant, or contaminant (U.S. EPA, 2017). The Environmental Protection Agency's (EPA) Brownfield Program was initiated in 1995 to change the way these properties are perceived, addressed, and managed. It provides economic assistance and resources to empower communities, stakeholders, and states to work together to prevent, assess, clean up and reuse these spaces (U.S. EPA, 2017). The EPA must be involved in the assessment and remediation of these sites.

Nutrients

Some trace nutrients are essential for human and animal health, particularly iron (Fe), manganese (Mn), copper (Cu) and zinc (Zn), but can be toxic when ingested beyond recommended levels (Harmanescu et al., 2011). Trace nutrients are essential for plant growth and vegetable production and include calcium (Ca), potassium (K), magnesium (Mg), phosphorous (P), boron (B), and sodium (Na). Soil can be assessed as a growing medium by Jefferson County Extension Services to identify concentration of nutrients including nitrogen (N), phosphorous (P), and potassium (K)), organic material, and soil pH (University of Kentucky, 2018). These tests inform soil improvements for optimal plant growth and production.

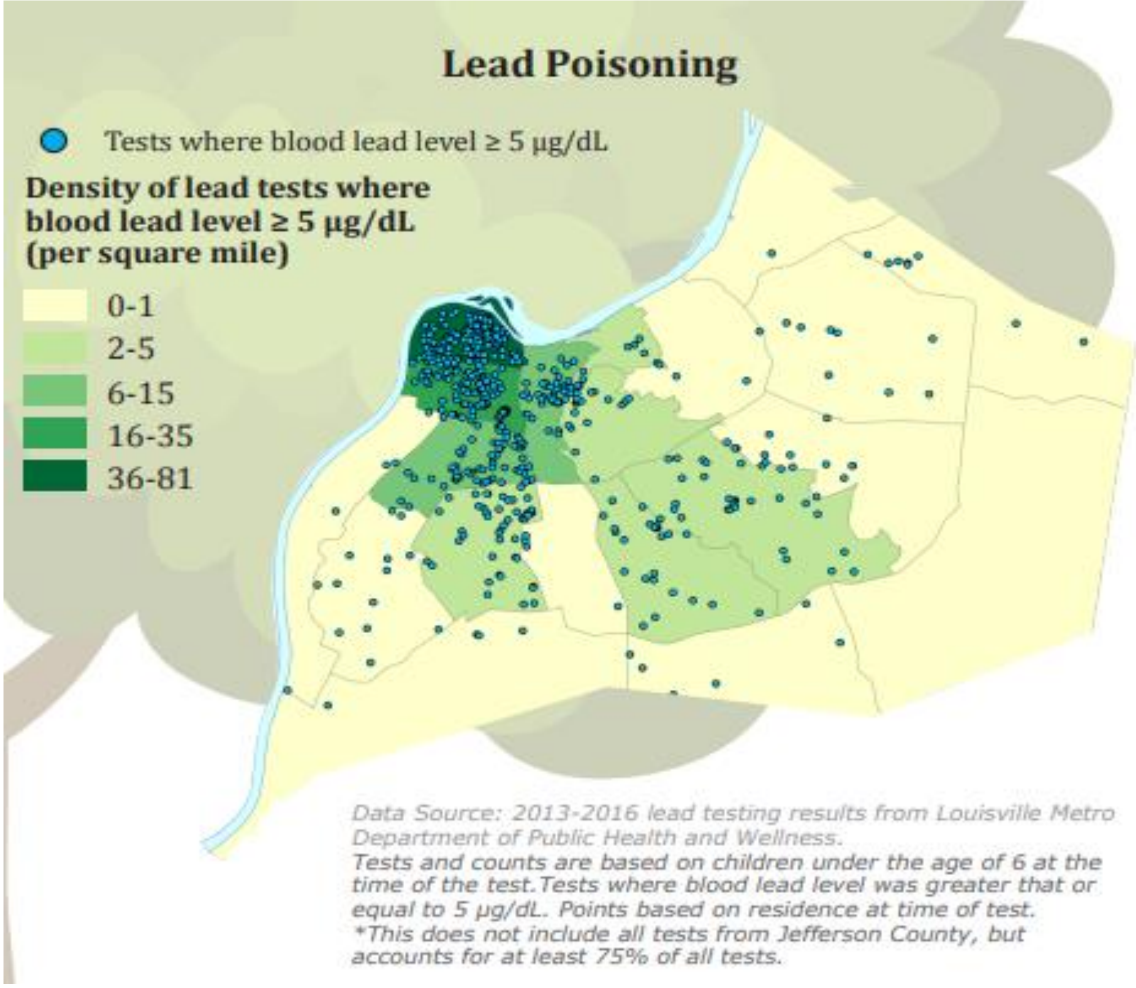
Other elements such as arsenic (As), cadmium (Cd), and lead (Pb) are nonessential for plants or animals and are highly toxic even at low concentrations (Khan et al., 2015, Leake et al., 2009, Harmanescu et al., 2011). Testing soil for heavy metals, As, pesticides, and other organic and inorganic contaminants can be performed to ensure safety of gardeners. Tests performed as part of Phase I Environmental Assessment determine potential for contamination, and Phase II Environmental Assessment collect samples for analysis. Environmental professionals available through local or state government (U.S. EPA, 2011) conduct this assessment.

Contaminants

The federal Resource Conservation and Recovery Act (RCRA) identifies eight toxic heavy metals arsenic (As), barium (Ba), cadmium (Cd), chromium (Cr), lead (Pb), mercury (Hg), selenium (Se), and silver (Ag). Pb, Cd, and As are listed on the Agency for Toxic Substances and Disease Registry (ATSDR) 2017 Substance Priority list (CDC, 2017) as they are known to have significant impacts on human health. These elements can remain present in the human body becoming more concentrated through each exposure, a process called bioaccumulation, and cannot be metabolized by the body.

Lead

Lead (Pb) is naturally present in soil in small amounts. Human activities including industrial emissions, lead-based paint (banned in 1978), and leaded gasoline (banned in 1996) contributed to atmospheric deposition of Pb. Ultimately, that Pb settled into the soil. Soil has been identified as an important pathway of Pb exposure in humans, especially children who engage in hand-to-mouth and pica, or ingestion of substances with no nutritional value (Mielke and Reagan, 1998). Pb dust can be inhaled or ingested when contaminated soils are disturbed (Varlamoff, 2016). Root vegetables and leafy vegetable plants accumulate Pb more readily from soil (Harmanescu et al., 2011, McBride, et al 2013). Exposure to Pb can cause developmental problems in children, specifically neurologic dysfunction, cause renal disease, decreased fertility, and is toxic at low concentration for people of all ages (CDC, 2017). A graphic from the 2017 Louisville Metro Health Equity Report identifies elevated Pb levels in children under 6 years of age (Fig. 1). The positive exposure tests are clustered downtown, west, and south Louisville where many community gardens are located (Pryor et al. 2017).


Lead Poisoning

Data Source: 2013-2016 lead testing results from Louisville Metro Department of Public Health and Wellness.
Tests and counts are based on children under the age of 6 at the time of the test.Tests where blood lead level was greater that or equal to 5 µg/dL. Points based on residence at time of test.
*This does not include all tests from Jefferson County, but accounts for at least 75% of all tests.

Fig 1. Elevated blood lead levels in children under 6 in Louisville, KY
Source: Elevated Louisville Health Equity Report 2017, p58

Cadmium

Cadmium (Cd) is naturally present in the earth's crust. Cd enters the soil through industrial production of metals, mining, and burning coal and remains in soil and sediment for several decades (Jaishankar et al., 2014). High concentrations can result from sewage sludge deposited in combined sewer overflows (CSOs) during extreme precipitation events (U.S. EPA, 2017). Cd has a relatively high rate of soil-to-plant transfer (Jaishankar et al., 2014). Exposure can cause cardiovascular and respiratory disease, neurologic disease, renal disease, and deterioration of bone. It affects fetal development and can cause reproductive problems. Cd is a known human carcinogen (CDC, 2017).

Arsenic

Arsenic (As) is a naturally occurring element and is naturally present in high concentrations in Kentucky due to underlying geologic makeup (Vosnakis and Perry, 2009). The U.S. EPA identifies Regional Screening Level (RSL) for residential soil as 0.39mg/kg based on incidental ingestion, inhalation, or dermal contact (U.S. EPA, 2017). Background Threshold Values (BTV) for Kentucky were found to be 15.9mg/kg (Vosnakis and Perry, 2009). Inorganic As was historically used in the production of pressure treated lumber, and in copper and lead smelting. Organic As is generally less toxic than inorganic and has been used in pesticides (Vosnakis and Perry, 2009). As can be inhaled or ingested as wind-blown dust, and individuals who apply pesticides are susceptible to exposure. Plants can take up As from the soil. Exposure causes malfunctioning of essential cellular functioning. High level exposure to inorganic As results in death. As is a known human carcinogen (CDC, 2007).

Zinc, Boron, Manganese, and Copper

Zinc (Zn) is an essential micronutrient for plant growth, but it is needed in small quantities. Zn enters the environment as the result of mining, steel production, coal burning, and burning of wastes. Little is known about the long-term effects of breathing Zn dust or fumes (CDC, 2011). Ingestion of large amounts of boron (B) can cause damage to the gastrointestinal and organ systems including stomach, intestines, liver, kidneys, and brain (CDC, 2011). Little is known about B toxicity in children or dangers to pregnant women. Children living near contaminated sites are more likely to be exposed to higher levels of Zn and B through drinking water and soil. It is unlikely that children would ingest enough Zn from eating soil to cause toxicity. Children should be supervised to prevent consumption of soil and wash hands after handling soil (CDC, 2011).

Inhalation of large quantities of dust containing manganese (Mn) can lead to lung irritation. Little is known about the impacts of Mn exposure. Mn can cross the placenta during pregnancy and cross the blood brain barrier. Studies have shown that high levels of exposure to Mn in children impacts brain development, resulting in behavioral changes, and decreased ability to learn, difficulty with speech and walking. It is unknown whether changes were related to Mn exposure alone, or if changes were temporary or permanent (CDC, 2011).

Copper (Cu) occurs naturally in rock, soil, water, sediment, and, at low levels, air (CDC, 2011). Its average concentration in the earth's crust is about 50 parts copper per million parts soil (ppm). Cu exposure is dependent on many variables including route, duration, and quantity of exposure in addition to age, sex, and state of health, especially pregnancy. Exposure to high levels of Cu long-term can lead to mucous membrane irritation (nose, mouth, eyes), can cause headaches, nausea, and diarrhea. It is unknown whether exposure to high levels of Cu causes developmental or birth defects in humans. Soil usually contains between 2 and 250 ppm Cu. Like Pb, Cu is carried from industrial dust into the atmosphere and deposited onto the soil. Children are more likely to ingest soil due to hand-to-mouth behavior (Mielke and Reagan, 1998, Varlamoff, 2016).

Soil pH

Soil pH measures acidity or alkalinity and generally ranges from 5.0 to 8.5 (Penas, 1990). Soil with a pH below 7.0 is considered acidic, while those over 7.0 are alkaline (Penas, 1990). Ideal pH range for vegetable gardening is between 6.0 – 7.0 (Penas, 1990).The pH is influential in nearly all soil reactions and heavy metal uptake by plants is strongly pH dependent (Bolan et al., 2003, Adamczyk-Szabela et al., 2015). Studies have shown that pH can mediate metal toxicity (Olaniran et al., 2013).

Volatile Organic Compounds

Volatile organic compounds (VOCs) are present in a variety of chemical products, including gasoline and chlorinated solvents, and dry cleaning chemicals as well as emissions from vehicle and gas-powered equipment and industry (U.S. EPA, 2017). Most VOCs are not acutely toxic, but have long term health effects including respiratory tract, eye, and skin irritation, liver and kidney damage, headaches, and central nervous system damage (Kanu et al., 2007).

Route of exposure

Humans are exposed to soil contaminants directly or indirectly. Direct exposure includes inhalation of dust, and accidental ingestion of soil due to inadequate washing of hands, tools, or vegetables that have direct soil contact. Any activity that involves manipulation of the soil increases exposure. Children are more likely to consume soil via hand-to-mouth contact. (Clark et al 2008) revealed that in children consumption of produce accounts for 3% of the daily exposure to Pb while ingestion of soil accounts for 82% of daily exposure (Clark et al., 2008). Children are particularly susceptible to the effects of toxicity. Indirect exposure occurs when plants that have taken up contaminants are consumed. Root vegetables grown in contaminated soils have been shown to have higher concentration of metals and Pb has the greatest potential for uptake in root vegetables (Harmanescu et al., 2011). Leafy vegetables have been shown to move contaminants from roots to above ground tissues and can be contaminated by soil particles because of the proximity to the soil (Khan, 2015, McBride, et al 2013).

Combined sewer overflows (CSOs) are the result of significant rainfall. Stormwater flows into sanitary sewer pipes during rain events and overflows into waterways, onto the ground, or into buildings rather than to wastewater treatment plants (Metropolitan Sewer District, 2019). CSOs have been identified as a source for bacteria, PAHs, hormones, medication, and other chemicals (Phillips et al., 2012).

METHODS

Louisville Community Gardens

Three community gardens were chosen (Fig. 2) based on their location within the city and land use history. Of these sites, Seventh Street has never been developed, Russell is in a residential area and historically housed a family home, and Emerson is the former site of an elementary school. All are allotment gardens, managed by the Jefferson County Cooperative Extension. Plots are in ground level soils and some raised beds were present. Plots range from 5 by 7ft to 30 by 30ft. A land use history was obtained from the Jefferson County Property Valuation Administrator (PVA) on February 2, 2019 for each of the sites. Details of land use history and demographics of area surrounding gardens are provided in each garden description. Soil assessment was performed when gardens were established, however results were unavailable.

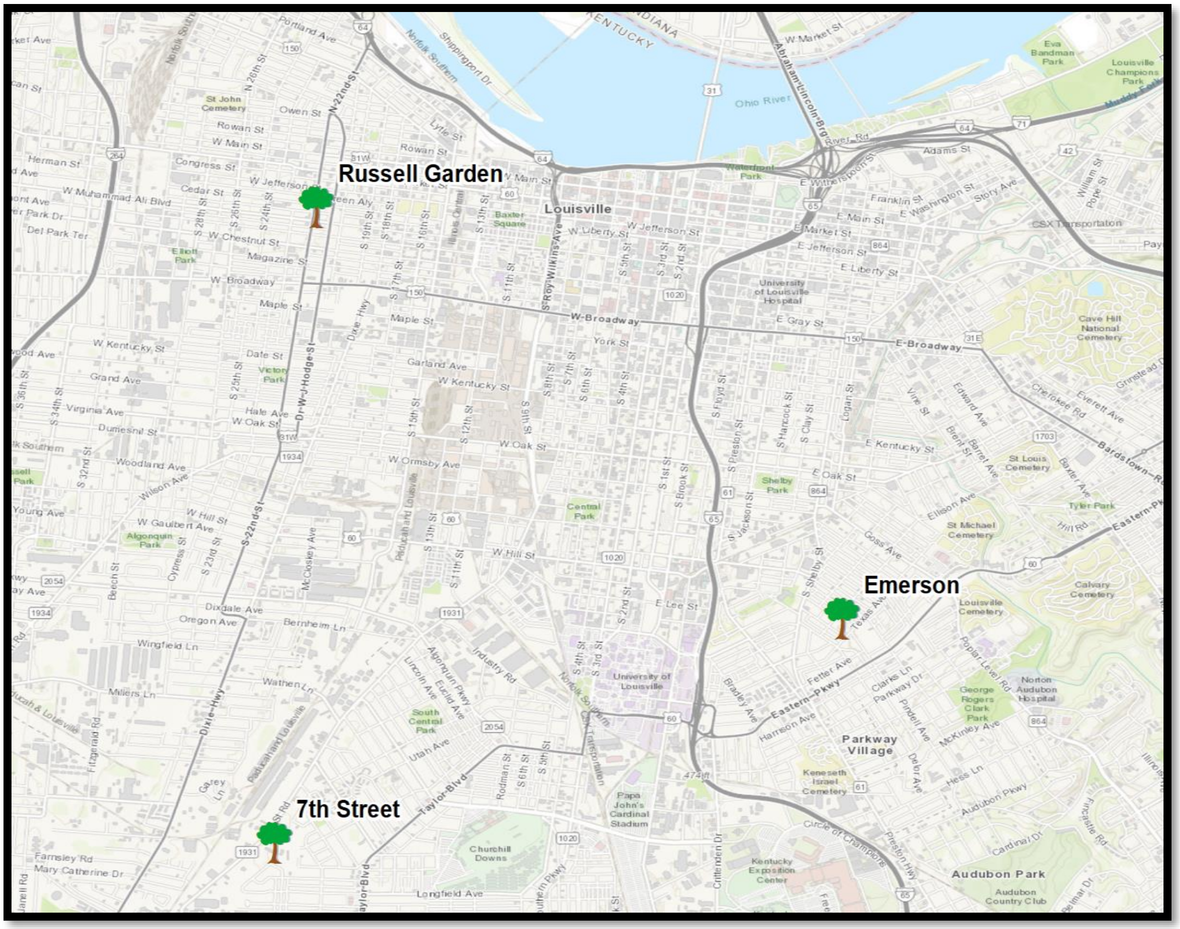


Fig 2. Garden locations – map provided by Dr. Matt Ruther using ArcGIS

Seventh Street Community Garden

Seventh Street Community Garden is in South Louisville in the Taylor Berry neighborhood at 3221 7th Street Road. This allotment garden provides the largest plots (30x30ft) for $20 per year. This is the largest community garden in Louisville on over 5 acres in ground level soils. This property is owned by the Metropolitan Sewer District (MSD) (LOJIC, 2018) and is identified as a Combined Sewer Floodprone area (LOJIC, 2018). According to deed transfers viewed at the Jefferson County Property Valuation Administrator (PVA) this property was sold to the Commissioner of Sewage in 1926 and has never been developed.

Demographic information (Table 2) revealed that the area surrounding 7th Street was the most diverse. This location reports a 33.92% poverty rate and 90% of residents in the area have access to a vehicle (LOJIC, 2018).

Russell Community Garden

Russell Community Garden is in West Louisville in the Russell neighborhood at 409 S. 22nd Street. K, V & B Enterprises Inc. (LOJIC, 2018) currently owns this property. Several raised garden beds are present at this site and a 6-foot fence surrounds the property. According to deed transfers viewed at the Jefferson County Property Valuation Administrator (PVA) this property has always been residential, with 10 deed transfers from 1918 to 1995 when it was sold to the current owner. The area surrounding Russell (Table 2) has the highest poverty rate at 35.64% and only 61.63% of Russell residents have access to a vehicle (LOJIC, 2018).

Emerson Community Garden

Emerson Community Garden is located 3 miles southeast of downtown Louisville in the Schnitzelburg neighborhood at 1100 Sylvia Street. Most plots are in ground level soils and some raised beds have been built in individual plots. This property is owned by Louisville Metro Government and is adjacent to Emerson Park. It is identified as a Combined Sewer Floodprone area (LOJIC, 2018). According to deed transfers viewed at the Jefferson County Property Valuation Administrator (PVA) this property was the site of the Emerson Public

School built in 1904. The school is listed on the National Register of Historic Places although it no longer stands. The area surrounding Emerson (Table 2) reports the lowest poverty rate at 15.59%, is 91.39% white, 6.19% African American, and 2.42% other (LOJIC, 2018). Emerson has the highest rate of vehicle access of all gardens at 93.3% (LOGIC, 2018).

Location	Pop	African American	White	Other	No car	Over 65	Poverty rate Louisville avg 16.6%	Pop density
7th Street	3720	36.34	56	7.66	9.4	8.84	33.92	5539
Russell	5225	90.81	4.17	5.02	38.37	8	35.64	6297.48
Emerson	2020	6.19	91.39	2.42	6.7	11.8	15.59	7814.16

Table 2. Demographic information of site locations
Source: LOJIC, 2020

Experimental methods

Randomized grid sampling of garden plots performed, and soil collected using an AMS Soil Turf Probe. Samples were transferred to labeled Ziplock® bags and shipped to Alabama A&M Auburn University Soil Testing Laboratory via UPS. Analysis of soil texture, pH, concentration of trace nutrients calcium (Ca), potassium (K), magnesium (Mg), phosphorous (P), boron (B), and sodium (Na) and metals arsenic (As), copper (Cu), iron (Fe), manganese (Mn), zinc (Zn), aluminum (Al), cadmium (Cd), chromium (Cr), lead (Pb), and nickel (Ni) using Mehlich 1 Extraction. Mehlich 1, also known as dilute double-acid, uses a double-acid extractant (HCl and H_2SO_4) that can extract essential plant nutrients (Mylavarapu et al., 2014). Mehlich 1 is a standard method of soil analysis, is cost effective, and is widely accessible to home and commercial growers.

Seventh Street and Russell soil samples were obtained on February 2, 2019. Emerson soil samples were obtained on January 15, 2018. Variable degrees of input in plots were observed and classified as high or low input. High input included presence of leaf mulch, manure, or cover crop (vetch and clover). Low input plots had little to no input. Microsoft Excel software was used to compare nutrient and metal concentrations to determine risk associated with these spaces.

Pivot tables were used to look input as it related to concentration of trace nutrients and metals to determine if input influenced element concentration. ANOVA was run to compare the three sites and determine if there were any statistically significant differences between them. If ANOVA revealed a statistically significant difference (p=0.05) post hoc testing was performed (t-tests/3) were used to compare each garden to the others independently.

Limitations

No definitive standard for soil contaminant levels exist in the United States. Significant variability exists between state guidelines and focus on identification and remediation of Brownfields (Jennings, 2006). Background standards are difficult to access, and risk levels are often based on lifetime or occupational exposure (Jennings, 2006). Additionally, many methods of soil testing exist some available only within the research community, and others better at extracting metals from soil (USDA, 2018, Gamble, 2018).

Financial constraints allowed for testing of 10 plots per garden and therefore limited analysis. Many of the most concerning substances were cost prohibitive including analysis for the presence of polycyclic aromatic hydrocarbons (PAH), polychlorinated biphenyl (PCB), persistent bioaccumulative toxins (PBA), dioxins (persistent environmental pollutant), volatile organic compounds (VOC), and hormones and medications discharged in combined sewer overflow (CSO) (Phillips, et al, 2012).

RESULTS

Results of soil texture analysis (Table 3) classified Seventh Street as sandy clay loam. Soil pH had a range of 6.86 to 7.5 with a mean of 7.26. Soil texture at Russell classified as loam. Soil pH had a range of 7.28 to 7.59 with a mean of 7.52. Soil texture at Emerson classified as silt loam. Soil pH had a range of 6.73 to 7.66 with a mean of 7.26.

Location	Soil texture	Sand	Silt	Clay	pH
Seventh Street	sandy clay/clay loam	43.75	31.25	23.44	7.26
Russell	Loam	35.625	40.94	23.44	7.52
Emerson	silt loam	19.69	60.315	20	7.26

Table 3. Soil texture and pH

Trace nutrient concentration (Table 4) at Seventh Street garden had means of Ca: 2495.3 ppm, with a range of 858-4059 ppm, K mean: 123.1 ppm with a range of 80-175 ppm, Mg mean: 463.8 ppm with a range of 233-608 ppm, P mean: 75 ppm with a range of 36-117 ppm. Pb, Cd, and As concentrations were <0.1ppm, the lowest reportable limit. Zn ranged from 2-96 ppm with a mean of 16 ppm. B ranged from .05 ppm to 1 ppm with a mean of 0.95 ppm. Mn ranged from 18 ppm to 31 ppm with a mean of 26.7 ppm. Cu concentration ranged between 0.1 – 3 ppm with a mean of 0.91 ppm.

Trace nutrient concentration (Table 4) at Russell garden had means of Ca: 2734.6 ppm, with a range of 2325 to 3102 ppm, K mean: 179.4 ppm with a range of 129-311 ppm, Mg mean: 530.2 ppm with a range of 405-628 ppm, P mean: 63.2 ppm with a range of 13-125 ppm. Pb concentration ranged from <0.1 to 32 ppm with a mean of 6.91 ppm. Cd, and As concentrations were <0.1 ppm, the lowest reportable limit. Zn ranged from 3-96 ppm with a mean of 28.4 ppm. B ranged from 1-2 ppm with a mean of 1.4 ppm. Mn ranged from 30-59 ppm with a mean of 48.5 ppm. Cu concentration ranged between 0.2 – 3 ppm with a mean of 0.67 ppm.

Trace nutrient concentration (Table 4) at Emerson garden had means of Ca: 2966.55 ppm, with a range of 858-4986 ppm, K mean: 154.76 ppm with a range of 60-311 ppm, Mg mean: 502.38 ppm with a range of 233-628 ppm, P mean: 89.34 ppm with a range of 13-331 ppm. Pb, Cd, and As concentrations were <0.1 ppm, the lowest reportable limit. Zn ranged from 7-25 ppm with a mean of 12.44 ppm. B ranged from 1 ppm to 3 ppm with a mean of 1.55 ppm. Mn ranged from 27-61 ppm with a mean of 40.67 ppm. Cu concentration ranged between 0.1 – 0.9 ppm with a mean of 0.41 ppm.

Element concentration (ppm)	Seventh Street range	Mean	Russell range	Mean	Emerson range	Mean
As	<0.1		<0.1		<0.1	
Cu	<0.1	0.91	0.2-3	0.67	0.1-0.9	0.41
Fe	15-59	38.3	1-9	3.8	3-15	7.11
Mn	18-31	26.7	30- **59**	48.5	27- **61**	40.67
Zn	2- **96**	16	3- **96**	28.4	7- 25	12.44
Al	109-240	137.8	17-193	114.4	25-213	108.1
Cd	<0.1		<0.1		<0.1	
Cr	<0.1		<0.1		<0.1	
Pb	<0.1		<0.1- **32**	6.91	<0.1	
Ni	<0.1		<0.1		<0.1	
B	0.05-1	0.95	1-2	1.4	1-3	1.55

Table 4. range and mean (ppm) in assessed nutrients and metals. Manganese (Mn) levels in red identify concentration may affect plant health (parameters provided by Auburn and Alabama A & M Soil Testing Laboratory. Those highlighted in red are identified as above desired maximum levels of elements in unpolluted soils (Denneman and Robberse, 1990).

T-tests were used to determine whether observed amendment influenced soil fertility. At Seventh Street differences between concentration of Ca, K, and P in high and low input gardens were not significant (Figs. 3, 4, and 5). No variation in concentration was found in heavy metals (As, Cd, Cr, Pb, and Mo) measuring the lowest measurable limit of <0.1ppm. Differences in plots containing As, Pb, Zn, Cu, and Ni were not significant in plots with high versus low input.

At Russell differences between concentration of Ca, K, and P in high and low input gardens were not significant (Figs. 3, 4, and 5). No variation in concentration was found in heavy metals (As, Cd, Cr, Ni, and Mo) measuring the lowest measurable limit of <0.1ppm. Concentration of Zn and Cu were not significant in plots with high or low input.

At Emerson Ca (Fig. 5) was not significantly influenced by soil amendment while P and K concentrations were higher in plots with high input (Figs. 3 and 4). No variation in concentration was found in heavy metals As, Cd, Cr, Ni, and Mo showing concentration of <0.1ppm for each element ($p>0.05$).

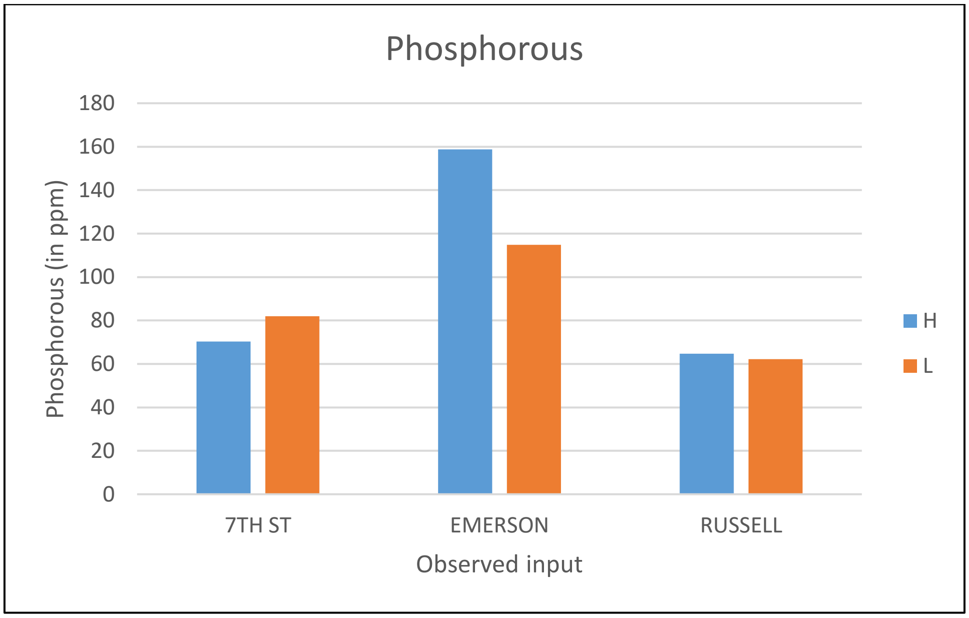


Fig 3. Phosphorous as it relates to observed soil amendment

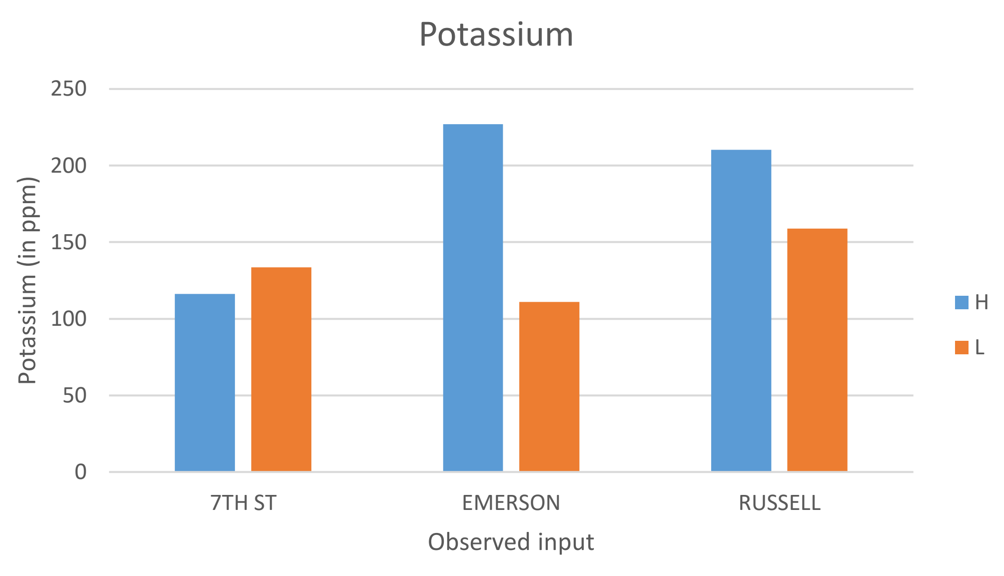


Fig. 4. Potassium as it relates to observed soil amendment

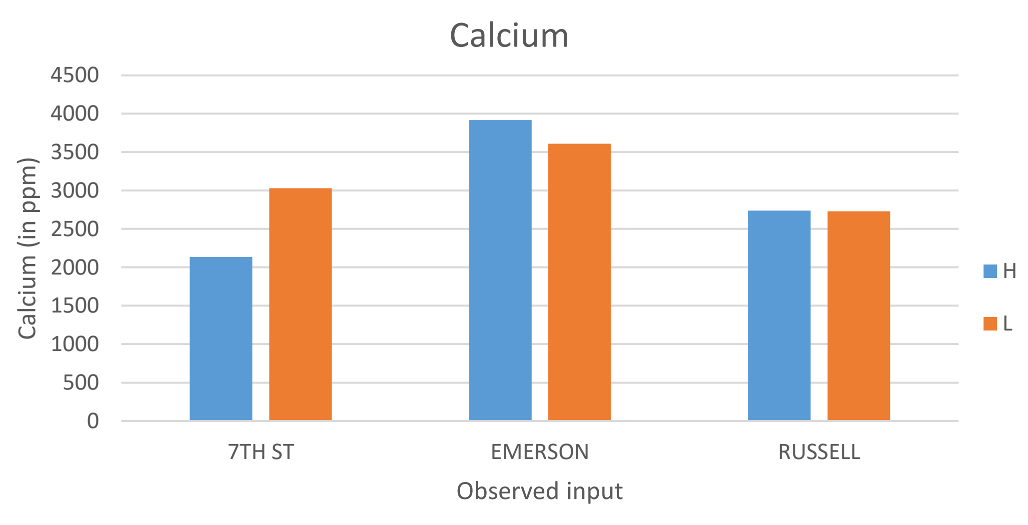
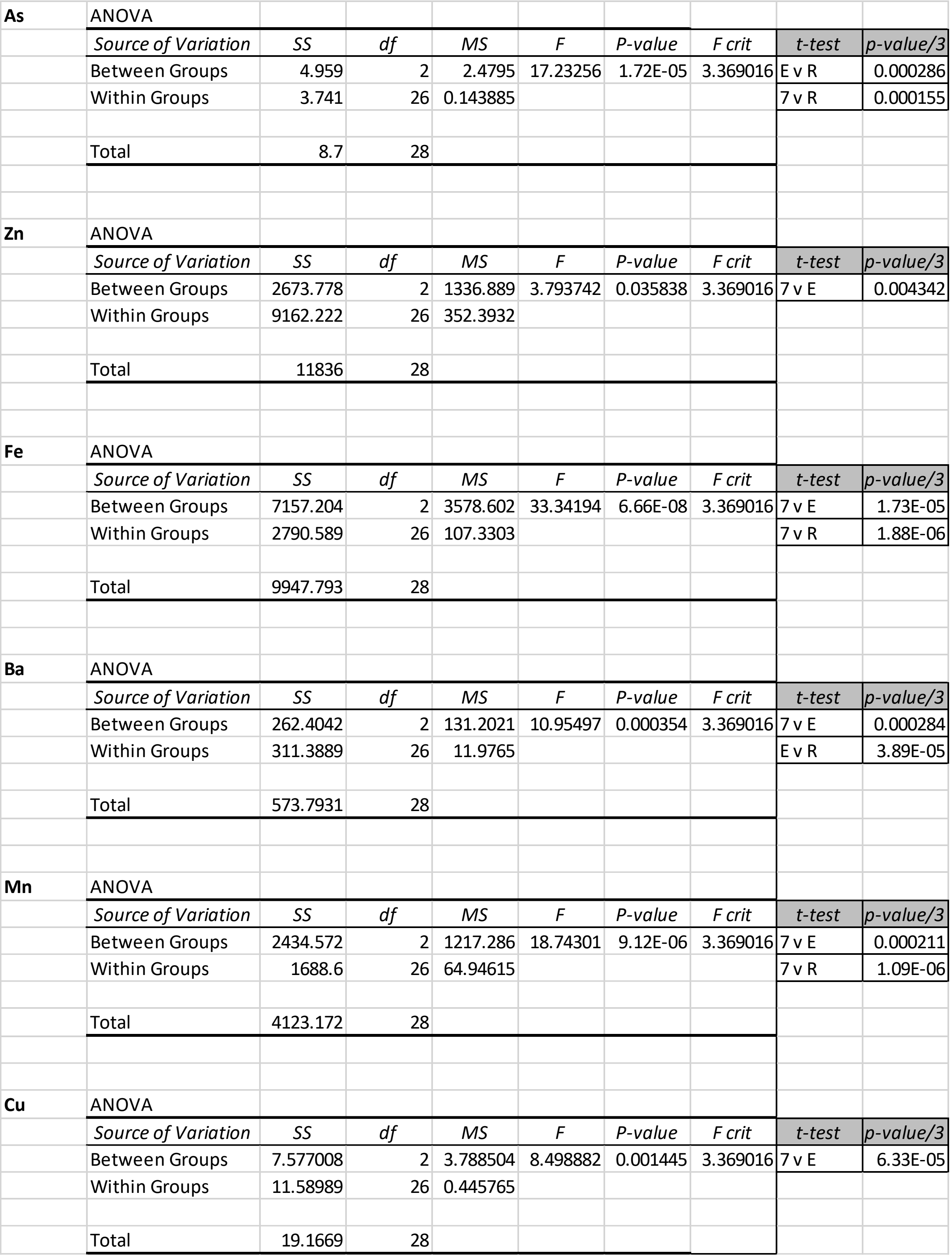


Fig. 5. Calcium concentration as it relates to observed soil amendment

Single factor ANOVA revealed differences were not significant among the three gardens in concentration of Al, P, K, Ca, B, Mg ($p>0.05$). Significant differences in concentration of As, Zn, Mn, Fe, Ba, and Cu were identified in the three gardens (Table 5). From ANOVA results T-tests were run to compare each garden to the other and p-value divided by 3. A p-value < 0.0167 identifies differences as significant. As between Emerson and Russell (p=0.00029) and Seventh Street and Russell (p=0.00015). Zn between Seventh and Emerson (p=0.00434). Fe between Seventh and Emerson (p=0.000017) and Seventh and Russell (p=0.0001). Ba between Seventh and Emerson (p=0.00028) and Emerson and Russell (p=0.0001). Mn between Seventh and Emerson (p=0.00021) and Seventh and Russell (p=0.0001). Cu Seventh and Emerson (p=0.0001).



As	ANOVA								
	Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*	*t-test*	*p-value/3*
	Between Groups	4.959	2	2.4795	17.23256	1.72E-05	3.369016	E v R	0.000286
	Within Groups	3.741	26	0.143885				7 v R	0.000155
	Total	8.7	28						

Zn	ANOVA								
	Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*	*t-test*	*p-value/3*
	Between Groups	2673.778	2	1336.889	3.793742	0.035838	3.369016	7 v E	0.004342
	Within Groups	9162.222	26	352.3932					
	Total	11836	28						

Fe	ANOVA								
	Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*	*t-test*	*p-value/3*
	Between Groups	7157.204	2	3578.602	33.34194	6.66E-08	3.369016	7 v E	1.73E-05
	Within Groups	2790.589	26	107.3303				7 v R	1.88E-06
	Total	9947.793	28						

Ba	ANOVA								
	Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*	*t-test*	*p-value/3*
	Between Groups	262.4042	2	131.2021	10.95497	0.000354	3.369016	7 v E	0.000284
	Within Groups	311.3889	26	11.9765				E v R	3.89E-05
	Total	573.7931	28						

Mn	ANOVA								
	Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*	*t-test*	*p-value/3*
	Between Groups	2434.572	2	1217.286	18.74301	9.12E-06	3.369016	7 v E	0.000211
	Within Groups	1688.6	26	64.94615				7 v R	1.09E-06
	Total	4123.172	28						

Cu	ANOVA								
	Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*	*t-test*	*p-value/3*
	Between Groups	7.577008	2	3.788504	8.498882	0.001445	3.369016	7 v E	6.33E-05
	Within Groups	11.58989	26	0.445765					
	Total	19.1669	28						

Table 5. ANOVA revealing significant concentration differences
Key: 7 = Seventh Street, E = Emerson, R = Russell

DISCUSSION

Identification of point source pollution is beyond the scope of this study, however, land use history can suggest reasons for differences between gardens. Property Valuation Administration (PVA) documents revealed that at the Russell ten site deed transfers occurred from 1918-1995. According to the Vision Russell project, Russell was one of the first and most desirable neighborhoods in Louisville (Vision Russell, 2018). Based on the residential neighborhood surrounding the site, it is likely there was a home located on this property. Since the history of the property is not available through deed transfers alone, it is unknown when structures at the side were demolished or if vehicles, chemicals, or pesticides were stored there. When soil sampling was performed, it appeared that this garden was not utilized as much as 7th Street and Emerson. Low input was observed on most plots. Due to the proximity of industry and history of poor air quality potential for atmospheric deposition exists. Over 80% of the toxic air pollution emitted in 2017 was in west and south Louisville (Van Velzer, 2019).

PVA documents revealed that the 7th Street site has never been developed and has been owned by the Louisville Metropolitan Sewer District since 1926. It is identified as a combined sewer overflow (CSO) area. To the west is 7th Street Road, a major arterial roadway with 5 lanes that is heavily used by personal vehicles and heavy trucks. Along the south side are 2 large elevated parking lots and to the east is residential. On the north side of the gardens is a pool supply company. Due to the presence of elevated roadways and parking lots, this site is vulnerable to runoff from vehicles, and road chemicals. The presence of commercial and industrial properties could contribute to atmospheric deposition of contaminants. Finally, the CSO located on the property increase the risk of exposure to bacteria, PAHs, hormones, medication, and other chemicals.

At Emerson, history of a school structure on property could correlate with Pb, although concentration was below the lowest measurable concentration (<0.1 ppm). High input gardens had visibly more input than high gardens at other sites, which is likely related to higher socioeconomic status around the garden. Emerson has the lowest poverty rate at 15.59% (LOJIC, 2018). Additionally, Emerson is surrounded by residential properties, making it possible to transport materials such as fallen leaves for use as mulch without the use of a vehicle. As with Seventh Street, Emerson has a CSO on the property increasing risk of exposure to the community through participation.

IMPLICATIONS

In both Seventh Street and Emerson gardens, concentration of Cu and Zn were well under the desirable maximum level of elements in unpolluted soils (Cu:36, Zn:50ppm) suggesting they are safe for gardening currently. In Russell, 2 plots were over the World Health Organization guidelines for Zn - 74 and 96ppm, respectively (Denneman and Robberse, 1990). As discussed in the literature review, Long-term exposure to copper dust has the potential to irritate nose, mouth, and eyes, and can cause headaches, dizziness, nausea, and diarrhea. Long-term effects of zinc dust exposure are unknown, but according to the CDC, it is unlikely that children would ingest enough zinc from eating soil to cause problems, but children should be supervised (CDC, 2007).

Russell community garden revealed the presence of Pb, though it was below the WHO guideline of 85ppm (Denneman and Robberse, 1990). In 2012 CDC restated a conclusion from 1991 that there is no safe level of lead exposure (Margenot, 2018). Presence of lead in Russell presents a risk for gardeners. As stated in the literature review, soil has been identified as a pathway of lead exposure, especially children, and exposure can cause developmental problems

(Mielke and Reagan, 1998). Exposure to lead in adults can cause renal disease, decreased fertility, and can be toxic at low concentration for people of all ages. Additionally, root vegetables and leafy vegetable plants accumulate lead more readily from soil (Khan, 2015, Harmanescu et al., 2011, McBride, et al 2013). The presence of Pb in Russell community garden is not a concern if EPA best practices are followed, however even low concentration of Pb is a concern if children are present in this garden as children are more likely to ingest soil via hand-to-mouth play (U.S. EPA, 2014).

While identification of volatile organic compounds (VOC), polycyclic aromatic hydrocarbons (PAH), and polycyclic biphenyls (PCBs) are beyond the scope of this project, it is important to recognize that these substances may be present in soil based on previous site uses. Future studies could perform the testing needed to identify presence of these contaminants.

RECCOMENDATIONS

Food production in potentially contaminated soil can be performed safely using best management practices established by Environmental Protection Agency (U.S. EPA, 2014). Best practices emphasize the need for sites far from traffic and industry, soil testing prior to starting an urban garden, and use of gloves when manipulating soil. Gardening in raised beds with a barrier between ground level and imported soils and addition of compost and other organic soil amendments can reduce risk of contaminant exposure. Variables that influence the degree of risk including soil pH, soil quality, organic material, and concentration of contaminant must be closely monitored.

Research

Since all gardens are located in close proximity to roadways, and two are in a combined sewer overflow (CSO) flood prone area, future research can include measurement of polycyclic aromatic hydrocarbons (PAH), polychlorinated biphenyl (PCB), and volatile organic compounds (VOC). Testing for these contaminants is especially important where roadways and parking lots are elevated around gardens. Variability within gardens and presence of lead suggest that transect sampling be performed in Russell. Use of an EPA accredited lab is recommended for lead soil testing.

Managers

Routine soil testing is performed when gardens are created, however guidelines are not provided for follow-up testing (University of Kentucky, 2018). Establishing a comprehensive soil-testing schedule will provide data to observe any changes in concentration of trace nutrients and contaminants. Providing this information to participants is important and provides peace of mind for urban gardeners. Collaborative efforts can help to increase funding to support community gardens. The EPA established the Office of Environmental Justice in 1994 dedicated to promotion of “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” (U.S. EPA, 2020). This federal agency provides community resources, grants, funding, and technical assistance to ensure environmental safety for all Americans.

Since management of gardens includes private citizens, governmental entities, and nonprofit organizations cooperation is critical. Management should work to develop a consistent and comprehensive education protocol to ensure safety for participants, increase awareness, and engage communities. A best management practices (BMP) protocol for gardeners, volunteers, and management organizations using EPA guidelines can be implemented. Education opportunities exist when participants pay for garden plots, however consideration of audience including education level and primary language spoken by participants should be considered. 7th Street community garden is used by many refugee families who are non-native English speakers. Increasing cultural competency can be accomplished by involving interpreters, posting information in multiple languages, and consideration of growers' diverse values, beliefs, and cultural needs. Cultural awareness can increase trust between management and growers and help to increase understanding of potential health risk for all growers. Further cooperation with refugee organizations in the community could provide additional resources and support for managers.

In Russell where lead and zinc are present raised beds with a physical barrier between beds and ground level soil should be constructed. Soil in raised beds should be tested prior to planting, and routinely retested as recontamination by wind dispersed particulate is possible (Clark, et al 2007). If this is not financially possible, contaminated gardens should be well marked to inform growers not to use them. Management should work to demonstrate best practices in all gardens as a participant education strategy including, thorough washing of vegetables, tools, clothing and skin that is in contact with soil, discarding lower leaves of plants that are more likely to have contact with soil (U.S. EPA, 2014). Finally, mulch should be placed in all walkways to decrease the potential for soil disturbance and grower contact with contaminated soil.

Growers

Observation of children in and around gardens can help to prevent accidental ingestion of soil through hand-to-mouth contact. Growers should avoid planting of root and leafy vegetables in plots where lead is present. Thorough washing of produce, peeling root vegetables, and thorough washing of clothing, tools, and hands after contact with soil are additional strategies to avoid exposure to contaminants (U.S. EPA, 2014).

Application of compost or other organic material can decrease contaminant concentration and make contaminants less available for plants to take up (U.S. EPA, 2014). Application of compost and winter cover cropping can improve soil health without the risk of runoff associated with conventional fertilizer. These management practices will not remove contaminants but will help to immobilize metals in the soil and reduce potential of plant uptake (USDA, 2000). Acquisition of compost may be difficult for participants. The University of Louisville operates a free composting center on campus. Management agencies could work together to transport compost for participant use.

CONCLUSION

This study identified the presence of contaminants in Louisville, Kentucky's urban community gardens. As previous results were unavailable, the results provide a baseline for comparative studies. A high degree of variability within gardens identified the need for additional studies. Participation in community gardens provides many health and social benefits and can be performed safely by following EPA best practices. In Louisville, management of community gardens includes private citizens, government entities, and nonprofit organizations. Management must work cooperatively to develop a comprehensive education protocol that can be shared across organizations. Management must ensure safety for participants, increase awareness using effective community engagement strategies, and dedicated to provision of accurate and culturally appropriate information to all participants.

REFERENCES

Agency for Toxic Substances and Disease Registry, (ATSDR), viewed 27 September 2018. Available at: https://www.atsdr.cdc.gov

Agency for Toxic Substances and Disease Registry (ATSDR). 2007. Toxicological Profile for Arsenic. Atlanta, GA: U.S. Department of Health and Human Services, Public Health Services.

Agency for Toxic Substances and Disease Registry (ATSDR). 2005. Toxicological profile for Zinc. Atlanta, GA: U.S. Department of Health and Human Services, Public Health Service.

Agency for Toxic Substances and Disease Registry (ATSDR). 2010. Toxicological Profile for Boron. Atlanta, GA: U.S. Department of Health and Human Services, Public Health Service.

Agency for Toxic Substances and Disease Registry (ATSDR). 2012. Toxicological profile for Manganese. Atlanta, GA: U.S. Department of Health and Human Services, Public Health Service.

Agency for Toxic Substances and Disease Registry (ATSDR). 2004. Toxicological profile for Copper. Atlanta, GA: U.S. Department of Health and Human Services, Public Health Service.

Agency for Toxic Substances and Disease Registry (ATSDR). 2007. Toxicological Profile for Arsenic (Update). Atlanta, GA: U.S. Department of Health and Human Services, Public Health Service.

Agency for Toxic Substances and Disease Registry (ATSDR). 2007. Toxicological Profile for Lead (Update). Atlanta, GA: U.S. Department of Health and Human Services, Public Health Service.

Agency for Toxic Substances and Disease Registry (ATSDR). 2008. Toxicological Profile for Cadmium (Draft for Public Comment). Atlanta, GA: U.S. Department of Health and Human Services, Public Health Service.

Adamczyk-Szabela, D., Markiewicz, J. and Wolf W.M. 2015 “Heavy Metal Uptake by Herbs. Iv. Influence of Soil Ph on the Content of Heavy Metals in Valeriana Officinalis L,” 226(4), pp. 106–106.

Andreatta, S. L. 2015 ‘Through the Generations: Victory Gardens for Tomorrow’s Tables’, Culture, Agriculture, Food & Environment, 37(1), pp. 38–46. doi: 10.1111/cuag.12046.

Birky, J. and Strom, E. (2013) “Urban Perennials: How Diversification Has Created a Sustainable Community Garden Movement in the United States,” Urban Geography. 34(8), pp. 1193–1216. doi: 10.1080/02723638.2013.784086.

Bolan, N. S., Adriano, D. C. and Curtin, D. (2003) “Soil Acidification and Liming Interactions with Nutrient and Heavy Metal Transformation and Bioavailability,” 78, pp. 216–272.

Carney, P. A. *et al.* (2012) “Impact of a Community Gardening Project on Vegetable Intake, Food Security and Family Relationships: A Community-Based Participatory Research Study,” 37(4), pp. 874–881. doi: 10.1007/s10900-011-9522-z.

Clark H.F., Hausladen, D.M., and Brabander, D.J. 2008 “Urban Gardens: Lead Exposure, Recontamination Mechanisms, and Implications for Remediation Design,” 107(3), pp. 312–9. doi: 10.1016/j.envres.2008.03.003.

Denneman, C.A. and Robberse, J.G., 1990. Ecotoxicological risk assessment as a base for development of soil quality criteria. In *Contaminated Soil’90* (pp. 157-164). Springer, Dordrecht/Boston/London.

Feeding America. 2016. Food Insecurity in Jefferson County. Map the Meal Gap Project. Available at: http://map.feedingamerica.org/county/2016/overall/kentucky/county/jefferson).

Food and Agriculture Organization of the United Nations. 2010. Available at: http://www.fao.org/economic/es-policybriefs/multimedia0/presentation-urban-agriculture-and-food-security/en/

Food in Neighborhoods Committee. 2010. The State of Food: A snapshot of food access in Louisville. Mayor's Healthy Hometown Movement.

Food in Neighborhoods Community Coalition. 2018. Urban Agriculture Map. Accessed 15, October 2018. Available at: https://foodinneighborhoods.org/grow/map/

Fung, Y.-C. D., Croft, B., Johnson, A. F. 2016. Urban Background Study Sampling and Analysis Plan and Quality Assurance Plan. U.S. Environmental Protection Agency, Region 4.

Gamble, A. & Mitchell, C. 2018. Interpreting Soil Test Reports From Commercial Labs. Alabama A&M and Auburn Universities Extension. Available at: https://www.aces.edu/blog/topics/farming/interpreting-soil-test-reports-from-commercial-labs/

Harmanescu, M. *et al.* (2011) “Heavy Metals Health Risk Assessment for Population Via Consumption of Vegetables Grown in Old Mining Area; a Case Study: Banat County, Romania,” 5(1), pp. 1–10. doi: 10.1186/1752-153X-5-64.

Heinegg, A., Maragos, P., Mason, E. Rabinowicz, J. Straccini, G, Walsh, H. 2002. Soil Contamination and Urban Agriculture: a practical guide to soil contamination issues for individuals and groups. McGill School of Environment, Quebec, Canada H3A 2A7.

Jaishankar, M. *et al.* (2014) “Toxicity, Mechanism and Health Effects of Some Heavy Metals,” Interdisciplinary Toxicology. 7(2), pp. 60–72. doi: 10.2478/intox-2014-0009.

Jennings, A. A. and Petersen, E. J. 2006 “Variability of North American Regulatory Guidance for Heavy Metal Contamination of Residential Soil,” Journal of Environmental Engineering and Science. 5(6), pp. 485–508. doi: 10.1139/s06-019.

Kanu, A. B. *et al.* (2007) “A Small Subsurface Ion Mobility Spectrometer Sensor for Detecting Environmental Soil-Gas Contaminants Electronic Supplementary Information (ESI) Available: Operating Conditions, VOC Data and Individual Ion Mobility Spectra. Journal of Environmental Monitoring. Vol. 9(1), pp. 51–60. doi: 10.1039/b610493b.

Khan A *et al.* (2015) “The Uptake and Bioaccumulation of Heavy Metals by Food Plants, Their Effects on Plants Nutrients, and Associated Health Risk: A Review,” Environmental Science and Pollution Research 22(18), pp. 13772–99. doi: 10.1007/s11356-015-4881-0.

Kortright, R. and Wakefield, S. (2011) “Edible Backyards: A Qualitative Study of Household Food Growing and Its Contributions to Food Security,” Journal of the Agriculture, Food, and Human Values Society 28(1), pp. 39–53. doi: 10.1007/s10460-009-9254-1.

Leake, J. R., Adam-Bradford, A. and Rigby, J. E. 2009 “Health Benefits of 'grow Your Own' Food in Urban Areas: Implications for Contaminated Land Risk Assessment and Risk Management?” 8 (Suppl. 1), p. 6. doi: 10.1186/1476-069X-8-S1-S6.

Louisville Metropolitan Sewer District. 2019. Consent Decree. Available at: https://louisvillemsd.org/consent-decree

Louisville Jefferson County Information Consortium (LOJIC). 2018. LOJIC online, Map Hub, Available at: https://www.lojic.org/lojic-online.

Margenot, A. 2018, March 1. Soil heavy metal contamination. University of Illinois Urbana-Champaign. 2018 Small Farms Winter Webinar Series, hosted by University of Illinois Extension Local Food Systems and Small Farm team.

McBride, M. B. et al. 2013 “Lead and Arsenic Uptake by Leafy Vegetables Grown on Contaminated Soils: Effects of Mineral and Organic Amendments,” 224(1), pp. 1–10. doi: 10.1007/s11270-012-1378-z.

McClintock, N. 2012. Assessing soil lead contamination at multiple scales in Oakland, California: Implications for urban agriculture and environmental justice. Applied Geography, 35, 460-473.

Mielke HW and Reagan PL (1998) “Soil Is an Important Pathway of Human Lead Exposure,” Environmental Health Perspectives. 106, pp. 217–29.

Mylavarapu, R., Obreza, T., Morgan, K. 2014., Hochmuth, V.N., Wright, A. Extraction of Soil Nutrients Using Mehlich-3 Teagent for Acid-Mineral Soils of Florida. University of Florida, IFAS Extension. Department of Soil and Water Sciences, University of Florida. SL407.

Olaniran A.O, Balgobind A and Pillay B. 2013. "Bioavailability of Heavy Metals in Soil: Impact on Microbial Biodegradation of Organic Compounds and Possible Improvement Strategies," International Journal of Molecular Sciences. 14(5), pp. 10197–10228. doi: 10.3390/ijms140510197.

Opitz, I. *et al.* (2016) "Contributing to Food Security in Urban Areas: Differences between Urban Agriculture and Peri-Urban Agriculture in the Global North," Agriculture and Human Values. 33(2), pp. 341–358. doi: 10.1007/s10460-015-9610-2.

Parece, T. E., Serrano, E. L. and Campbell, J. B. (2017) "Strategically Siting Urban Agriculture: A Socioeconomic Analysis of Roanoke, Virginia," The Professional Geographer 69(1), pp. 45–58. doi: 10.1080/00330124.2016.1157496.

Parece, T. E. and Campbell, J. B. (2017) "Assessing Urban Community Gardens' Impact on Net Primary Production Using NDVI," Urban Agriculture and Regional Food Systems. Vol. 2(1), pp. 1–17. doi: 10.2134/urbanag2016.07.0004.

Penas, E.J. and Lindgren, Dale T., "G90-945 A Gardener's Guide for Soil and Nutrient Management in Growing Vegetables" (1990). Historical Materials from University of Nebraska-Lincoln Extension. 1017. https://digitalcommons.unl.edu/extensionhist/1017

Phillips, P. J. et al. (2012) “Combined Sewer Overflows: an Environmental Source of Hormones and Wastewater Micropollutants,” Environmental Science and Technology. 46(10), pp. 5336–5343. doi: 10.1021/es3001294.

Pryor, B.N., Hollenbach, R. Barber, A, Gonzales. (2017). Louisville Metro Health Equity Report. Center for Health Equity, Louisville Jefferson County Public Health and Wellness. Available at: https://louisvilleky.gov/government/center-health-equity/louisville-metro-health-equity-report-2017

Silveira, A. *et al.* (2016) “Assessment of Loose and Adhered Urban Street Sediments and Trace Metals: A Study in the City of Poços De Caldas, Brazil,” Journal of Soils and Sediments. Vol. 16(11), pp. 2640–2650. doi: 10.1007/s11368-016-1467-5.

Taylor, K. G. and Robertson, D. J. (2009) “Electron Microbeam Analysis of Urban Road-Deposited Sediment, Manchester, UK: Improved Source Discrimination and Metal Speciation Assessment,” Applied Geochemistry. Vol. 24(7), pp. 1261–1269. doi: 10.1016/j.apgeochem.2009.03.011.

United States Department of Agriculture, Economic Research Service. (2019). Food Insecurity in the U.S. Available at: usda.gov/topics/food-nutrition-assistance/food-security-in-the-us/measurement/

United States Department of Agriculture, Natural Resources Conservation Service. n.d. Urban Soil Quality Restoration. https://www.nrcs.usda.gov/wps/portal/nrcs/detail/null/?cid=nrcs142p2_008533

United States Department of Agriculture, Natural Resources Conservation Service. 2000. Heavy Metal Soil Contamination. Urban Technical Note 3. Available at: https://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/nrcs142p2_053279.pdf

United States Census Bureau. 2017. 2010 Urban Area FAQs. Available at: https://www.census.gov/programs-surveys/geography/about/faq/2010-urban-area-faq.html. Accessed: 20 April 2019.

United States Environmental Protection agency 2017. EPA Brownfield and Land Revitalization Program. Available at: https://www.epa.gov/brownfields/overview-epas-brownfields-program

United States Environmental Protection Agency. 2011. Reusing Potentially Contaminated Landscapes: Growing Gardens in Urban Soils. Available at:

https://www.epa.gov/sites/production/files/2014-03/documents/urban_gardening_fina_fact_sheet.pdf

United States Environmental Protection Agency. 2017. Regional Screening Levels (RSLs) - Generic Tables. Available at: https://www.epa.gov/risk/regional-screening-levels-rsls-generic-tables.

United States Environmental Protections Agency. 2020. Environmental Justice. Available at: https://www.epa.gov/environmentaljustice.

University of Kentucky, College of Agriculture of Food and Environment. 2018. Jefferson County Cooperative Extension. Community Gardens. https://jefferson.ca.uky.edu/content/community-gardens.

University of Kentucky. College of Agriculture of Food and Environment. 2018. Jefferson County Cooperative Extension. Soil Tests. Available at: https://jefferson.ca.uky.edu/content/soil-tests

Van Velzer, R. 2019. Unequal: What More Can Louisville Do To Improve Toxic Air Pollution. Unequal. News. Louisville, KY. 89.3 WFPL. Available at: https://wfpl.org/unequal-what-more-can-louisville-do-to-improve-toxic-air-pollution/

Varlamoff, S., Lessl, J., Sonon, L., Bauske, E. 2016. Urban Gardening: Assessing Soils for Contamination. Georgia Center for Urban Agriculture. University of Georgia Extension. Circular 1075. Available at:

https://secure.caes.uga.edu/extension/publications/files/pdf/C%201075_2.PDF.

Vision Russell. 2018. History of the Russell Neighborhood. Available at: https://visionrussell.org/about/russellneighborhood/

Vosnakis, A. S. & Perry, E. 2009. Background Versus Risk-Based Screening Levels - An Examination of Arsenic Background Soil Concentrations in Seven States. International Journal of Soil, Sediment, and Water. Vol 2 n2.

Winne, M. 2008. Closing the food gap : resetting the table in the land of plenty, Boston, Beacon Press.

Wolch, J. R., Byrne, J. and Newell, J. P. (2014) "Urban Green Space, Public Health, and Environmental Justice: The Challenge of Making Cities 'just Green Enough,'" 125, pp. 234–244. doi: 10.1016/j.landurbplan.2014.01.017.

Wong, R. Gable, L, & Rivera-Nunez. 2017. Perceived Benefits of Participation and Risks of Soil Contamination in St. Louis Urban Community Gardens. Journal of Community Health. 43, 604-610.

World Bank. 2018. United Nations Population Division. World Urbanization Prospects. Available at:

https://data.worldbank.org/indicator/SP.URB.TOTL.IN.ZS?end=2018&locations=US&start=1960

Xing, R., LI, Y., Zhang, B., LI, H. & Liao, X. 2017. Indicative and complementary effects of human biological indicators for heavy metal exposure assessment. Environmental Geochemistry and Health, 39, 1031-1043.

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University of Louisville, Urban and Public Affairs
Louisville, Kentucky, USA
Advisor: Dr. Aaron Rollins
GPA 3.968 (4.0 scale)

Master of Science, Environmental Studies **2017-2018**
Kentucky State University - Frankfort, Kentucky
Advisor: Dr. Leigh Whittinghill
GPA 3.8 (4.0 scale - 18 credit hours completed)

Bachelor of Arts, English Literature **2013**
Indiana University Southeast – New Albany, Indiana

Academic Experience and Scholarly Activity

University of Louisville
Graduate student team project **December 2018**

For Sustainable Social-Ecological Systems
"Sustainability and Redevelopment: a case study of the Vision Russell Project"

> A team project evaluating the human and environmental impacts of the Vision Russell redevelopment project in Louisville. Utilizing Elinor Ostrom's Institutional Analysis Development Framework and Stephen Wheeler's Dimensions of Sustainability, we assess overall structure and sustainability of the Vision Russell Plan.

Environmental Studies student team project **May 2017**
"Land Management Plan for a Forested Ecosystem at St. Francis School Oldham County, Kentucky"

A team project developing a land management plan for St. Francis School. We developed strategic objectives for maximizing the productivity of the landscape for environmental education. This plan contains suggestions for forest management, prescribed grazing, integrated pest management, establishment of pollinator habitat, construction of windbreaks, restoration of grasslands and wetlands, reforestation, and siting of outdoor classrooms. All suggestions informed by soil data, timber cruise data and consultation with local and regional professionals.

Poster Project – Introduction to GIS **Fall 2017**
"*Suitability Model for a vegetable garden at St. Francis School Goshen, Kentucky*"
This project used ArcGIS to map ideal locations for a vegetable garden for the primary school to use for education. Flooding of the current garden has affected the quality and quantity of harvest. Raised beds have improved the issue, but the school wishes to increase production for use in the cafeteria. A map was generated identifying suitable areas containing well-drained soil, no existing or planned structures, desirable slope, and is not a wooded area.

Awards and Leadership

American Society for Public Administration **April 3-7, 2020**
2020 Founders' Fellow

Congress for the New Urbanism (CNU) Louisville **June 12-15, 2019**
General scholarship

Ecological Society of America (ESA) in partnership with United States Society for Ecological Economics (USSEE) Annual Meeting **August 11-16, 2019**
Earth Stewardship Initiative Fellow

University of Louisville **August 2018 – May 2020**
University Fellowship (full tuition and stipend awarded)

Kentucky State University **August 2017 – August 2018**
Graduate Research Assistantship (stipend awarded, USDA Evans Allen Grant)

Kentucky State Fair, First Premium - garlic, **August 2018**
Vegetables and Melons

Professional Experience

Every Drop Intern **September 2019 - present**
Kentucky Waterways Alliance

- Assess sites for rain barrel and rain garden installation for Every Drop Program

- Facilitate plantings and barrel installation, monitoring, follow-up with previous participants to identify planting success, and obtain qualitative data of participant perception.
- Check-in with participants, communicate important dates, record outcomes, develop and revise owner's manual.
- Participate in environmental education events as needed as a representative of KWA.

Graduate Research Assistant **August 2017 – August 2018**
Kentucky State University

- Participated in set up of research platforms; raised beds, container gardens and green roof including installation of drip irrigation system, construction of raised beds, and installation of water collection system.
- Collected samples of rainwater runoff, plant, harvest and quantify production from research platforms.
- Performed water quality analysis: Ammonium-N, nitrate-N, total phosphorous, potassium, turbidity, pH, color and conductivity.
- Conducted urban farm surveys at Louisville area farmers markets.

Field Technician
Garvin Brown Preserve **February 2009- October 2016**

- Performed fieldwork to control purple loosestrife, an invasive, non-native plant species in a protected wetland area including early identification, cutting, application of herbicide, and reseeding with native species.
- I was the primary project coordinator from 2010 to 2016.

Veterinary Technician **October 2013- May 2015**
Animal Dermatology Clinic

- Utilized strong communication and facilitator skills in building supportive client-doctor relationships and significant client instruction.
- Regularly demonstrated interest and compassion in providing thoughtful and thorough client service.
- Knowledge base includes animal restraint, venipuncture, intradermal skin test testing, biopsy, maintenance of patients under anesthesia, and maintenance of supply stock.
- Maintained detailed and timely medical records, scheduled appointments and maintained client-doctor communications. Traveled extensively to satellite clinics in Kentucky and Indiana.

Veterinary Technician **October 1999- October 2013**
Metropolitan Veterinary Specialists/Metropolitan Veterinary Emergency Service

- Assisted for internal medicine procedures including echocardiogram, EKG, abdominal ultrasound, trans-tracheal wash, endoscopy and Holter monitor placement.

- Monitored surgical and ophthalmology patients in the operating room and scrubbed in when requested.
- Actively involved in client education and instruction.
- Knowledge and experience in placement of IV catheters, IV and gas anesthetic, anesthesia monitoring, intubation of canine and feline patients, radiographs, postoperative patient care, placement of telemetry monitoring equipment, critical patient care, and venipuncture.
- Developed a safety protocol for zoonotic disease prevention for patients and staff in hospital.

Conference Presentations

"The effect of legacy contamination and influence of observed soil **August 2019**
amendment in an urban community garden Louisville, Kentucky USA"
Ecological Society of America (ESA) Annual Conference Louisville, KY

University Service

University of Louisville
Sustainability Council, Education and Research Committee **August 2018-present**

Sustainable and Local Foods Committee **August 2018-present**

Kentucky State University **August 2018**
College of Agriculture, Communities and the Environment graduate student/faculty liaison

Memberships and Affiliations

American Society for Public Administration, student member	**2019 - 2020**
Ecological Society of America, student member	**2018 - 2020**
Congress for the New Urbanism, student member	**2018 - 2020**
Kentucky Waterways Alliance, student member	**2018 - 2020**
Eco-Reps, student member	**2018 - 2020**
Urban Agriculture Coalition, Louisville, Kentucky	**2018 - 2019**
Green Society Kentucky State University**,** student member	**2017- 2018**

Technical Skills and Certifications

University of Louisville
General Laboratory Safety
and Hazardous Waste Classroom Training **April 22, 2019**
Basic Biosafety Training **May 28, 2019**

Kentucky State University
Leopold Education Project (LEP) Educator Certification **May 18, 2018**

RCRA Hazardous Waste Awareness
for Large Quantity Generators **March 19, 2018**

OSHA Globally Harmonized System, Hazardous Communication Standard (29 CFR 1910.1200) **March 19, 2018**

Master Gardener Certification **August 2015**

<u>Volunteer Activities</u>

DuPont Manual Regional Science Fair 2019-2020 (plant science, environmental science judge) **March 9, 2019**

Volunteer tree giveaway, Division of Community Forestry, Office of Sustainability Louisville Metro Government **March 16, 2019**

Salt River Watershed Watch Annual Conference attendee **February 28, 2019**

Reforest Frankfort 2018 **April 14, 2018**

Sustainability Summit 2018, Louisville Sustainability Council **October 19, 2018**

Sustainability Summit 2019, Louisville Sustainability Council **November 1, 2019**

St. Mary’s Center garden and Eastern Area Community Ministries
food pantry garden **March – July 2016**

Alley Cat Advocates, Big Fix volunteer **2015 – 2016**
Prepare animals for spay/neuter, assess for illness and injury

Commonwealth of Kentucky/International Wildlife Rehabilitation Council
Licensed Wildlife Rehabilitator – mammals and reptiles **2008 – 2011**