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Master's Thesis

Soil for Sustainability:
Impacts of urban agriculture on soil health

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Abstract

Urban agriculture (UA) is growing in popularity around the world, transforming vacant parcels into flourishing farms and gardens. While UA is typically associated with positive environmental, social, and economic benefits, multiple challenges and barriers to UA exist. In many post-industrial landscapes, soil lead contamination poses a real threat to agriculture, with potential implications for human health as well as impacts on other aspects of soil health, such as fertility and microbial activity. The addition of compost, use of cover crops, or other management practices in urban gardens has the potential to reduce lead bioavailability and can simultaneously improve soil fertility; however, little is known about the impact of these management practices on urban soil health. This suggests that risks, such as lead contamination, should be considered within a broader soil health framework to ensure a healthy and sustainable future for UA practices. To advance these goals, this study investigated how a range of management practices within UA impact urban soil health. Soil samples were collected from 13 UA sites in Detroit, Michigan, and analyzed for a suite of biological, chemical, and physical soil health components. Results show that lead levels were lower in managed areas than in unmanaged areas of the farms and gardens sampled ($p = 0.006$), suggesting that management practices have a significant impact on lead bioavailability. Further, multiple soil health variables were significant predictors of reduced lead bioavailability throughout garden sites. While management practices such as compost addition have the ability to reduce lead bioavailability, tradeoffs exist for excess levels of soil phosphorus and potassium on UA sites. This study also analyzed urban growers' motivations for participating in UA and the challenges growers face in advancing UA goals. Specifically,

farmers and gardeners identified that economic factors present the greatest barriers sustainable management practices. To fully understand the impacts of UA, and its contribution to city sustainability, both environmental and social components of urban gardens must be considered.

I. Introduction

Rapid urbanization is increasingly becoming a concern for cities. Cities currently hold half of the world's population, and are expected to hold two-thirds of the world's population by 2050 (Guitart et al. 2012; Pickett et al. 2011). As cities grow in both population and in size, their management becomes increasing complex, leading to issues such as high unemployment rates, decreased food security, social inequalities, increased vacant lots, and environmental degradation (Cohen, 2008). While there is no one solution to these pressing issues, city residents, policymakers, scholars, and community organizations have shown increased interest in urban agriculture (UA) as a mechanism that can address a subset of these issues while improving the overall sustainability of cities.

Urban agriculture has been rising in popularity over the last 30 years, expanding to cities worldwide, often with the explicit intention to enhance resiliency and sustainability. Urban agriculture can be defined as the practice of growing, cultivating, and distributing food, and the raising of livestock, in and around cities (Mougeot, 2006; Cohen, 2011). Historically, food production in urban environments had a prominent role in city life, particularly in times of war and economic hardship (Deelstra and Girardet, 2000; Gregory et al. 2015). Today, however, the expansion of UA can be attributed to its multifunctionality; that is, its potential to address both human and environmental goals. Urban agriculture participation can also be attributed to the potential environmental it brings, such as increased biodiversity, improved nutrient cycling, storm water management, and enhanced air quality and local climate regulation (Camps-Calvet et al.

2016). Beyond the environmental benefits, public engagement in UA has also been shown to provide social benefits, such as fostering community connections (White 2011). Increasing the availability of healthy, nutritious food options for city residents, and improving mental and physical health through acts of gardening, may also address public health needs (McClintock & Simpson 2017).

Detroit, Michigan is currently an example of UA's multifunctionality and diversity. The city estimates that over 1,500 UA sites exist within the city limits, ranging in size from small home gardens to large scale farms (Keep Growing Detroit). Detroit has always contained UA within its boundaries, but in recent years, UA has grown as part of grassroots community efforts to improve nutritional quality and environmental education opportunities. UA participants in Detroit have transformed vacant lots into centers of food production, in attempts to improve food security, create more sustainable food systems, generate social resiliency, and provide culturally appropriate foods to communities (White 2011; Colasanti et al. 2012). While research in the field of UA, especially in Detroit, has focused on social resiliency and food justice, it is important for research in this region to expand to the natural sciences, to further understand the impacts of UA on urban ecosystems (Wortman and Lovell 2013).

To date, the natural science research on UA has found that it has the potential to alter urban ecosystems to enhance positive ecological interactions. In a review by Lin et al. (2015), authors found that UA practices, such as those within community gardens, increased overall species richness and biodiversity, providing habitats for arthropod, avian, and mammalian species. Agriculture performed within urban spaces also provides storm water management by creating permeable soils and increasing the amount of infiltration of water during storm events. (Pataki et al., 2011). Urban agriculture has also been predicted to provide soil health improvements, but little research has evaluated urban agriculture's impact on soil. More research is needed to develop a comprehensive understanding of the overall environmental impacts of UA and its associated management practices. For instance, while UA has the potential to offer multiple environmental benefits, hazards like soil contaminants, including lead, pose a serious risk to the production of food in urban environments.

Case studies of UA soil contamination have begun to surface in the literature, bringing up concerns for the viability of UA and making the need for more research on urban soil contamination crucial. Lead occurs naturally in soil at concentrations of 10-50 ppm, but concentrations larger than this pose a potential threat to plant growth and human health. According to the Environmental Protection Agency, lead is considered hazardous in soil above concentrations of 400 parts per million (ppm) (USEPA, 2017). A study conducted in Toronto and Ontario, Canada found that within the urban environment, soils had lead levels higher than 400 ppm, and were mildly contaminated with other contaminants such as chromium, iron, zinc, lead, copper, and cadmium (Nazzal et al., 2015). Sharma et al. (2014) found that in 43 vacant lots throughout Cleveland and Columbus, Ohio, arsenic concentrations were higher than the Environmental Protection Agency's Soil Screening levels. While heavy metal contamination is a problem in urban environments, lead is one of the most commonly studied contaminants, and has been found to pose a risk to UA sites. McClintock (2012) found that in Oakland, California, on a city-wide scale, lead levels averaged around 108 mg kg^{-1}, but ranged from 3 to 979 mg kg^{-1}. Together, these studies demonstrate the large spatial variability in soil lead levels, and the potential of UA sites to have hazardous lead levels. Lead contamination is therefore a serious issue for UA sites, which should be addressed.

The destruction of older buildings that contain lead-based paint is the primary source of lead contamination within cities, and lead can spread throughout soils through a multitude of mechanisms. In urban environments, lead contamination can occur through deposition from the air and uptake of lead into plant roots. Soil lead binds tightly on the surfaces of very fine clays and organic matter, and is highly insoluble. Lead therefore tends to accumulate in the top 1 to 2 inches of soil, unless mixed into deeper soil layers. While lead is bound tightly in soils, and can be challenging to remove, this also means that not all lead is available for absorption by plants, animals, and humans. The bioavailable fraction of lead or of other heavy metals in the soil is fraction that is available for absorption into living organisms, and is a critical consideration for understanding and addressing the potential threats of lead on UA sites (Attanayake et al., 2014). In soil, the bioavailable fraction of lead is typically small, however, in soils that are highly contaminated, bioavailability can vary (Brown et al., 2015).

Much of the literature around lead and UA focuses on human health impacts, as lead poisoning is a serious threat to children, and can potentially impact adults if ingested or inhaled in large quantities. Soils in urban farms and gardens, however, are less often considered from an ecological perspective, specifically regarding relationships between management and soil and plant health (Perez-de-Mora et al., 2006; Chen et al., 2015). Soil heavy metal contamination has been known to impact biological aspects of soil health, such as microbial activity and fertility (Wortman and Lovell, 2014). Soil lead has also been found to reduce plant growth and productivity. In a study by Hussain et al.

(2013), authors found that soil lead contamination led to decreased seed germination percentage and plant biomass, and reduced plant protein content. The impacts of lead on both soil and plant health.then, have the ability to reduce food production, and, as a result, could potentially impact food security and nutritional quality of crops (Chibuike and Obiora, 2014). These findings stress the importance of addressing soil lead contamination and other dimensions of soil health simultaneously.

Alongside this growing interest in UA and soil lead contamination, there is a growing interest in UA soil health. Soil health has been broadly defined as the "capacity of soil to function as a vital living ecosystem that sustains plants, animals, and humans," (USDA NRCS, 2012). The main goal of soil health analyses is to identify a range of indicators of overall soil quality that are sensitive to both measurement and changes in management practices. With UA expanding in cities across the world, and soil contamination becoming a more permanent problem in developing UA, it is important to understand the broader scope of soil health with a UA context, particularly linkages between management, soil health, and soil lead contamination. Extending the soil health framework to UA can determine key components of urban ecosystem sustainability, as well as impacts of soil health on ecosystem function including soil lead remediation.

Soil heavy metal removal techniques are highly expensive. Since many urban gardens primarily focus on social goals, such as increasing community resiliency, rather than commercial production, urban farmers often cannot afford the high prices of remediation strategies like soil removal. There are, however, other strategies for reducing soil lead contamination, such as bioremediation. Bioremediation techniques, such as the addition of compost or planting of crops for harvest and disposal, are commonly used on urban farms, as a relatively inexpensive mechanism for addressing soil contamination. For example, the addition of phosphorous-based fertilizers, including compost that has high levels of phosphours, can result in the formation of pyromorphite, which immobilizes soil lead (Attanayake et al., 2014). These techniques, however, have been found to vary in their effectiveness. One review reported that the impacts of compost and phosphorus fertilizer addition varied over time (Henry et al. 2015). That is, as these amendments decompose, they become less effective for reducing lead bioavailability; more research addressing the long-term impacts of compost and phosphorus fertilizer amendments is needed to improve overall soil health within cities. Urban soil contamination poses a threat to UA and city sustainability. While bioremediation strategies show promise in reducing the presence of urban soil contaminants, more knowledge on the effectiveness of soil remediation strategies, as well as how organic management practices influence soil contamination, is needed to fully address the issue.

As UA expands across the urban sector, through management, farmers and gardeners will play a large role in contributing to city sustainability. It is therefore also important to understand how farmers manage their land and perceive sustainability, as well as the barriers they face. For many urban farmers and gardeners, lack of experience, knowledge, and resources stand in the way of managing soils sustainably. In fact, a lack of resources, such as experience, staff, volunteers, and secure land tenure, has been reported as a large challenge for urban farmers and gardeners, and can contribute to the way farms and gardens are managed (Gregory et al., 2015). Identifying challenges to sustainable management practices can help to create appropriate and effective garden management plans, and can help identify potential resources that would benefit urban farmers and gardeners in the future.

To advance these ecological and social goals, this study investigates how a range of management practices within UA sites impact urban soil health in Detroit, Michigan. The specific research objectives are to: 1) Fully characterize the management practices of 13 urban gardens in different locations around Detroit; 2) Identify linkages between management and soil health by assessing soil lead content along with a suite of other chemical, physical, and biological soil health parameters; 3) Evaluate urban farmers' and community gardeners' perceptions of barriers they face in developing sustainable management practices; and, 4) Identify site-specific best management practices and share project findings with farmers. Systematic studies of UA's impact on soil health are necessary in order to gain a more comprehensive understanding of its impact on soil lead, and to further understand the potential for UA to contribute to environmental and social sustainability.

II. Methods

2.1 Site Location

Data for this study was collected in Detroit, Michigan, an expansive urban city with an industrial past. The city is approximately 142 square miles, with a relatively flat topography. Historically, Detroit's soil texture has been classified as silty clay loam, however, years of urbanization and alteration have led to further variations of soil texture throughout the city. Currently, the city's landscape has multiple different uses. Downtown Detroit serves as a hub for gray infrastructure and civilian life, while areas surrounding the city are a mixture of housing and natural landscapes. For this study, soil samples were collected from 13 urban farms and community gardens in Detroit, Michigan. Farmers were contacted through various social media modes, and asked if they were willing to participate within the study. Those that responded were selected for the study. Farm and gardens spanned diverse characteristics, from small community gardens all the way to large functioning farms on multiple acres.

2.2 Soil sampling

Soils were sampled between late August and November 2017, from the end of the growing season through the harvest period. Samples were collected from two plots per farm or garden site based on the following criteria: i) a plot under active UA management for vegetable production, and ii) an adjacent plot, which was vacant of crop production, for baseline characterization of soil lead. In each plot, 15-20 soil cores (2 cm diameter by 20 cm depth) were collected and composited. A subset of fresh soil was sieved to 2mm before processing and analysis. Both sieved and unsieved samples were air dried before further analysis.

2.3 Physical Analysis

Bulk density, soil texture, and aggregate stability were measured as physical properties and indicators of soil health. Soil physical properties influence how water and nutrients move through soil, as well as their availability to plants. Both laboratory and field analyses were used to determine the physical properties of soil on all UA sites. Bulk density was estimated by taking the fresh weight of 10-11 cores per field using a field scale, and was adjusted for soil moisture. A subset of dried soil was sent to A&L Great Lakes laboratories for soil texture (i.e., particle size) analysis.

Wet aggregate stability was determined with the use of a rain simulator within a laboratory setting. Approximately 25 grams of soil were spread evenly across a 0.25 mesh, 125 mm diameter sieve. The sieve was placed on a funnel with a previously weighed filter paper, which were then placed on top of a ring stand, and exposed to a rain simulator dripping at a rate of approximately 15 cm/hour. Rain exposure lasted for five minutes. Any soil material that remained on the sieve was thoroughly washed and any small stones that remained on the sieve after 5 minutes were washed off into a drying tin. Both the filter paper with slaked soil, and the stones in the tin were dried in the oven for approximately 2 days in a 100^{O} C oven. After samples were dried and weighed, aggregate stability was determined as the percentage of soil that was retained on the sieve during rain simulation.

2.4 Chemical Analysis

Soil chemical analysis consisted of measuring extractable inorganic nitrogen (N), total carbon (C), total nitrogen (N), soil lead bioavailability, and all macro and micronutrients. Chemical indicators of soil health allow for a deeper understanding of soil nutrient availability, it's pH, and how well the soil can retain nutrients. These factors in turn, impact other properties of soil health.

Soil was processed immediately in the laboratory for soil moisture and extractable inorganic nitrogen (NO_3^- and NH_4^+). To determine soil moisture, 10 grams of soil (sieved and unsieved) were placed into a tin, and dried for 48 hours at 105^{O} C. The following formula was used to determine soil moisture:

Soil Moisture (%) = ((Fresh Soil (g) – Dry Soil (g))/ Dry Soil (g)) x 100

Extractable inorganic nitrogen (N) was used to understand soil N availability on UA sites. For inorganic N determination, triplicate samples of sieved soil were extracted with 2M KCl. The NO_3^- and NH_4^+ concentrations in each soil sample was analyzed colorimetrically on a continuous flow analyzer (AQ2, Seal Analytical). Total C and N were determined by dry combustion analysis of approximately 0.4 grams of dried, sieved soil on a Leco TruMacCN Analyzer.

A subsample of unsieved soil was sent to A&L Great Lakes Laboratories to quantify the availability of lead (Pb), by the Mehlich 3 (IPC) method (Wolf and Beegle, 1995)), and phosphorus (P), potassium (K), magnesium (Mg), and calcium (Ca) concentrations. Soil samples were also analyzed for particle size (texture), and pH through soil analysis at A&L Great Lakes. Previous studies have found that the Mehlich-III soil lead bioavailability test strongly correlates with USEPA total lead concentrations. For example, Minca et al. (2013) found a high correlation (R^2=0.97) between the Mehlich-III test for lead bioavailability and the USEPA test for total soil lead. Witzling et al. (2011) also found a high correlation (R^2= 0.92) between the Mehlich-III test and the EPA standard lead test for UA garden sites in Chicago. This test is less expensive for gardeners, yet still provides valuable insight into the bioavailable fraction of lead.

2.5 Biological Analysis

Soil organic matter, short-term C mineralization and potentially mineralizable N (PMN) were measured as biological indicators of soil health. Biological properties of soil provide the most holistic perspective of soil health, because the activity of microorganisms and other soil biota determine soil nutrient availability and many other aspects of soil function. Total soil organic matter analysis was performed by A&L Great Lakes Laboratories.

An indicator of labile, or active C was measured with a short-term aerobic incubation on dried, and rewetted, soil. That is, mineralizable C is the measure of the flush of CO_2 produced by microbial activity over a 24-hour incubation period. This indicator reflects the quality of organic matter as an energy source for microbial activity. Briefly, 10 g of dried soil were weighed into 50mL centrifuge tubes in triplicate. These tubes were fitted with an airtight, rubber septa, and the CO_2 concentrations were measured when samples were first sealed and again 24 hours later. To measure the CO_2, approximately 0.5 mL of gas was extracted with a needle syringe and injected into a Li-Cor LI-820 infrared gas analyzer (Li-Cor Biosciences, Lincoln, NE).

A 7-day incubation with triplicate soil samples was used to determine PMN. Potentially mineraliable N is the fraction of organic N converted to plant available N under specific conditions (Drinkwater et al. 1996). Triplicate samples of sieved soil were added to 50mL centrifuge tubes with 10mL of DI water, and the headspace was flushed with N_2 to create anaerobic conditions. Samples were incubated in a chamber at 32^0 C for 7 days, followed by extraction using 2M KCl. Analysis of NH_4^+-N was conducted colorimetrically on a continuous flow analyzer (AQ2, Seal Analytical), and converted to PMN (g N kg dry soil^{-1} wk^{-1}).

2.6 Management interviews & farmer challenges survey

Management interviews were conducted both in person and by phone between August 2017 and February 2018. The purpose of these interviews was to learn more about soil management practices on urban farms and gardens, soil lead testing, and knowledge of soil lead. Surveys consisted of general management questions including: year of farm or garden establishment and size, motivation for participation in UA, land ownership, planting style, top 5 crops grown, animal residence, soil origin, prior soil testing, and type of soil amendment(s), if any, used. More detailed questions were asked regarding farmer and gardener knowledge of soil testing and farmer knowledge and perceptions of soil lead.

A second, online survey was developed to further understand the motivations farmers and gardeners have for participating in UA and the challenges they face in developing their farms and gardens. This survey used a Likert scale, followed by open response questions. The survey consisted of seven categories including: motivations for participation in UA, economic challenges, environmental challenges, knowledge-based challenges, resources challenges, community challenges, regulation and policy challenges, and challenges to implementing sustainable management practices. In this study, we defined sustainable management practices as environmentally sound, ecologically-based management practices, that reduce the risk, both short-term and long-term, for harming people and the surrounding environment. Examples of these practices include the use of cover crops, compost or other organic nutrient sources, the use of crop rotation, waste reduction, and farm and plot-scale agrobiodiversity. For the purposes of this study, we focused on the challenges farmers and gardeners face in implementing sustainable management practices. Descriptive statistics were used to analyze survey results.

2.7 Statistical Analysis

Descriptive statistics were used to analyze survey results. The mean, median, and standard error were calculated for all soil health parameters, to determine the distribution of soil health variables across all farms. These descriptive statistics were also shared with farmers, to farmers, to help them better understand their soil health status in relation to their neighbors, and with respect to typical ranges of the indicators measured for agricultural soils.

To assess differences in soil lead between the managed and the unmanaged farm and garden sites, we used a Welsh's paired t-test assuming unequal variances was used. Following this analysis, simple linear regressions models were used to identify the relationship between soil lead bioavailability and other soil health variables. All soil parameters were checked for normality and transformed as needed to meet model assumptions. Data were log transformed for extractable inorganic N, short-term C mineralization, total organic matter, total C, and total N, which had skewed distributions. General linear regression models were also used to identify soil health predictors of lead bioavailability. Finally, Likert survey descriptive statistics were determined for the top 5 motivations and challenges to urban farming and gardening.

III. Results

3.1 Characterization of UA management practices

Farms and gardens spanned diverse management characteristics across all sites (Table 1). They ranged in size from small community and school gardens (e.g., 18 to 557 m^2) to larger-scale farms (e.g., 4047 m^2). Year of establishment also varied, with some UA sites had been in production for over 10 years, while other sites had just developed in the last three years. Raised beds and field beds were the two main planting styles used in the gardens. Farms and gardens were considered to have a raised bed planting style if crop production occurred in large mounds of compost that were kept separate from the ground (with or without a physical barrier). Use of compost amendments was standard, with all but one site applying compost on an annual basis. Amounts of compost, however, ranged from place to place, with four farms and gardens growing strictly in compost material. Use of other management practices, such as tillage, cover cropping, and crop rotation was also variable. Cover cropping was the least used management practices, largely due to lack of knowledge and difficulty using this management practice.

3.2 Soil Lead Bioavailability

As predicted, there were significant differences in soil lead bioavailability between managed and adjacent, unmanaged sites. Figure 1 displays the results of the paired t-test for lead bioavailability between managed and unmanaged sites. Managed sites had significantly lower concentrations of bioavailable lead compared to their adjacent, unmanaged sites ($p=0.006$, Figure 1). The distribution of bioavailable lead values also varrieted between the managed and unmanaged sites also varied. The unmanaged UA sites had a wider range of values than the managed sites, which makes sense given the spatial variability of lead in soil.

Individual farm and garden soil lead concentrations are shown in Figure 2, both for soil lead bioavailability (ppm) and total lead concentrations (ppm). For our study, we used a linear regression equation by Minca et al. (2013) to estimate total lead concentrations using our Mehlich-III soil lead test results.

All individual farms and gardens had a lower lead concentration in the managed site versus the unmanaged site, both for soil lead bioavailability and total lead concentrations. The degree to which the managed site was less than the unmanaged site varied between farms and gardens. Some UA sites were found to have total lead concentrations nearing 400 ppm, the EPA crop production cutoff value (Figure 2b). However, no sites had total lead concentrations higher than 400 ppm.

We also examined the relationship between the number of years a farm had been established, and the difference in lead concentrations between managed and unmanaged sites, which serves as a proxy for change in lead with UA managment. Results show that for these sites there was no relationship between the number of years the farm had been established and the difference in bioavailable lead concentrations between the managed and unmanaged sites ($P=0.64$, Figure 3).

3.3 Soil Health Parameters and Soil Lead Bioavailability

We examined the relationship between multiple soil health parameters and soil lead bioavailability across managed areas only. Significant results were found between multiple soil health parameters and soil lead bioavailability (Figure 4). Log total C, phosphorus, and PMN all had a significant, negative relationship with lead bioavailability, where as bulk density had a positive relationship with lead, explaining 14-22% of the variation in lead bioavailability. This was an expected result because total C, bulk density, phosphorus, and PMN all have an influence on lead in soil, with the ability to reduce soil lead bioavailability.

3.4 Soil Health Parameters and Soil Management

Soil health indicators have been developed in part because they are dynamic and responsive to management practices. It is predicted that soil management practices, such as the addition of compost or phosphorus fertilizer, increases total soil organic matter content and nutrient cycling on UA sites, which is supported by results from this study. For example, sites that applied compost, which contains relatively high concentrations of phosphorus, had higher amounts of both organic matter and phosphorus in the soil. These sites also had lower lead bioavailability concentrations. Due to the small sample size, however, this study did not allow us to predict how specific management practices drive individual soil health parameters.

Table 2 displays the results of a linear regression analysis of bioavailable lead across farms using soil health parameters as predictors. Results indicate that soil organic matter (%), phosphorus (ppm), and wet aggregate stability are all predictors of soil lead bioavailability ($P=0.0001$; Adjusted $R^2= 0.43$). Specifically, within the model, soil organic matter and aggregate stability were shown to be highly significant predictors ($P<0.01$).

Finally, we examined whether soil organic matter and aggregate stability were correlated across farms, which has been found in other agricultural contexts (Figure 5). Surprisingly, for these UA sites we found a negative correlation between log organic matter and wet aggregate stability (Figure 5). This result is unexpected, as typical understanding is that as organic matter increases, aggregate stability also increases due to the formation of stable aggregates. However, the highest organic matter sites were primarily compost, rather than soil, which drove this relationship.

3.5 UA Farmer and Gardener Challenges

The top five ranked challenges that farmers and gardeners face in adopting management practices to improve sustainability on their UA sites were as follows: long-term financial viability; access to farming and gardening equipment; lack of fertile, healthy soil; profitability; and current zoning ordinances (Table 3). A variety of reasons were given regarding why particular management challenges hindered an urban grower's ability to use sustainable management practices on their farm. Some UA growers had limited management practices put in place already to improve sustainability, but cited challenges that hindered them from adopting new or different sustainable management practices on their UA site.

IV. Discussion

Soil lead contamination is thought to be one of the primary ecological concerns for urban growers. Soil lead contamination has the ability to disrupt biological soil health on UA sites, reducing microbial activity and decreasing crop productivity (Igalavithana et al., 2017; Sharma et al., 2014). Lead also poses a serious threat to adults and children, with the potential to cause developmental delays, high blood pressure, mood disorders, and more (Mayo Clinic, 2016). Soil management practices have been shown to reduce soil lead bioavailability, and improve overall soil health, but primarily on large-scale, industrial sites, not within UA sites. Although an increasing number of studies have explored lead contamination in UA sites, research in the field of UA has neglected a broader focus on soil health, making our study unique.

Furthermore, while soil management practices, such as the addition of compost, phosphorus fertilizer, and cover cropping, have been shown to have many positive benefits for reducing the impacts of soil lead contamination, it is unclear whether these practices remain effective over time, or how they impact the surrounding urban environment. As UA continues to expand throughout cities, it is important for researchers, and farmers and gardeners to consider the implications of UA management practices have on overall soil health.

To extend and build upon research, this study tested whether the use of ecological management practices, such as the application of compost, phosphorus-based fertilizers, and use of cover crops, reduce soil lead bioavailability and improve overall soil health. Specifically, we evaluated soil health on UA sites from a broad sustainability perspective, to fully encompass the physical, chemical, and biological properties of soil and how they are impacted by management. Soil samples were taken from a managed site, where crop production was occurring, and from nearby unmanaged site at each farm or garden, to provide a proxy for baseline soil lead levels. Beyond understanding the ecological sustainability of urban soils, this study also identified the key challenges that UA farmers and gardeners face in using these practices on their farms. Through this social-ecological systems lens, we can gain a more complete understanding of complex urban agroecological systems, and the ability of farmers and gardeners to mitigate potential contaminants.

4.1 Soil Lead

We found that soil lead bioavailability was significantly lower on managed sites. This is a critical finding, which highlights the potential of sustainable management practices on UA farms and gardens to mitigate soil lead contamination. Beyond this finding, our study showed that lead bioavailability did not differ between raised-beds and fields, which is contrasts with prior studies (Witzling et al., 2011). Therefore, construction of raised beds versus fields did not have a large impact on lead bioavailability, for this relatively small sample in Detroit. This may largely be due to the high compost application rates on all UA farms we sampled, which would reduce lead bioavailability across all sites. It is also possible that lead concentrations overall were lower within the sites we sampled compared to concentrations typically found in urban environments.

To date, only a few studies have evaluated soil lead differences between managed and unmanaged garden sites. Witzling et al. (2011), conducted a similar evaluation in Chicago and found similar results. When comparing total lead levels between food producing UA areas and of non-food producing UA areas, food-producing UA areas had significantly lower lead levels. High amounts of phosphorus and compost in these farm and garden sites largely contributed to the reduction of lead levels among sites. Witzling et al. (2011), however, found that there were significant differences between raised-beds and non-raised beds within managed areas, which we did not find here.

The lead bioavailability and estimated total lead levels on managed sites we found in this study were relatively similar to findings from previous studies in UA sites, although somewhat lower. The maximum lead concentration we found in a managed site was 69 ppm, which is relatively low. Witzling et al. (2011) found that six out of ten sites (both food producing and non-food producing) had mean total lead levels below 100 ppm, with all but one site under the EPA growing standard of 400 ppm. Another similar study by Clark et al. (2008) showed that the average lead concentrations across 23 raised beds was 336 ppm. Defoe et al. (2014) demonstrated that urban gardens in Tacoma, Washington had lead concentrations that ranged from 51-312 ppm. Taken together, these studies, and our research in Detroit, support the hypothesis that UA management practices are effective for reducing soil lead levels; however, more research between raised-beds and non-raised beds (fields) is needed to fully conclude whether lead levels are differentially impacted by planting style.

Unmanaged sites within our study had lower lead levels relative to other studies (Figure 1 and 2). For instances, Finster et al. (2004) found a median lead level of 800 ppm, however, concentrations ranged from 27 to 4580 ppm. McClintock (2012) found that total lead found on UA sites in Oakland, California ranged from 3 to 979 ppm, but the mean concentration was 108.7 ppm, similar to that of our study. Our results were similarly spatially variable. Lead bioavailability across sites ranged from 11-159 ppm and total lead levels ranged from 20-300 ppm. These results are expected, as lead is highly spatially variable in soil due in part to its low solubility and mobility (Bugsalski et al., 2015; Wortman and Lovell, 2013). Several factors influence soil lead distributions, including previous site conditions, environmental dynamics, and physico-chemical properties of soils (Chen et al., 2015; Brown et al., 2016). This study thus contributes to the growing body of research demonstrating lead's high spatial variability, which has important implications for both soil testing and management. For instance, these findings are highly important for new UA growers to consider when starting a UA business. They also demonstrate the need for grid-sampled soil testing, such as that performed within this study, as lead hot spots can exist within gardens and should be considered when choosing which areas to put into food crop production, or which types of crops to plant.

A key question in the literature is whether soil management practices, such as compost and other strategies to build soil organic matter, or phosphorus fertilizers, maintain reduced lead bioavailability over time (Henry et al., 2015). Clark et al. (2008) found that lead concentrations in raised beds were twice that of the initial lead concentrations when sites were first established, demonstrating that management practices could potentially become less effective over time when recontamination of raised beds occurs. In addition to recontamination, soil properties can mediate a soil amendment's ability to reduce lead bioavailability. Specifically, phosphorus amendments have been found to be variably effective over time due to changes in both phosphorus solubility and soil structure (Henry et al., 2015; Scheckel and Ryan, 2004). Zwonitzer et al. (2003) found that soluble phosphorus was effective at maintaining reductions in soil lead bioavailability overtime by continuing to effectively bind to lead, however, results varied for other types of phosphorus fertilizers.

In this study, we found that the difference in lead concentrations between managed and unmanaged sites – which served as a proxy for baseline lead concentrations – did not depend on how long UA management had been in place (Figure 3). This contrasts with the studies just discussed, which found variability in the effectiveness of management practices to maintain reduced lead bioavailability over time. This finding for farms in Detroit is encouraging, in that the effects of management on lead appear to persist over time, suggesting that recontamination is negligible. However, we estimated baseline lead levels by sampling adjacent unmanaged areas, because most sites did not have a reference soil test from within the managed area at the farm or garden establishment. Future research should continue to track change over time within managed sites to confirm this result. Another key implication of these results is that ecological practices that improve soil health can reduce lead levels quickly, and do not depend on the length of time since the practices were initiated.

4.2 Impacts of Soil Health on Soil Lead

Soil health indicators had a significant impact on soil lead bioavailability (Figure 4, Table 2), which we expected based on the management practices in place on farms and gardens in the study. All farms and gardens applied compost to their sites, or had applied compost within the past year. COmpsot amendments increased soil organic matter, total soil C, and phosphours levels, which can reduce the bioavailability of lead through chemical reactiosn while also improve overall soil function (Chen et al., 2015; Henry et al., 2015). In this study, higher levels of total C, plant-available phosphorus, and PMN, and lower soil bulk densities, were all significantly correlated with lower lead bioavailability. When we put the measured soil health predictors into linear regression models, the best fit model for lead bioavailability (Table 2) included soil organic matter, phosphorus, and aggregate stability. Many of these soil health indicators also co-vary (e.g., total C, soil organic matter, PMC, PMN), demonstrating the positive impacts of generally increasing soil health. While the overall model was highly significant ($P<0.0001$), the predictors only explained 48% of the total variation in soil lead bioavailability. This is potentially due to our small sample size, or to other factors such as changing environmental conditions (i.e., rainfall, site history, etc.) that we did not measure across sites. That said, our findings highlights that managing for soil health is a strategy to simultaneously reduce soil lead and improve the sustainability of UA ecosystems, and that lead should be considered as one of a broad suite of soil health indicators. More research is needed to understand relationships between soil health and soil lead across a wide gradient of environmental and management conditions in order to provide specific management guidelines for farmers in different contexts.

4.3 Soil Lead-Soil Health Trade-offs

While soil health parameters have the ability to reduce soil lead bioavailability, there are also trade-offs that exist with excess nutrient inputs to managed sites. Soil nutrient excesses are common with sustained, large additions of compost or phosphorus-based fertilizers overtime. Specifically, we found that the large amounts of compost applied by farmers and gardeners resulted in high to excessive amounts of both phosphorus (average = 92.2 ppm) and potassium (average = 285.2 ppm) within all garden sites (Figure 4). Witzling et al. (2011) reported a similar result in their study, with potassium levels over 150 ppm. Such nutrient excesses can result in nutritional imbalances within crops that may impact yield or nutritional quality (Wang et al., 2008). Nutrient excesses also pose a threat to nearby waterways, as they have the potential to leach or runoff during heavy rainfall events and contribute to increased water eutrophication. These results stress the importance of soil testing for urban farmers and gardeners, and the need to balance multiple goals to optimize overall soil health. When possible, soil testing should be performed to track soil nutrient concentrations on UA sites. This can help farmers and gardeners better manage balance nutrient inputs with harvested exports through more judicious management of compost and other inputs.

Another potential trade-off identified by our soil health assessment was the inverse relationship between soil organic matter and wet aggregate stability across sites in this study (Figure 5). Most studies have found that increases in organic matter result in increases in aggregate stability because increased microbial activity and organic C result in the formation of more aggregate "glues" (Moebius-Clune et al., 2017; Chaney and Swift, 1984) Our result is likely due to the fact that 4 farmers were growing crops directly in compost, and another seven sites contained more compost-based material than soil. The highly constructed soils in UA sites, with low or no levels of mineral soil, would greatly limit soil aggregation. This has implications for water retention and soil erosion on UA sites, and represents another trade-off between management practices intended to reduce soil lead and overall soil function. Future research is needed to identify levels of compost addition that can reduce exposure to lead while maintaining or increasing other indicators of soil health that confer critical ecosystem functions such as water infiltration and retention, and balanced nutrient budgets.

4.4 Social Barriers to UA Management

In addition to the farm and garden management trade-offs we identified for ecological outcomes it is also critical to consider barriers to UA management from a social perspective. Sustainable, ecologically-based management can be difficult for farmers and gardeners to implement, based on financial standing, environmental conditions, perceptions of UA by neighbors, and policy regulations. We evaluated farmer and gardener perceptions of the key challenges they face in using ecological management practices. Overall, we found that long-term financial viability presented the greatest barrier to use of these management practices. For instance, cost of materials and equipment, lack of outlets for selling produce, and lack of funding for staff were all cited as hindering farmers' and gardeners' abilities to implement sustainable management practices. One farmer within our study stated "The cost of materials, equipment and labor hours has been a challenge to implementing cover crops or a more serious compost operation." This finding is supported by other studies in UA sites. Dieleman (2017) found that conservation of natural resources, increasing water demands, and organic based management practices are all costly, and often hinder UA's growth and development in Mexico City.

Costs, however, can be reduced, as we found that many UA farmers and gardeners within this study were applying compost in excessive amoutns. This challenge has been reported in other UA studies as well (Witzling et al., 2011). Reductions in the amount of phosphorus and compost being applied to UA sites could help reduce expenses. Beniston et al. (2014) found that the quantity of compost required to amend 0.1 hectares of land on their research site, to significantly reduce lead levels and increase soil quality, costs $225, which his potentially feasible for many UA growers. Our results indicate that lowering inputs of soil amendments would not only reduce farm and garden costs, but would simultaneously improve overall soil health, and can help reduce some of the hindrances by improving soil health (e.g., reducing P and K excesses, and potentially improving soil structure through aggregate stability). This would have a synergistic effect of overcoming a social challenge while also improving soil health. In the future, researchers, policy makers, and planners should consider the benefits of sustainable management, and the potential costs to establishing these practices, to better provide resources, both physical and financial, for urban growers.

4.5 Study Limitations

A primary limitation of this study was the relatively small sample size. While we had 13 participants for our study, this number clearly does not represent the 1,500 plus farms and gardens that are thought to be present in Detroit (Keep Growing Detroit). While we did not have the resources to sample a large number of farms and gardens, our study benefited from applying a soil health framework to a UA context, measuring lead alongside a wide range of other soil health indicators, which requires significant labor to analyze. We were also able to sample a diversity of farm and garden sites. Farms and gardens ranged from their planting style, to the number of years since they had been established, to their size, and to the social networks that help make their growth and development possible. This diversity and variation allowed us to identify relationships between soil health and soil lead bioavailability, and also to find some commonalities across a range of gardens with varying practices.

As future studies continue to evaluate the impacts of UA on urban environments, there is a need for continued integration of soil health indicators to fully understand their impact on soil lead concentrations as well as mechanisms leading to these effects. Our study was not able to identify which soil management practices most influenced soil health parameters, which remains a key research need for the future. Such research would inform best management practices in different contexts, and produce generalizable understanding regarding the effectiveness of UA management practices. More data is especially needed within Detroit, which has had limited social-ecological systems research on UA, particularly considering that it is such a large UA hub.

Conclusions

As a whole, this study contributes to the growing body of literature on UA, and is unique in extending a soil health framework to an urban setting. We found that UA management practices, mainly the addition of compost, influenced soil health parameters, which, overall, reduced soil lead bioavailability. We also identified the potential trade-offs that exist for UA management practices, from both ecological and a social perspectives. These trade-offs could be reduced, by increasing the availability of resources – including knowledge of ecological management – to UA farmers and gardeners. Such trade-offs and opportunities should be considered by local governments when considering the future of UA. While debates may continue over whether and to what extent UA benefits to urban environments, our study provides specific evidence for the benefits of UA from both ecological and social perspectives. As UA continues to grow in popularity, it is important for growers, researchers, policy makers, and planners to work together to understand the broader impacts of UA, so that it can continue to grow and increase urban resilience and sustainability in the future.

Table 1. Characterization of management practices at UA farms and gardens in Detroit, MI.

UA farm/ garden ID number	Year of establishment	Planting Style	Use of Compost Application	Use of Tillage	Use of Cover Cropping	Use of Crop Rotation
1	2014	Raised Beds	Yes	No	No	Yes
2	2013	Beds	No	Yes	No	Yes
3	2016	Beds	Yes	Yes	No	Yes
4	2014	Beds	Yes	Yes	No	Yes
5	2011	Beds	Yes	Yes	Yes	Yes
6	2012	Beds	Yes	No	No	Yes
7	2007	Raised Beds	Yes	No	No	Yes
8	2015	Raised Beds	Yes	No	No	No
9	2015	Beds	Yes	Yes	No	Yes
10	2010	Beds	Yes	Yes	No	Yes
11	2011	Beds	Yes	Yes	Yes	Yes
12	2014	Raised Beds	Yes	Yes	Yes	Yes
13	2016	Beds	Yes	Yes	No	Yes

Figure 1. Box plots of soil lead bioavailability measured in managed and adjacent, unmanaged sites on 13 UA farms and gardens. Managed sites had significantly lower concentrations of bioavailable lead (P = 0.006), and concentrations were much more variable in unmanaged sites.

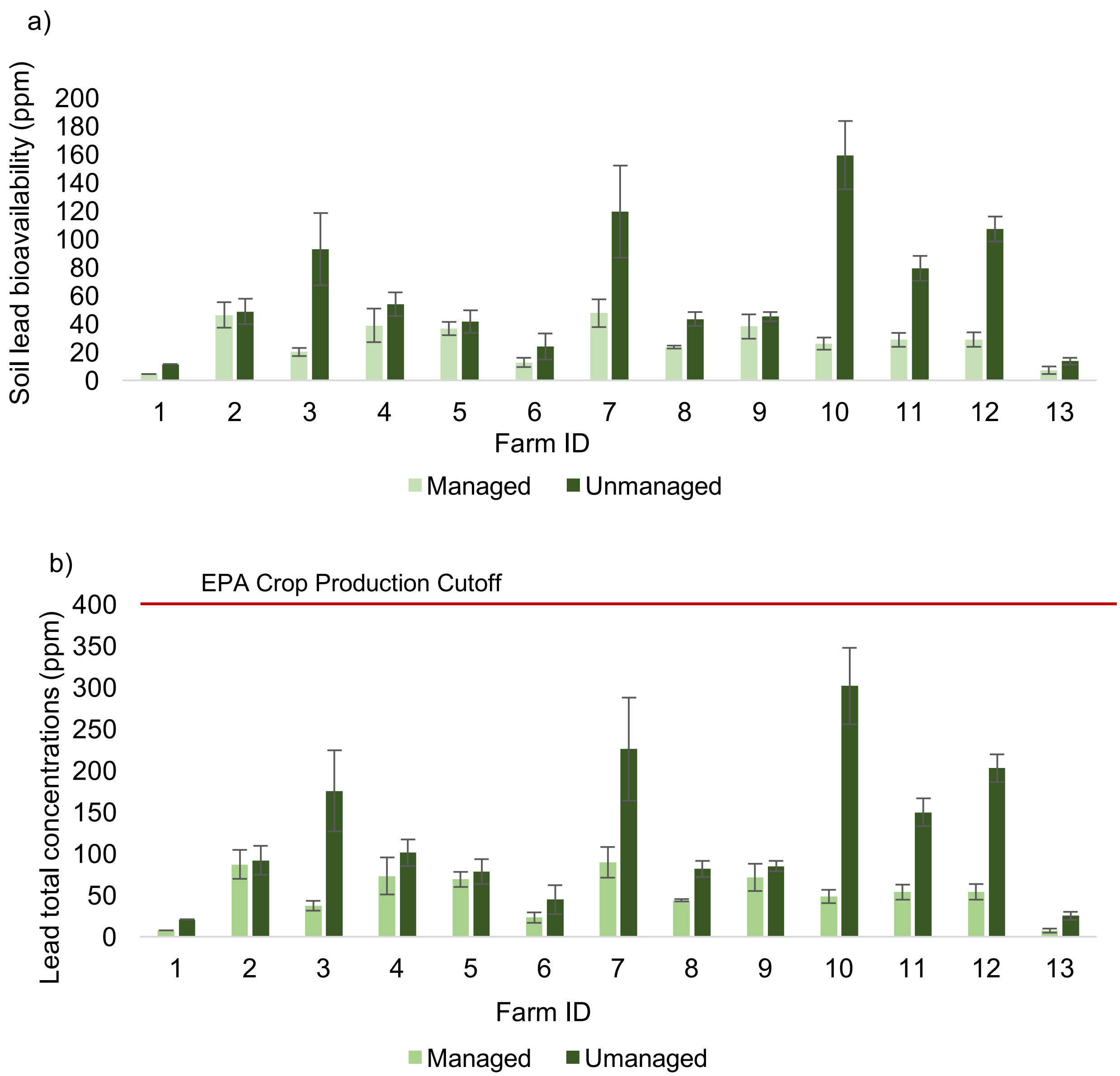

Figure 2. Soil lead concentrations: a) Mean concentration of Mehlich 3 (M3) bioavailable soil lead (ppm) with standard error for each sampled UA farm or garden, by managed versus unmanaged areas, and b) Estimated mean total lead concentrations with standard error for each sampled UA farm or garden, by managed versus unmanaged areas. The red line depicts the EPA crop production cutoff for lead concentrations in soil. Total lead concentrations were estimated using formulas determined by Minca et al. (2013) (Total Pb= 1.91*M3 – 0.93).

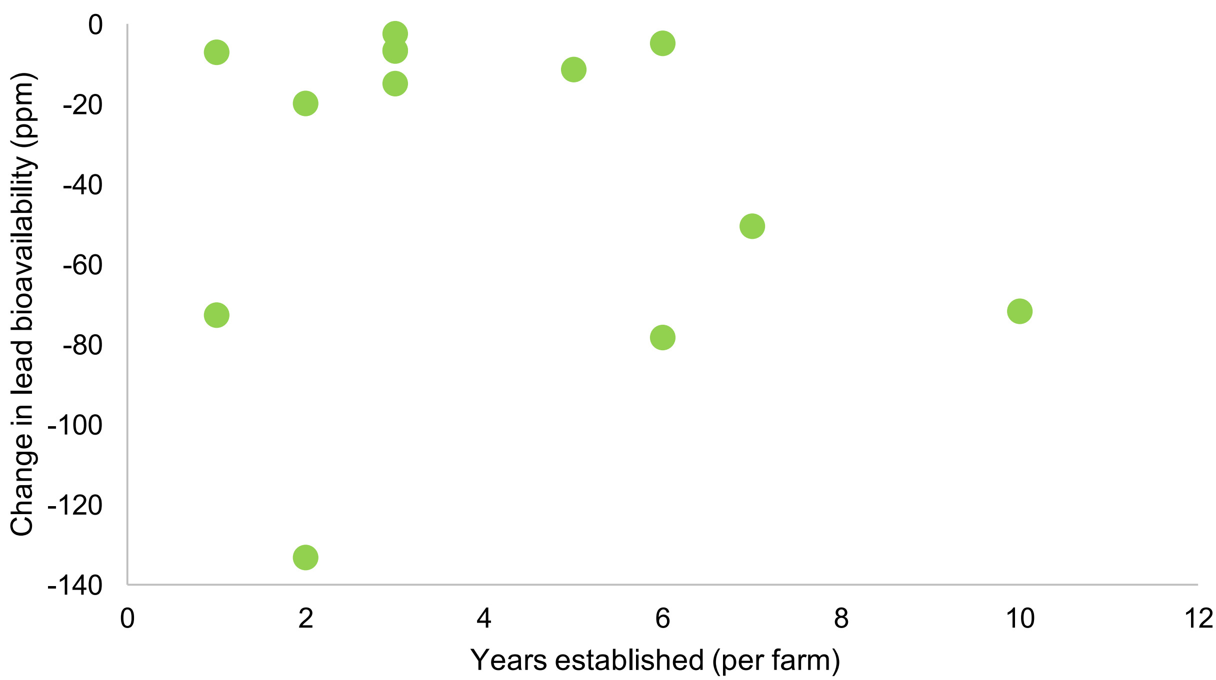

Figure 3. There was no relationship between the number of years since farm establishment and the difference in bioavailable lead concentrations (ppm) between unmanaged and managed sites on each farm. The change in lead concentrations in the managed site therefore does not depend on how long the UA management has been in place (R^2= 0.02, P= 0.64).

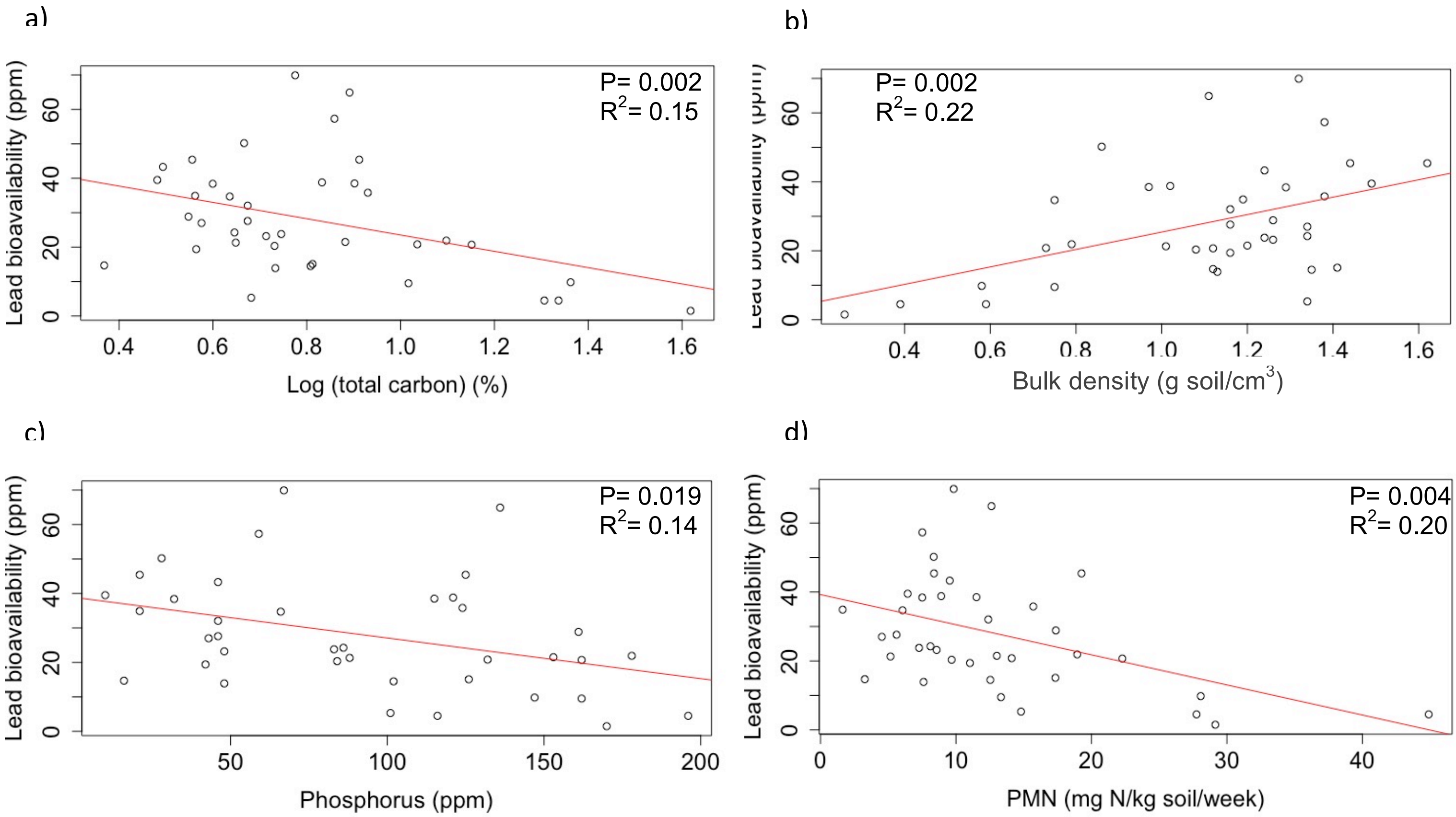

Figure 4. Regression relationships between soil health parameters and soil lead bioavailability (ppm) across all managed sites.

Table 2. Regression coefficients and standard errors (in parentheses) for regression analysis of bioavailable lead (ppm) across farms using soil health parameters as predictors. Coefficients in bold font are significant, and the estimated model fit is indicated by the R^2 and adjusted R^2.

Intercept	62.44
	(6.90)
SOM (%)	**-1.50***
	(0.69)
Bray-1 P (ppm)	-0.06
	(0.07)
Agg. Stab.	**-0.48*****
	(0.11)
R^2	0.48
Adjusted R^2	0.43
N	35
Model P-Value	0.0001

Significance: *P< 0.05, **P<0.01, ***P<0.001

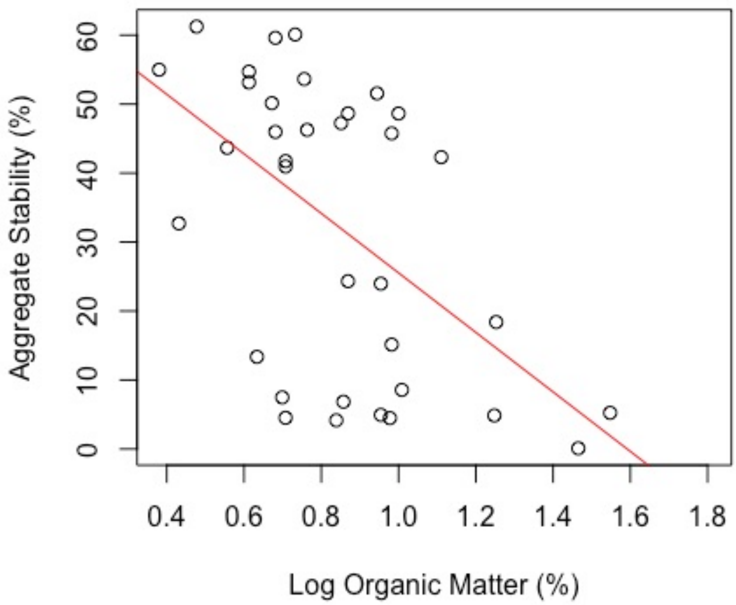

Figure 5. Regression relationship between soil organic matter (%) and wet aggregate stability (%) across all managed sites (R^2= 0.20, P=0.007).

Table 3. Top five, ranked challenges that farmers and gardeners face in adopting management practices to improve sustainability on their UA sites.

Ranking	Management Challenges	Strongly Agree (%)	Agree (%)	Examples
1	**Long-term financial viability**	12.50	62.50	Lack of opportunities and outlets in the city for selling produce
2	**Access to farming and gardening equipment**	0	62.50	Cost of materials Cost of equipment Proximity to materials
3	**Lack of fertile, healthy soil**	25	37.50	Lack of equipment Cost of materials Lack of land with fertile soil Difficulty incorporating soil building practices such as cover crops
4	**Profitability**	14.29	42.86	Lack of volunteers and staff members to produce enough to be profitable
5	**Current zoning ordinances**	12.50	37.50	Negative public perceptions of UA Lack of support for expansion through zoning

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Chapter 2

Soils for Sustainability: Broader Challenges to Urban Agriculture Growth and Development

I. Introduction

Urban agriculture (UA) has become a flourishing movement throughout the United States, increasing by greater than 30% within the past 30 years (Alig, King, and Lichtenstein, 2004). While UA is complex and challenging to define, UA is often referred to as the practice of cultivating food and animal husbandry on urban and peri-urban land (Travaline, 2016). The concept of growing food in urban environments may seem counterintuitive, but UA has played a prominent role in cities since the 1800s. When economic hardships took a toll on city prosperity, urban residents were often encouraged to grow their own food as a mechanism of social resiliency (Travaline, 2016). While UA is not a new phenomenon, its increase in popularity in modern times can largely be attributed to a growing movement for social, environmental, and economic resiliency. Scholarship proposes that the diversity of services UA provides, such as food justice, community development, and ecological resiliency, sparks motivation for public participation in UA, and makes it an important element of cities today (Travaline, 2016; White, 2011).

Food justice has become a recent motivation for grower participation in UA (White, 2011). Cities across the United States lack an abundance of food distributors, and often contain grocery stores that only stock processed foods. Economic divides in cities also create food disparities; residents of lower economic status are not able to afford fresh produce with high nutritional quality, leading to an uneven distribution of goods within city boundaries (Lovell 2011). In cities where access to fresh, healthy produce is limited or lacking, UA allows residents to take action into their own hands, increasing food security and nutritional quality. McClintock and Simpson (2017) found that food security, food quality, and public health and nutrition were among some of the largest motivations for growers participating in UA. Through UA, residents are not only able to grow their own food, they are also able to decrease their dependence on institutions, and create social and self-resiliency for themselves. On the other hand, these changes have also sparked criticism that UA efforts reflect a wider trend toward neoliberal governance with reduce public support for social welfare (Pothukuchi, 2017).

Urban agricultures' ability to foster social resiliency and community development for a diversity of residents is well known, expanding the connections between residents and food production and allowing residents to connect with one another. In Basel, Switzerland, a group of young individuals started a community garden that grew to be a social and educational hub within the city; an area in which people could come together and learn about food production and cooking (Moschitz and Kueffer, 2016). White (2011) found that women in Detroit who participate as urban growers not only have the opportunity to grow their own food, they also have the opportunity to build intimate relationships with other women participating in UA and develop a space for social interactions. While UA space serves as an area for relationships to bloom, UA can also serve as aesthetic hubs of green space and biodiversity, creating space for people of all ages to come together to connect with nature.

UA has been found to provide multiple ecosystem services to urban environments, such as wildlife habitat, biodiversity hubs, and areas for stormwater management. UA growers often plant a wide variety of crops and vegetation in and around their gardens, providing a biodiverse space for insect populations and wildlife within the city (Lin 2015). UA also serves as a form of green space, and can mitigate large amounts of storm water runoff, due to increased infiltration potential and decreased impervious surface space (Gittleman et al., 2017). On top of stormwater management potential, UA spaces have been found to mitigate pollutant contamination. Compost has the potential to reduce lead bioavailability on UA sites, while crops on site can mitigate storm water pollutants such as phosphorus (Ng et al., 2018; Brown et al., 2016). This is especially valued by city governments and planners, as they attempt to manage public health and potential hazards. The biodiversity and aesthetics that UA brings to city environments provides residents with opportunities to grow with nature, as well as with one another.

While the services of UA are numerous, the challenges that urban growers face in implementing farms and gardens and partaking in urban growing are often undermined. Social, environmental, educational, political, and economic challenges exist for urban growers today, and are often looked over by researchers, policy makers, and planners when considering future prospects for cities, especially post-industrial cities.

The practice of food production in urban environments is often met with mixed reviews, bringing about challenges for urban growers. Urban agriculture is often viewed as a temporary solution to urban decline, not as a long-term component of city environments. In Detroit, Michigan, some community members cited UA as a “visible symptom" of urban decline, and as a stepping stone to urban redevelopment (Paddeu, 2017). This perspetive is also common among governmental bodies and planners, who often do not develop beneficial policies or provide resources and economic opportunities for urban growers. Contentions especially arise in the context of animal husbandry, as many individuals do not approve of raising livestock in city environments, citing concerns over smell and sanitation (Paddeu 2017). In Canada, cities such as Toronto, Vancouver, and Victoria have had to address negative perceptions of UA when implementing policy changes, largely due to urban residents stating preferences for park space, rather than community garden space (Huang and Drescher 2015). Issues of crime also make people warry of UA. Urban growers often face issues of crime and food theft, leading to debates among residents interested in starting a UA site or in further developing and expanding UA sites (Hess 2004; Turner 2013).

Challenges for urban growers are also context-dependent. Gregory et al. (2015) found that community gardeners cited building and maintaining soil quality, insect pest damage, and weed management as some of the largest challenges to maintaining an UA site. Pollutants such as lead, cadmium, and mercury, also pose a real threat to UA, even years after industrial practices have ceased. Kaiser et al. (2015) found that gardens sampled in both Columbus and Cleveland ha cadmium levels well over background levels, and higher than the EPA standard for growing. Often these pollutants are the product of prior land usage, often coming from housing demolitions that contained lead paint and industrial sites where cadmium and mercury were previously used. McClintock et al. (2015) found that lead concentrations were higher in gardens and vacant lots, largely in relation to the density of old housing stock. Pollutants are highly challenging and costly to remove from the soil, especially heavy metals such as mercury, cadmium, and lead. Removal of these pollutants is extremely costly, and often challenging to perform. While proper management can decrease the bioavailability of these pollutants, educational barriers and knowledge of soil and vegetation contaminants can lead to continued contamination and has the ability to negatively impact human health (Wortman & Lovell, 2013). The cost of implementing proper management practices and maintaining soil health can also hinder an urban grower's ability to mitigate contamination on site.

Economic issues are a persistent challenge facing growers today. The start-up costs of UA, such as purchasing land, farming equipment, site materials, and structures, are known to be expensive, with few economic opportunities or resources for growers to utilize (USDA 2016). Further, cities also lack incentives and opportunities for selling local produce, with some cities even banning the sale of local produce within city borders (Dieleman, 2017). Some farmers' markets require growers to have regular soil testing performed or require growers to have organic farming certifications, which can be expensive to purchase. This inhibits opportunities for growers to find financial stability, either initially, or when considering expanding an existing UA site.

Access to land is one of the largest challenges cited by urban growers. Tenure ranges for UA growers, especially in the city of Detroit. Some residents own the land, some rent the land from a land owner or from the city, and some residents squat on the land, meaning that they use it until permitted otherwise. While many UA growers have opportunities to establish farm and gardens on vacant land, but run into difficulties when trying to acquire tenure. Difficulties tend to arise from rental situations, when the communal land is taken back by the state, often creating community backlash and distrust in governmental bodies (Werkerle & Classens, 2015). As city governments work to redevelop areas, urban growers are often kicked off the land. Unfortunately, many cities to not view UA as a long-term component of cities, and therefore prioritize incoming developments that provide greater profits for the land owner and the city (Lovell 2011). As UA continues to develop throughout cities, it is important for governmental bodies, researchers, and urban planners to consider the potential benefits UA provides, as well as the challenges growers face in implementing growing practices in urban environments.

Nationwide, cities are seeing the expanse of UA, as well as the environmental, social, and economic services it provides (Duiz et al., 2017; Moschitz and Kueffer, 2017; Horst et al., 2012; Thibert, 2012; Dubbeling et al., 2009). Many governmental bodies and urban planners are considering incorporating UA into future policies and plans, but lack sufficient information and research to fully understand what challenges UA growers face in developing and building UA hubs and what growers need to continue to grow and expand UA. This is especially true of post-industrial cities, such as Detroit, Michigan, which are looking to redevelop space to house centers of social, environmental, and economic prosperity (Detroit Future City). Not only do these challenges exist, they also differ between UA sites, and even more so between cities across the United States today, making it a challenge for researchers to learn more about the hardships UA growers face. While many challenges have been cited, more research is needed to fully understand the nuances of UA challenges, in order to develop a larger knowledge base about UA's and its role in city environments.

This study investigated a wide range of challenges urban growers face in Detroit, Michigan. Specifically, this study: 1) evaluated farmer and gardener perceptions of challenges they face in developing and expanding urban agriculture sites; and 2) developed a simplified, efficient survey tool that can be utilized by researchers, policy makers, and planners. As UA continues to grow in popularity, it will be important for there to be a body of knowledge on UA challenges, from both a broader scope and from a city-specific scope, in order to better develop policies, provide resources, and create opportunities for UA to be a long term, sustainable product of cities.

1.2 Case Study: Detroit, Michigan

Detroit, Michigan, where our study took place, is a unique hub for UA. Detroit was one of the first cities in the United States to promote the practice of UA, with the mayor of Detroit promoting UA as a mechanism to address economic and agriculture hardship back in 1890 during the long depression (Allen 2004; Travaline 2016). Detroits UA has continued to increase and maintain a presence throughout history, both in the form of victory gardens, and today, primarily as community gardens, educational gardens, individual gardens, and large-scale farms (Hand and Gregory, 2017). It is Detroit's history, and set of unique social and economic challenges that have sparked the rise in UA today.

The collapse of the automotive industry, followed by multiple economic challenges in Detroit largely lead to the decline in population, and the abandonment of housing property across the city. In 2012, Detroit had approximately 20 square miles of vacant land (Detroit Future City). These vacant lots throughout the city were mostly unmanaged over long periods of time, creating the potential for UA space. Beyond land abandonment, Detroit, MI faces issues surrounding food injustices and food insecurity. Detroit is devoid of large grocery stores, and most city residents obtain their food from service stations and liquor stores, where fresh produce is often lacking (White 2011). This has lead to multiple nutritional imbalances and food insecurities throughout the community.

While Detroit remains a blossoming hub for UA, it faces serious challenges and many uncertainties for the future. The growth and magnitude of UA in Detroit was due primarily due to the actions of community, grassroots movements, with practically nonexistent support from the city in terms of policies or financial subsidies (Pothukuchi, 2015). In 2013, the first of Detroit's policies involving UA emerged, with Urban Agriculture Ordinance going into effect. Today, contention remains over whether to embrace UA as part of Detroit's future, or to use it only as a stepping stone until greater industrial and cooperative redevelopment can ensue. While communication between governmental bodies, planners, and UA growers is happening, many unknowns remain as the city considers how to rebuild and repurpose miles of abandoned land and developments. Understanding what growers view as challenges to starting or expanding UA is important to find out UA's next steps within the city.

II. Methods

2.1 Surveys

Both in-person interviews and online surveys were used to address research objectives. In person interviews (n=13) were conducted from August to November 2017. Surveys were conducted with a single grower, who was cited as the primary farm or garden manager or coordinator. In-person interviews questions were focused on the specific challenges UA growers face, were designed to provide an opportunity for growers to elaborate on their experiences and share their stories in relation to the challenges they have faced or are facing. Questions included topics such as: motivations for participating in UA; challenges urban growers feel they face in starting up a site; challenges urban growers feel they face in expanding a UA site; knowledge of agricultural practices; and knowledge of soil contaminants.

We also developed an online survey tool to asses a larger scope of UA challenges. We used Qualtrics, as the online survey distributor. Qualtircs is an online survey software, that allows researchers to simply generate surveys and analyze results directly using the software. This survey software also allows for surveys to be conducted via smartphone, making the data more easily accessible. The survey we developed used a Likert style, to allow growers to rank a wide range of challenges by the degree to which they feel they are affected by them.

A literature review was first conducted to identify challenges that already have been identified within the literature. Approximately twenty papers were analyzed to determine the main UA challenges. This literature review was all encompassing, identifying all possible barriers and challenges, from all areas across the United States. This list of challenges was coded and broken into broader categories. Ultimately, the broad categories identified were: economic, environmental, knowledge, resources, community, and regulatory. These categories included a list of specific challenges, which were coded from prior UA challenge studies, to create a large numbert of options for UA growers to comment on. This survey was distributed in February 2018, with a three month period for participants to respond. The survey was distributed to a small set of UA growers (n=8) in Detroit, in order to conducted a pilot-test for the survey.

Table 1 shows the six broad categories developed for the purposes of the online survey, as well as their individual topics. When taking the survey, urban growers were first asked the degree to which they thought a broad category was a challenge for them. Then, they were asked to select the degree to which they thought a specific type of challenge impacted their ability to start or expand a UA site. A short-response option followed at the end of the section, to allow farmers and gardener to elaborate on why something may be challenging.

2.2 Coding and Analyses

We determined the top three dominant identified challenges for each UA frame presented. We ranked all challenges according to the percentage who selected either "strongly agree" or "agree." Percentages ranked "strongly agree" were given a higher ranking.

III. Results

3.1 Survey Response

Overall, we collected data from 13 farmers and gardeners for this study. We had direct contact with 13 respondents through the in-person interview conducted on farm sites. Only 8 of those 13 respondents, however, participated in the online, Likert style survey. All participants were residents of Detroit. Farm locations, however, varied, from downtown to city outskirts. The length in which a participant had been involved in UA varied; 12% were found to have been involved in UA for 0-3 years, 50% from 3-5 years, and 38% over five years (Figure 1). Growers varied in their gender and ethnicity. 50% of respondents were male and 50% of respondents were female (Figure 1). 75% of respondents were white, 12.5% of respondents were Latino, and 12.5% of respondents were African America.

3.2 UA Challenge Frame Rankings

Table 2 displays the rankings of UA challenge frames as identified by growers, with 1 being identified as the most challenging and 5 being identified as less challenging. Economic challenges were ranked as the most challenging (87.5%), followed by environmental (87.5%), community (75%), resource (75%), regulation (50%), and knowledge (50%) challenges. Strongly agreed upon responses were ranked higher than that of agreed upon responses, resulting in economic, community, and regulation responses being ranked slightly higher. Multiple dominate challenges were cited by growers within both the economic and environmental frames, emphasizing the need for research, policies, and planning help for these frames.

3.3 Dominant Challenges Identified

Table 3 shows the results of the top three dominant UA challenges, as perceived by urban growers. Dominant challenges were ranked based on the number of participants that strongly agree and agree with each UA challenge presented. The open-ended questions proposed at the end of the survey, as well as the in-person interviews allowed us to gain a core complete understanding of the specific dominant challenges UA growers face.

3.3.1 Economic Challenges

Both in-person interviews and survey results revealed multiple economic hindrances that exist when trying to develop and expand UA. Economic challenges were cited as long-term financial viability (87.5%), farm/garden expansion costs (85.72), and maintenances costs (71.37%). One grower emphasized the connection between farm/garden expansion costs and long-term financial viability, stating:

> "Although we potentially have access to credit, we have opted not to use it and instead grow slowly in a more-risk free manner…therefore our main issue is more with developing the most successful, streamlined business model in order to maximize profitability at a small scale."

Maintenance costs were another highly cited issue, specifically labor costs related to maintenance and upkeep of the UA sites. Multiple growers within our study citied lack of funding for labor workers, with one grower saying, "We cannot afford a garden manager, and therefore rely on volunteers which isn't always sustainable and reliable." Economic challenges, therefore, present a large issue for growers.

3.3.2 Environmental Challenges

Environmental challenges were cited as the second largest UA challenge within our study (85% strongly agree or agree) (Table 2). Specifically, farmers and gardeners participating in the study strongly agreed or agreed with access to water irrigation (85.72%), weed management (85.64%), and insect/pest damage (85.72%) as some of the largest concerns (Table 3). In-person interviews revealed similar results, with participants citing specific issues, such as lead pollution, garbage dumping, soil fertility, pest damage, and water access as concerns. One survey participant stated " The garbage and contamination is nearly always on my mind, especially lead. There is so much trash that I have to spend a lot of time picking out broken glass bottle or bits of plastic and it can never all be removed." One UA grower within our study even considered the broader context of environmental issues connected to UA growing stating "The main environmental issue I identify is the lack of coherent, functional ecosystems in urban areas which means we are also lacking some of the beneficial services and processes of a functional ecosystem." Water issues were cited by nearly every grower in the study, a unique issue to the Detroit area. Environmental issues are therefore a serious challenge for grower in the city of Detroit.

3.3.3 Community Challenges

Community barriers remain a challenge in Detroit today, being cited as the third largest challenge to UA growth and development. The top three community challenges were security/vandalism (83.3%), government acceptance (57.15%), and food safety concerns (57.15%). While ranked third, farmers and gardeners identified specific community barriers within the community frame. One grower we surveyed responded, "We have had challenges with one neighbor who has been quick to contact Environmental Control when we would have finished compost delivered and they thought we were dumping on our property," brining to light some of the community perception challenges UA growers face. This is a commonly cited challenge within this study, as well as within other studies across the United States.

3.3.4 Resource Challenges

Resource barriers were cited by many growers as a challenge to UA growth and development. Resource barriers for UA growers exist as lack of employees/volunteers (71.43%), lack of access to farming/gardening equipment (71.43%), and lack of access to land (57.15%). One of the interesting topics frequently cited during in-person interviews was the role of volunteer positions and management in UA expansion. Many growers within our study cited that lack of regular volunteers made it highly challenging to expand UA facilities. One grower within our study stated:

> "Growing a dedicated and regular volunteer base has been challenging. We do a great job at accommodating and scheduling big groups but the day-to-day volunteers to help maintain the growing space has been a challenge."

Another grower within out study echoed a similar statement:

> "Having a lack of funding puts us in a position of relying on volunteers and that often puts the responsibility of the garden care back on the teachers and students and especially during summer months, the garden then is overlooked and overgrown."

These findings relay the importance of UA resources in farm and garden maintenance and expansion.

3.3.5 Regulation Challenges

Regulation barriers also exist for urban growers today. The top three regulation challenges cited by growers were stormwater tax (71.43%), land use regulations (71.43%) and city development plans (62.50%). While regulation barriers exist, they remain less of a challenge than that of the other challenges frames presented. One grower within our study stated, "We have a partnership with the city of Detroit and a lease agreement with the city to farm this space for 10 years. We have had no issues with restrictions, regulations or ordinances." The regulatory frame, therefore, is cited as a lower challenge for growers amongst our study.

3.3.6 Knowledge Challenges

Lastly, knowledge challenges were ranked as the sixths, as the least challenging issue for UA growers. 50% of growers identified the knowledge frame as being challenging.

Among growers that cited knowledge challenges, lack of marketing (85.72%), lack of financing (85.72%), and lack of business management knowledge (71.43%) were identified as dominant UA challenges. Few individuals within out study (42.86%) felt they were lacking agricultural management knowledge. These findings stress that it is not agricultural and ecosystem knowledge gaps that hinder urban growers, at least from their perspective, but rather the marketing and business-based knowledge gaps.

IV. Discussion

Urban growers in Detroit, Michigan identified a large set of specific challenges they face, both in starting up and expanding their UA sites. While there was variability in responses, many Detroit growers identified similar challenge frames and dominant challenges, supporting our hypothesis that UA growers often times face similar challenges, especially within an individual city. Furthermore, growers also identified a series of challenges that surveys of UA participants in other cities have not previously identified, adding to the growing amounts of evidence that UA challenges are often city-specific, and that growers throughout the countries face unique sets of challenges. This once again stresses the importance of understanding the challenges growers face to expand UA, both from a broad perspective, as well as from a city-specific standpoint.

4.1 Perceived Urban Agriculture Challenges

We found many parallels between our study and the existing literature regarding UA challenges. Similar findings regarding economic challenges exist, however, they are relatively sparse. Oberholtzer et al. (2014) found that economic challenges were cited as a key concern among stakeholders throughout 15 cities. Participants in their survey cited farm viability and profitability as significant concerns, with 60% of participants reporting they relay on off-farm income as their primary source of income, and 49% of respondents stating their total gross sales were lower than $10,000 annually (Oberholtzer et al., 2014). This largely supports our findings (Table 3), in which respondents cited long-term financial viability and profitability as the largest economic challenge. Within our study, long-term financial viability was typically described the ability of growers to turn a profit on an annual basis, and have it be enough to support themselves and their families over an extended period. Profitability was largely referred to as how much a grower is able to make when selling their produce, which largely varied, especially due to the size of a garden. Ackerman et al. (2014) found that urban growers in New York city identified challenges in starting up a small business, specifically in securing loans and grants that can support the economic start-ups. While some studies, such as these have identified economic challenges similar to our findings, the lack of literature discussing economic challenges should be cited, and considered for future studies.

Environmental challenges are similarly echoed across cities in the United States (Kessler, 2013; Wortman & Lovell, 2013). Oberholtzer et al. (2014) found that access to water, infrastructure, and environmental pollution were all among concerns raised by growers spanning 15 U.S. cities. Gregory et al. (2015) found that in New York City, 64% of urban growers surveyed cited soil quality and fertility, and insect pest damage as a challenge; 23% of people surveyed stated lack of water availability as an environmental issue. Mitchell et al. (2014) found that farmers in New York city cited soil contamination as a major land issue, with 70% of the 54 participants having at least one soil samples that exceeded recommended levels for human health (Angotti, 2015). These findings, including ours, are common in post-industrial cities, where contaminants and access to water remain a prominent concerns. Water was one of the most cited environmental challenges in our study. Access to water, access to irrigation, and water capture methods were cited as the dominant challenges, which are not always echoed throughout other urban environments. Pest issues also remain a problem, not just within cities, but largely within the larger agricultural industry. Pests may arise more in UA practices, largely due to the fact that many urban farmers, including those within this study, incorporate organic, environmentally friendly practices, which prevent the use of pesticides and herbicides. We talked to one grower in this study, who largely stressed the need to "incorporate insect habitat, and learn to manage insects rather than kill them," a tool she learned through a Michigan State University extension class. Others, however, largely cited insects as more of an issue. This largely stresses the need for more knowledge on how pests can be managed without the use of chemicals within urban environments.

We found that urban growers lack business management and marketing knowledge, which hinders them expansion of their UA sites. Agricultural and environmental knowledge gaps, however, did not appear to be an issue from growers' perspectives. This finding is echoed throughout the literature, once again connecting our findings to the larger UA challenge framework. Gregory et al. (2015) found that most gardeners interviewed in New York city had a basic understanding of agricultural practices such as cover cropping and crop rotations. Sumane et al. (2017) found that in all case studies conducted, business knowledge was one of the largest knowledge gaps farmers had, with a large interest in obtaining knowledge related to marketing. When surveying urban growers, Oberholtzer et al. (2014) found that many UA participants rated training programs as being highly needed, and many UA growers stated that current trainings programs negelct business management. This too was cited by our participants, who would like to see more training opportunities presented within Detroit, not just focusing on agricultural management, but on business and profitability management. These commonalities between prior studies and our study should be cited by policy makers, planning organizations, and local non-profits that focus on UA. While many UA growers stated they feel like they are fairly knowledgeable on a variety of UA topics, knowledge gaps persist related to marketing and management. However, in a companion study we conducted on UA soil lead contamination and soil health, we found that some common management strategies used to mitigate soil lead comprised other aspects of soil health, particularly driving nutrient excesses that have the potential to cause water contamination. A few recent studies have found similar trade-offs (Witzling et al., 2011). This suggests that although growers do not perceive agricultural management and environmental knowledge gaps, they may in fact also be important to address.

4.2 Unique Challenges for the City of Detroit

Many challenges cited within this study are unique to Detroit, and add to the growing UA literature within the city. The challenges cited by Detroit growers support our hypothesis, in that challenges are often city specific, emphasizing the need to develop a broader UA challenge framework to be more encompassing of specific UA challenges. These findings offer potential insight into challenges that should be discussed when researchers, policy makers, and planners are attempting to further understand the hindrances to UA growth and development, to better support UA growers.

Economic challenges are often not identified as a barrier to UA growth and development, making this an interesting finding within this study (Table 2). Rather, studies have found that economic frames are cited as a driving motivational framework for participating in UA (McClintock and Simpson, 2017; Nugent, 2000). Even within this study, 71% of farmers and gardeners cited UA's ability to provide a personal alternative economy as a motivation for urban growing. In fact, many of the urban growers participating in this study cited growing as their primary job, listing multiple outlets to which they sell their produce too. This may seem contradictory; however, possibilities exist for economic frames to be both motivational and challenging, especially as farms seek to expand. In recent years, Detroit's explosion of farmers markets has created outlets for grower to sell out, including that of the famous Eastern Market venue. One grower within out study stated that they sold their produce to three local restaurants in the area, meaning that restaurants have the potential to create an outlet for growers to sell to. Three growers within out study met and created a business together, where they now are selling a few local CSA boxes to Detroit residents every month. These recent avenues may be lowering grower's perceptions of UA economic challenges.

While start-up costs have the potential to be covered, through personal savings, loans, and UA start-up programs, long-term support is often necessary to progress forward in UA development. Equipment, infrastructure, and the purchasing of land are all very expensive, and can be a challenging process for growers to go through. One grower within our study cited difficulties with having a volunteer board as part of a UA organization, stating "we haven't had a person chairing a committee for seeking grand funding…we do not have the funding to support my role and our programming at the same time." While this is a unique situation, other growers in our study cited competition for the limited amount of grants available on an annual basis as true challenge, stressing the importance of long-term funding opportunities and the need for funding for expansion.

More research into economic challenges should be considered, from both a research, policy, and planning perspective. While research can provide more depth to economic challenges and city-specific cases, policy makers and planners need to consider that UA economic development is not just a motivation, but a challenge to UA development. Access to more economic resources, such as loans and grant opportunities, can help ease some of the economic concerns to expand UA.

Some of the water challenges cited by growers appear to be unique to Detroit. Water challenges have been found to be cited by urban growers in other studies, but largely in the context of water contamination and water recycling methods (Attwater et al., 2016; Moglia, 2014). Within our study, access to water irrigation was found to be one of the most cited environmental challenges, not only ranked within the online survey, but cited as a consistently challenge when conversing with growers during in-person interviews. Farmer and gardeners participating in our study cited city water connection expenses, distance from a water source/connection, and shared water pressure were all cited as specific concerns related to environmental challenges. One grower within our study cited multiple concerns related to water resources, stating:

> "We do not have a water source close the beds and we do not have the raised beds irrigated. We also share our water source with a splash pad park so we are battling for

water pressure. I decided to install a rain water collection system to help supplement but it still does not meet our needs."

Another grower within the study said that water access and water expenses "are a consistent, expensive bill that makes water for increased crop production a hesitant action." These issues largely arise in Detroit due to costly water hookups, which are often absent on vacant UA sites where farmers choose to establish. Costs for basic amenities continue to increase throughout the city, as they attempt to increase revenue to rebuild the city's outdated water and sewer infrastructure (Laitner, 2017). Beyond this, the reimplementation of the stormwater tax within the city of Detroit is creating economic problems for UA growers. One grower within our study cited that through the stormwater tax, they now owe approximately $20,000 to the city, a cost they are not able to pay (Hester, 2016). With the environmental services UA provides, including stormwater management, city governments, especially that of Detroit, should provide resources and incentives for UA growers to implement and expand UA sites.

Community barriers continue to exist for UA growers today, especially in Detroit. While many governmental bodies across the United States have embraced UA within city limits, Detroit remains cautious in it's acceptance. An interview-based study in Detroit on the topic of UA revealed that some Detroit community members cited UA as regressive, and as a symbol of the death of Detroit (Colasanti et al., 2013). Beyond community members, the city of Detroit's government was often unsupportive of UA development in the city, which was largely shown through lack of policy's and resources targeting UA. One participant within our study stated, "The City of Detroit enjoys the PR it gets from large Urban Agriculture projects, but has yet to align policy in regards to sales and zoning." These notions echoed by growers indicate the need for better community relationships to expand and grow UA in the city, and are largely tied to city regulatory challenges.

Regulation challenges are often cited within the literature as one of the largest challenges, both when starting up and when expanding UA sites. This result, however, was not seen within our study, with regulation challenges being ranked fifth. This is not to say that regulation challenges do not exist for urban growers in Detroit; city development plans, stormwater taxes, and land use regulations were all cited as being regulatory challenges (Table 3). Growers, however, perceived regulatory challenges in the city of Detroit, to be less challenging than other factors. This may, however, be due more to confusion and disorganization regarding UA regulations within the city of Detroit.

Detroit has been known to lack regulations surrounding land development and UA. Until 2013, when the city adopted an UA ordinance, little regulation was in place for UA development. Today, regulation challenges still exist. A participant within our study affirmed:

> "All regulations have been unclear and seem to often change week to week. Enforcement is also very inconsistent. Regulations are not clearly communicated to growers…and we're still waiting for our animal ordinance!"

An animal ordinance for the city of Detroit is still in the works, making it challenging for growers to decide whether or not they should raise livestock on their farm, especially if the ordinance eventually put in place is not supportive of urban livestock. Challenges also remain in the context of land ownership and land sales, as the Detroit land bank has a difficult time keeping track of the parcels they own. Land ownership records are challenging for both the land bank and citizens to track down, making it challenging for UA growers to purchase vacant land (Hester, 2016). This is often not the case for other cities throughout the country, making it a Detroit-specific challenge that needs to be addressed. Further regulations in support of UA, such as increased policies and ordinances are needed to support UA moving into the future.

4.2 Study Limitations and Future Research

While this study provides insight into UA challenges, both in the context of a broader UA framework and a city-specific framework, there are obvious limitations to our study. Our small sample size contributes to our lack of statistical analysis, which hinders the ability of our study to expand the bounds of urban agriculture social research. Beyond this, our study is does not encompass the views of all Detroiters. While we had a relatively even gender split, the ethnicity of most growers was identified as white. With Detroit being a primarily African American dominated city, our results do not encompass the full diversity of UA participants.

While our study was hindered by sample size, our style of surveying opens-up possibilities for future research. The Likert style, online survey we developed and tested for the purposes of this study was highly effective, however, and should be considered as a potential tool for researchers and policy makers to utilize when identifying UA challenges in the future. Such streamlined tools increase opportunities for drawing connections across a large number of sites and contexts. Many participants were able to access the survey on their phone, making it more widely accessible and available. They survey was also relatively short, with the average response time clocking in at about 30 minutes. Using the online format also allows for a broader diversity of growers to be accessed. While that was not necessarily the case for this study, future studies can reduce the amount of time they spend interviewing participants by widely distributing this survey, increase sample size, as well as allowing for increased input and identification of UA challenges.

V. Conclusions

Urban agriculture is continuing to expand within an urbanization world. As city governments, policy makers, planners, and researchers consider the future of urban agriculture, it is important that they survey and understand the challenges growers face in growing and expanding UA. While rankings varied, all participants identified economic, environmental, knowledge, community, regulatory, and regulation barriers, driving home the point that growers face multiple, complex challenges in moving UA forward. Survey's, such as the one we developed, should be considered a potential mechanism for systematically UA challenges in the future, to grow and develop a broader UA framework within the literature. Beyond that, our survey confirms that UA challenges largely exist within a city specific framework, with cities across the United States facing different sets of challenges. The solutions generated, therefore, must be city-specific, in order to effectively address UA challenges. In order to truly support UA as a lasting component of cities, UA challenges must be identified and addressed, to help lead UA forward.

Table 1. Summary of challenges urban growers face when participating in UA practices, including challenges for both starting up and expanding a site. This table is representative of our survey, showing both the broader framework we identified and the specific challenges we considered.

UA Challenge Frame	Dominant Identified Challenges
Economic	Access to credit Lack of grant funding and opportunities Production costs Maintenances costs Equipment costs Farm/garden expansion costs Property taxes Long-term financial viability Profitability; labor
Environmental	Access to water and irrigation systems Presence of pollutants Climate Lack of fertile, healthy soil Insect/pest damage Weed management
Knowledge	Lack of agricultural management knowledge Lack of environmental knowledge Lack of marketing knowledge Lack of financing knowledge Lack of business management knowledge
Resource	Lack of access to farming and gardening equipment Lack of employees/volunteers Lack of access to land Lack of legal services and assistance
Community	Community acceptance Government acceptance Security/vandalism Poor relationships with other UA sites Lack of relationships with other UA sites Food safety concerns
Regulation	Current zoning ordinances Lack of zoning ordinances Land use regulations Restriction on sale of products City development plans Building codes Land tenure Storm water tax

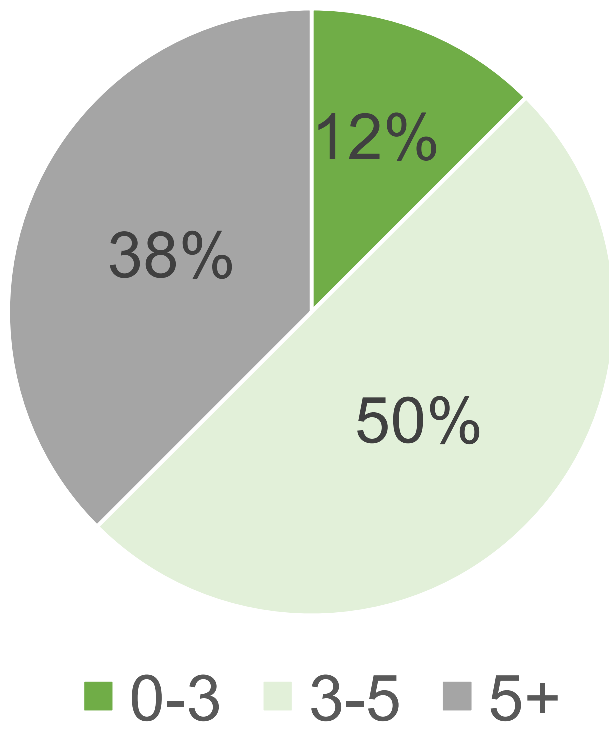
Table 2. The rankings of UA challenges, as identified by growers and UA participants (n=8). These rankings are for the broader categories, and consider those who both agree and strongly agree.

Ranking	Urban agriculture challenges	Strongly agree and agree (%)
1	Economic	87.5
2	Environmental	87.5
3	Community	75
4	Resource	75
5	Regulation	50
6	Knowledge	50

Table 3. The top three specifically cited challenges UA growers (n=8) face in participating in UA, for each challenge category.

UA Challenge Frame	Dominant UA Challenge Ranking	Strongly Agree and Agree (%)
Economic	1. Long-term financial viability 2. Farm/Garden expansion costs 3. Maintenance costs	87.5 85.72 71.37
Environmental	1. Access to water irrigation 2. Insect/pest damage 3. Weed management	85.72 85.72 85.64
Knowledge	1. Lack of marketing knowledge 2. Lack of financing knowledge 3. Lack of business management knowledge	85.72 85.72 71.43
Resource	1. Lack of employees/volunteers 2. Lack of access to farming/gardening equipment 3. Lack of access to land	71.43 71.43 57.15
Community	1. Security/vandalism 2. Government acceptance 3. Food safety concerns	83.3 57.15 57.15
Regulation	1. Stormwater tax 2. Land use regulations 3. City development plans	71.43 71.43 62.50

Figure 1. Number of year urban growers have been participating in UA through owning their own farm or garden.



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