

# **Scrumptious Science:** opportunities for using scientific research to increase yields in community agriculture

Katherine Jacobs

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Committee:

Julie Johnson

Ken Yocom

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# Introduction

## *Overview*

This thesis focuses on opportunities for landscape architects to help reduce food-related emissions through designs that increase urban agricultural production. Such a design approach necessitates a science-based understanding of the processes that underlie food production. This approach is demonstrated in three case studies of particular relevance to urban agriculture in Seattle, Washington.

## *Background*

There is broad consensus in the international scientific community that human activities are contributing to unprecedented changes in the earth's climate.<sup>1</sup> Among other impacts, these changes threaten human health and safety in the form of extreme weather events, loss of arable land, loss of fresh water resources, and sea level rise. In order to sustain a population that is expected to reach 8.1-10.6 billion by 2050,<sup>2</sup> global socio-economic systems must shift to ways of functioning that are less detrimental to long term survival. The task of changing how our global social, economic, and political structures work will require numerous strategies, working across scales and disciplines.

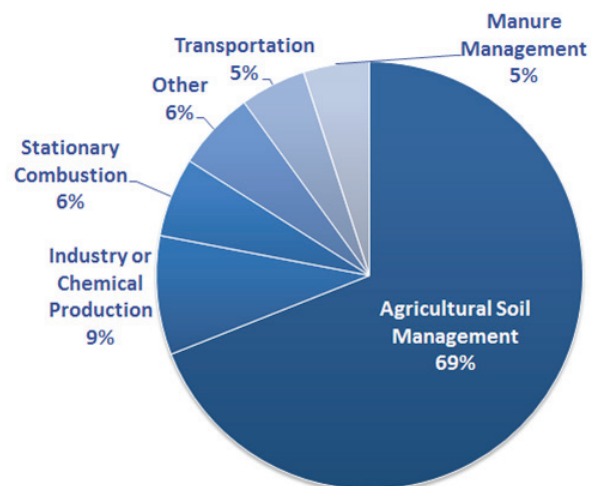
In the United States, local food production is a strategy for reducing greenhouse gas emissions that has recieved significant popular attention in the last few years, evidenced by increasing numbers of farmers markets across the country<sup>3</sup> and an urban agriculture topic page

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- 1 Metz, B., OR Davidson, PR Bosch, R Dave, and LA Meyer. (2007). *Contribution of Working Group III to the Fourth Assessment Report of the IPCC*. New York.
  - 2 The United Nations Population Division. (2011). "World Population to Reach 10 Billion by 2100 If Fertility in All Countries Converges to Replacement Level."
  - 3 USDA Marketing Services Division. (2012). "Farmers Market Growth: 1994-2012." <http://www.ams.usda.gov>. Accessed 20 April 2013.

on NYTimes.com. Since the majority of the average American diet is transported long distances to get from the point of production to the consumer<sup>4</sup> and current transportation methods emit greenhouse gasses,<sup>5</sup> producing food closer to consumers would reduce greenhouse gas emissions and thus mitigate for potential climate change.

In addition to reducing emissions associated with transport of food, urban agriculture is often associated with a reduction in the use of synthetic fertilizers. Urban settings provide opportunities for gardeners to take advantage of on-site or nearby waste streams as nutrient inputs. Furthermore, it is common for community gardening organizations like Seattle's P-Patch Program to forbid the use of chemical fertilizers.<sup>6</sup>

Synthetic nitrogen fertilizers make a significant contribution to national emissions of nitrous oxide ( $\text{N}_2\text{O}$ ) by creating imbalances in the naturally occurring nitrogen cycle.<sup>7,8</sup> In the absence of human activities, processes that changed elemental nitrogen ( $\text{N}_2$ ) into reactive forms (inorganic reduced forms, oxidized forms like  $\text{N}_2\text{O}$ , and organic compounds) and processes that change reactive forms of nitrogen into



$\text{NO}_2$  Emissions in the US by Source  
Source: EPA Climate Change Division

elemental nitrogen occurred at roughly the same rate. Human activities now transform elemental

- 4 Canning, Patrick, Ainsley Charles, Sonya Huang, Karen R Polenske, and Arnold Waters. (2010). "Energy Use in the U . S . Food System." Economic Research Report, 94.
- 5 Metz, B., OR Davidson, PR Bosch, R Dave, and LA Meyer. (2007). *Contribution of Working Group III to the Fourth Assessment Report of the IPCC*. New York.
- 6 P-Patch Community Gardening Program. "P-Patch Community Gardening Program Rules For Participants." [http://www.seattle.gov/neighborhoods/ppatch/documents/2013RULESStandard\\_121113\\_000.pdf](http://www.seattle.gov/neighborhoods/ppatch/documents/2013RULESStandard_121113_000.pdf). Accessed 22 April 2013.
- 7 US EPA, Climate Change Division. (2013). "Nitrous Oxide Emissions." <http://epa.gov/climatechange/ghgemissions/gases/n2o.html>.
- 8 Galloway, James N., et al. (2003). "The Nitrogen Cascade." *Bioscience* 53 (4): 341.

nitrogen into reactive forms more rapidly than atmospheric and ecosystem processes do the inverse, resulting in higher concentrations of reactive nitrogen.  $\text{N}_2\text{O}$  is the most concerning form of reactive nitrogen because it has a 100 year residence in the troposphere.<sup>9</sup>

Agricultural practices that transform elemental nitrogen into reactive forms include practices that promote nitrogen-fixing bacteria, fossil fuel combustion, and the Haber-Bosch process,<sup>10</sup> with the latter being the most significant factor.<sup>11</sup> Since 85% of the reactive nitrogen produced globally by the Haber-Bosch process is used for fertilizer, food production systems that recycle nitrogen from waste streams rather than depending on synthetic fertilizers derived through the Haber-Bosch process would significantly reduce  $\text{N}_2\text{O}$  emissions.

In the interest of reducing food-related greenhouse gas emissions, this thesis discusses opportunities for landscape architects to support urban food production. The following sections, “Critical Stance” and “Scope,” further articulate the purpose and parameters of this project. “Methods” reviews my interview and research process, and “Connections Between Agricultural Research and Community Agriculture” provides an overview of how information about agricultural processes reaches the people involved in urban agriculture. The subsequent three chapters provide a detailed exploration of processes that impact agricultural production, describing how landscape designs that are informed by an understanding of these processes would support higher urban agricultural yields. I conclude with reflections on the implications of these opportunities and the questions that remain unanswered.

## Critical Stance

One might expect landscape architects to play a key role in work on urban agriculture.

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9 Ibid.

10 The Haber-Bosch process is an industrial method for reacting nitrogen gas with hydrogen gas to produce ammonia ( $\text{N}_2 + 3\text{H}_2 \rightarrow 2\text{NH}_3$ ), thereby transforming elemental nitrogen into a reactive, bio-available form.

11 Ibid.

Definitions of landscape architecture generally involve negotiating or curating the relationship between humans and natural systems.<sup>12</sup> Agriculture is an ancient and fundamental component of that relationship, making it a realm that is theoretically significant to the work of landscape architecture. In their expertise working with plants, community process, temporal processes, ecological systems, site analysis, and site planning, landscape architects thus have a skill set that lends itself to work in urban agriculture.

In landscape architectural design for urban agriculture, there are several standard design elements that respond to the processes that will take place on the site.<sup>13</sup> Several of these elements, like gathering spaces, kiosks, and ornamental buffers between gardens and the surrounding neighborhood, anticipate the social processes that are integral to success in urban agriculture. Other standard elements like compost and irrigation systems anticipate the agricultural process that will take place on site and are therefore extremely relevant to this project. This thesis proposes going a step beyond incorporation of these standard elements by exploring other agricultural processes that can be enhanced through design, and by basing this design work in scientific research.

In order to discuss the subject in depth, this project focuses on one of the many ways urban community gardens are beneficial. As noted in *Greening Cities, Growing Communities: Learning from Seattle's Urban Community Gardens*, these urban spaces can provide a wide variety of environmental, social, economic, and health benefits.<sup>14</sup> Some benefits include horticultural therapy, contact with nature, education, and community building. *Greening Cities, Growing Communities* also points out that these benefits vary in importance depending on the community involved: the design of

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12 Foster, Kelleann. (2010). *Becoming a Landscape Architect : a Guide to Careers in Design*. Hoboken, N.J.: Wiley.

13 Hou, Jeffrey, Julie Johnson, and Laura J. Lawson. 2009. *Greening cities, growing communities: learning from Seattle's urban community gardens*. Washington, D.C.: Landscape Architecture Foundation in association with University of Washington Press, Seattle. 36.

14 Ibid, 3.

Bradner Gardens allocates more space to community gathering than the design of Thistle P-Patch does, which reflects differences in the two communities' goals. While food production varies in its relative importance, it is a goal that community gardens share.

By exploring how design interventions can support cultivation, this thesis transcends any division between the physical designed landscape and the processes that it enables. According to the *Oxford English Dictionary*, a process is “A continuous and regular action or succession of actions occurring or performed in a definite manner, and having a particular result or outcome; a sustained operation or series of operations.”<sup>15</sup> Since these actions or operations are shaped by their physical surroundings, the design of a site's physical characteristics has a direct and significant impact on the processes that take place there.

The idea that good site design intentionally engages site processes for a desired outcome is a cornerstone of the University of Washington's Landscape Architecture program and is demonstrated in Nancy Rottle and Ken Yocom's 2010 book, *Ecological Design*. This book provides a detailed conceptual framework for design that engages with ecological processes and case studies that demonstrate the prevalence of ecological design in landscape architectural practice. One characteristic of ecological design is that interventions enable a variety of ecological processes.

Design for urban agriculture enables a variety of processes, including those that are involved in food production. The critical stance of this thesis is that there are opportunities for designers to play a more significant role in supporting urban agriculture by delving into agronomic research and engaging with agricultural processes.

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15 <http://www.oed.com/view/Entry/151794?rkey=vU92YK&result=1&isAdvanced=false#eid>. Accessed 11 June 2013.



## Scope

I limited the geographic scope of my research to Seattle did for several reasons. First, I live here. I began my research already having a basic familiarity with the climate and culture. Living here also enabled interviews that might not have been possible if I were researching different cities.

Second, Seattle is an ideal city to study in this particular project because it is home to an active urban agricultural scene, as surveyed by Magdalena Celinska in 2011 for *Productive Neighborhoods: A Case Study Based Exploration of Seattle Urban Agriculture Projects*.<sup>16</sup> There are a variety of institutions supporting urban agriculture in Seattle, including municipal efforts, non-profit organizations, and for-profit businesses. There is also a strong legacy and culture of community action in Seattle, supported institutionally by the City of Seattle, The P-Patch Program, The Department of Neighborhoods, Sustainable Seattle, Interim Community Development Association, and many other non-profits. As a result, there is significant institutional support for urban agriculture projects undertaken by communities (henceforth referred to as community agriculture) compared to food production in yards and on for-profit farms. The institutional and cultural support for community agriculture make it a rich area of focus for this project.

Finally, community gardens are more significantly shaped by landscape architects than privately owned urban agriculture. Therefore, focusing on community agriculture enables me to identify ways designers in my field can work in the existing professional structure to create more productive spaces.

## Methods

Initially, the methods for this project were structured to explore how designers of Seattle's urban agriculture spaces used scientific information to inform their work. I expected that the

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16 Celinska, Magdalena. (2011). "Productive Neighborhoods: A Case Study Based Exploration of Seattle Urban Agriculture Projects." Seattle.

designs would focus on food production among other project goals, and I was curious about what kind of research design professionals did to inform the design of spaces that would produce food.

I set out to interview urban agriculture professionals including, but not exclusively, trained designers. I was interested in comparing the work of landscape architects to that of urban agricultural professionals who are not trained in design. I anticipated that differences in approach and practice would reveal something about landscape architectural training.

However, I was not able to compare the work of these two groups due to lack of data. My sample size was limited due to time constraints and by my choice to conduct interviews rather than surveys. I was only able to interview four designers trained in landscape architecture, one permaculture designer, one community garden coordinator, and no professional urban farmers. This unequal representation began in the group of people I initially contacted: seven with degrees in landscape architecture, one permaculture designer, one community garden coordinator, and two professional urban farmers. One factor that influenced this bias was my own situation in the world of landscape architecture studies, which exposes me to the work of local professionals in my field. Although I am involved in local urban agriculture organizations, I am not in any urban agriculture professional networks; ultimately, my exposure to these professionals did not match my exposure to professionals in my own field. Another factor that contributed to the imbalance was my decision to limit the pool of possible interviewees to professionals based in Seattle. If my primary goal had been to compare how landscape architects and small scale farmers differed in their use of scientific research, I could have expanded my scope to include all the small farms in King County.<sup>17</sup>

However, as I explain further in “Initial Findings,” I quickly realized in the course of conducting interviews with designers that their work for urban agricultural spaces was not based in

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17 Washington Tilth Producer’s directory supports the idea that there are more small farms outside the city in that it lists 8 in the county and 0 in Seattle. <http://tilthproducers.org/washington-organic/directory/> accessed 12 April 2013.

any scientific research. I therefore decided that my thesis would be more useful as a presentation of the idea that urban agricultural yields can be increased through design that is informed by research on agricultural processes. This possibility is explained through three subject-based case studies: lead-contaminated soil, pollinators, and club root (*Plasmodiophora brassicae*). These three case studies were selected based on their relevance to community agriculture in Seattle, the availability of scientific information, and the opportunities they reveal for increasing yields through design. I also selected these topics to represent the breadth of opportunities for supporting agricultural processes with design.

Julie Bryan, a P-Patch staff member and one of my interviewees, brought my attention to soil contamination and several pathogens as issues that are relevant to Seattle's community gardens. I chose club root, which Julie Bryan assessed to be the most prevalent pathogen, to demonstrate that design based in research can help reduce infections. I also chose to research soil contamination because it is extremely prevalent in urban settings. Lead in particular is a contaminant that historically originated from non-industrial sources, lead paint and leaded gas, which gives lead contamination a broad significance to a wide variety of urban sites.

While those two case studies demonstrate the potential for design to reduce or eliminate barriers to productivity, I developed the third case study to demonstrate the potential for design to support higher productivity, even in the absence of barriers. To demonstrate this idea, I chose to look at pollinators. Pollinators emerged as a good subject to study that was relevant to urban agriculture in Seattle through two projects that are ongoing at the time of this writing: The Pollinator Pathway,<sup>18</sup> a project in Seattle's Capitol Hill neighborhood that creates a corridor of pollinator-friendly plantings on parking strips; and the Urban Pollinator Project,<sup>19</sup> a citizen science initiative coordinated by researchers at The University of Washington that is evaluating the impact

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18 <http://www.pollinatorpathway.com/>

19 <http://nwpollination.org/>

of pollination by bumble bees on tomato production.

### *Initial Findings*

My interviews with designers trained in landscape architecture showed similarities in the type of work they did that challenged the initial premise of my research. First, I realized through the course of my interviews that the majority of landscape architectural design work in support of urban agriculture was in community gardens. I also found that the programmatic elements interviewees focused on were circulation, access to water, proper site drainage, and gathering areas. None of the designers interviewed worked addressed plant choices or pest control in their work. In other words, the designers I interviewed were not concerned with shaping the site to directly enable food production, but with shaping the site to enable the work of community members. In this approach, things like pest management belong in the hands of the community. Since I was interested in the potential for scientific research to inform design solutions for things like pest management, this warranted re-thinking of my focus.

Design for communities involves a risk that the designer's work may disempower the community. My understanding is that more in-depth design strategies to support food production are considered overstepping the appropriate role of the designer, taking away the community's self-determination. An example would be a landscape architect who is contracted for the design of a public orchard, and creates a design with apple trees. If there is a significant immigrant population in the local community that doesn't use apples in their cuisine, this orchard design might be useless to that community. Further, the act of self-determination in itself is valuable- even if the landscape architect used culturally appropriate trees, the community wouldn't feel as much ownership over the space as they would if they select and plant the trees themselves.

While these considerations are absolutely vital, the current boundaries between the work

of the landscape architect and the work of the community make it impossible to use some design strategies that would further the goal of urban food production. There is potential in combining a scientific understanding of agricultural processes with a designer's perspective to create highly productive urban agricultural systems that are sustainable economically, ecologically, and socially. However, it is clear that this kind of work is not enabled by the current structure of how landscape architects work with community gardens, and redefining that relationship would be beyond the scope of this thesis.

### Connecting Agricultural Research and Community Agriculture

Before delving into my case studies, I discuss existing connections between agricultural research and community agriculture in Seattle. This context is significant to my project because these resources can be useful for a landscape architect engaging with agricultural research for the design of community agriculture, and because landscape architects can become another point of contact between scientific research and the community.

As stated, Seattle residents are fortunate to have extensive organizational infrastructure supporting community agriculture. For example, the active and visible non-profit Seattle Tilth lists 50 other local urban agriculture organizations on the “Our Community” section of their website.<sup>20</sup> This list includes a number of blogs, Facebook pages, Google groups, and listserves that help connect Seattle's urban agriculture community. These social network platforms are well-suited for peer-to-peer sharing of information. Gardeners are constantly doing informal experiments inspired by questions like: “Is it better to put my squash on the side of the house that gets direct sun in the morning, or on the side that gets sun in the afternoon?” Existing social network platforms are useful in enabling exchange of information gleaned from these informal experiments, but they are limited in two major ways. The first limitation is that it can be extremely difficult to locate

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20 <http://seattletilth.org/our-community>, accessed 24 March 2013.

information. This difficulty is in part because the information is very decentralized, and it is often organized chronologically rather than by subject matter. Another limitation is that people don't necessarily describe all the variables that were important in determining the outcome they had.

Classes and workshops led by community members, non-profits, and small businesses are another forum for people in Seattle's urban agriculture community to share knowledge. Especially when it involves hands-on learning, this can be one of the most enjoyable and effective methods of sharing information. These classes can be a useful point of connection between the community and scientific research, particularly if teachers have scientific backgrounds and stay up to date on relevant research.

There are also local programs that use classes and workshops to transform community members into educators, including the Master Gardener and Master Composter programs. These community teachers have the potential to be liaisons between the urban agriculture community and the scientific community.

Master Gardeners are especially well positioned to connect the community to the world of scientific research because they are affiliated with Washington State University, an agricultural research institution, via Washington's Cooperative Extension Service. For the 2014 training session, people interested in becoming Master Gardeners will pay \$275 for 84 hours of training, including homework and open book assessments.<sup>21</sup> The training is taught by specialists on a variety of topics, including one session on the scientific method.<sup>22</sup> After their initial training, Master Gardeners have a continuing education requirement, which keeps them informed of ongoing research.<sup>23</sup> In the two years after completing training, Master Gardeners each spend 90 hours

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21 <http://county.wsu.edu/king/gardening/mg/Pages/Apply.aspx> Accessed 28 March 2013.

22 <http://www.mgfk.org/wp-content/uploads/2013/01/2013-MGTraining-Open-to-Visitors.pdf> Accessed 28 March 2013.

23 <http://county.wsu.edu/king/gardening/mg/Pages/Apply.aspx> Accessed 28 March 2013.

educating the community. They reach out to the community through Garden clinics, located throughout Seattle in farmers markets and stores; an online e-clinic; presentations to groups; a children's garden; and demonstration gardens, one of which is connected to the Picardo P-Patch.<sup>24</sup>



*Picardo P-Patch and Master Garden Demonstration Garden  
Source: Google Earth. Accessed 28 April 2013.*

Due to its size and proximity to a large and well-established P-Patch, the 5,000 square foot demonstration garden adjacent to the Picardo P-Patch is an exceptional opportunity for Master Gardeners to connect community gardeners to scientific research.

<sup>24</sup> <http://county.wsu.edu/king/gardening/Pages/default.aspx> Accessed 28 March 28, 2013.





*Demonstration Garden Kiosk  
Source: photo by Katherine Jacobs, March 2013*

The site's kiosk could provide gardeners with any number of the well-researched and informative brochures developed by Washington State University extension on subjects related to growing food plants, but in early 2013 it proffered a single leaflet on "Fantastic Foliage." Given that their mission is not limited to edible plants, it is appropriate for the Master Gardeners to use this space to educate people about ornamental plants as well as edible ones. However, the proximity of this demonstration garden to the Picardo P-Patch warrants some emphasis on cultivation of edible plants. In the kiosk in particular, it is clear that it would be possible to provide more information about cultivating edible plants without removing information about ornamentals.

There are many informative and useful brochures developed by Washington State University as well as other extension offices that summarize scientific research in a concise format and in language that is accessible to a wide audience. The P-Patch website also has links to a



number of similar resources. These are available for free to anyone with internet access.

It would also be possible to layer additional information in the planting design. Currently, there are thematic beds showcasing techniques such as esplanade, perennial borders, and the bed shown above/below: bulbs for summer and autumn bloom. Without compromising the existing messages, Master Gardeners could amend plant selections and/or signage to instruct visitors about additional topics such as nitrogen fixation, companion planting, or plant choices for pollinators. This bed that showcases summer and autumn blooming bulbs could include edible plant choices like chives, onions, and Jerusalem artichoke.



*Summer and Autumn Blooming Bulbs (Existing)*  
Source: Katherine Jacobs, Photo taken March 2013



*Summer and Autumn Blooming Bulbs, Proposed*  
Source: Katherine Jacobs

Community garden site coordinators and Master Gardeners can be instrumental in helping gardeners identify the name of a problem plant or pest, without which it may be difficult to research. These leaders are also important in finding resources for gardeners who don't speak English and/or don't have internet access.

In summary, there are many existing pathways for scientific research to reach Seattle's urban agriculture community. Many of the existing resources and institutions are quite useful as they are, and there are a variety of ways they can be altered to become even more so. Designers can play a role in connecting community members to scientific research through the community design process or through educational design elements. In addition, designers can make use of this existing body of agricultural research to inform designs that support abundant yields. The following three case studies explore particular issues that highlight the utility of scientific

information in increasing community agricultural yields.

## Case Study 1: Lead-Contaminated Soil

According to ecologist Richard Pouyat and colleagues (2010), “elevated heavy metal concentrations are almost universally reported [in urban soils], although often with high variances.”<sup>25</sup> While there is an emerging discourse about the human health impacts of such contamination,<sup>26</sup> there has been relatively little discussion for how soil contamination impacts the productivity of urban agriculture. In this section, I discuss lead contamination as an illustrative example, demonstrating that contamination of urban soils can negatively impact crop yields. Designers for urban agriculture can therefore support higher yields by exploring the possibility of soil contamination during site analysis and initiating appropriate steps toward remediation.

### Background

Researching a site’s history through municipal records, historical maps, or interviews with elderly residents can reveal possible sources of contamination. This research may reveal that contamination is quite unlikely, indicating that soil testing is unnecessary. In other cases, research into site history may reveal which contaminants are likely to be present on the site. Because testing for all possible contaminants is prohibitively expensive, site history research enables soil testing that is targeted to contaminants that are most likely present. For community groups with limited funds, site history research may provide enough evidence of contamination to move ahead with remedial strategies without soil testing.

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25 Pouyat, R., Szlavacz, K., Yesilonis, I., Groffman, P., Schwarz, K. (2010). “Chemical, Physical, and Biological Characteristics of Urban Soils.” In J. Aitkenhead-Peterson & A. Volder (Eds.), *Urban Ecosystem Ecology* (pp. 119–152). Madison, WI: American Society of Agronomy, Crop Science Society of America, Soil Science Society of America. P 124.

26 A collection of research on lead and its health impacts can be found at <http://www2.epa.gov/lead/technical-studies>.

The two main sources of lead contamination are lead paint and leaded gasoline. Use of lead paint was standard in the United States before 1940, after which residential use declined, and was banned in 1978.<sup>27</sup> Soil near painted structures that were built before 1978 may therefore be contaminated with lead. Leaded gasoline was another important historical contributor to lead in urban soils. Engines that ran on leaded gas emitted leaded exhaust, which would settle on nearby surfaces and accumulate over time.<sup>28</sup> Because Seattle's comprehensive street grid was fully developed by the time lead was outlawed in 1995, there is likely some lead contamination everywhere in the city, with higher concentrations near older and more heavily-used roadways.<sup>29</sup>

Some sources indicate that "the quantities of lead found in most lead-contaminated soils typically are not high enough to reduce plant growth and yield."<sup>30</sup> However, research on the impact of lead on plants seems to disprove that claim. One laboratory experiment compared the growth of Scarlet White Tip radishes (*Raphanus sativus* L.) grown in soil with 100ppm-2000ppm lead ( $\text{Pb}(\text{NO}_3)_2$ ) with radishes grown in uncontaminated soil. This experiment found higher dry weight in the radishes grown in uncontaminated soil.<sup>31</sup> Another study found that all of the five plant species they used were stunted at 500ppm of lead compared to 0.<sup>32</sup>

To frame these experiments in reference to lead concentrations that might be found in an urban environment, soil samples taken from the Leo Street P-Patch were found to contain 700 - 2400 ppm of lead.<sup>33</sup> Based on the experiments referenced above, that range of concentration may have a negative impact on plant growth.

### *Soil Testing*

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- 27 Peryea, F. J. (1999). "Gardening on Lead and Arsenic Contaminated Soils." Washington State University Cooperative Extension. Retrieved February 19, 2013, from [http://www.ecy.wa.gov/programs/tcp/area\\_wide/AW/AppK\\_gardening\\_guide.pdf](http://www.ecy.wa.gov/programs/tcp/area_wide/AW/AppK_gardening_guide.pdf)
  - 28 Ibid.
  - 29 Ibid.
  - 30 Ibid.
  - 31 Zaman, M. S., & Zereen, F. (1998). "Growth responses of radish plants to soil cadmium and lead contamination." *Bulletin of environmental contamination and toxicology*, 61(1), 44-50.
  - 32 Begonia, G. B. (1997). "Comparative Lead Uptake and Responses of Some Plants Grown on Lead Contaminated Soils." *Journal of the Mississippi Academy of Sciences*, 42(2).
  - 33 Phillip Defoe. Personal Communication. 17 May 2013.

Soil testing for heavy metal contamination is the most direct and definitive way to determine soil contents. Unfortunately, it is far from standard practice. According to the EPA,

“Many community gardening ... organizations test for agronomic parameters – nitrogen, phosphorus, and potassium (N-P-K) as well as pH and organic content. [However,] A recent compendium of urban agriculture practice and planning by the American Planning Association ... noted few local requirements for soil testing [for contaminants] and very few examples of locally driven testing on behalf of community organizations.”<sup>34</sup>

Consistent with the EPA’s findings, The King Conservation District, an agency funded by Washington State, currently has a free soil testing program for King County residents that only tests for agronomic parameters.<sup>35</sup> Expanding its services to test for heavy metals would support food production in the county and would further their mission of resource conservation. The King Conservation District could get support for such an expansion from other existing institutions in the region that would be interested in having the lab as a resource, for example: The King County Board of Public Health, Seattle’s Office of Sustainability and Environment, Seattle’s Food Interdepartmental Team, and various entities within the University of Washington like the Food Studies Program. Examining precedents for municipal support of heavy metal testing, such as the City of Minneapolis, which offers free soil tests for lead,<sup>36</sup> could provide insights into how such a program might work.

Another institution that would be a useful part of this effort is the National Resources Conservation Service (NRCS), originally The National Soil Conservation Service. The NCRS is

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34 EPA. (2011). “Brownfields and Urban Agriculture: Interim Guidelines for Safe Gardening Practices.” p2.

35 King Conservation District Soil Testing Service. (n.d.). Retrieved February 24, 2013, from [http://www.kingcd.org/pro\\_far\\_soi.htm](http://www.kingcd.org/pro_far_soi.htm)

36 Wieland, B., Leith, A., & Rosen, C. (n.d.). “Urban Gardens and soil Contaminants: A Gardener’s Guide to Healthy Soil.” University Of Minnesota Extension. Retrieved February 19, 2013, from [http://www.misa.umn.edu/prod/groups/cfans/@pub/@cfans/@misa/documents/asset/cfans\\_asset\\_287228.pdf](http://www.misa.umn.edu/prod/groups/cfans/@pub/@cfans/@misa/documents/asset/cfans_asset_287228.pdf)

a federal entity that does soil research and provides information on soil quality for agriculture. Although urban soils and heavy metal contamination are currently peripheral to their work, the NRCS has an existing structure for soil research in the National Cooperative Soil Survey (NCSS) that could be expanded to do more work evaluating urban soil contamination. The NRCS currently has soil conservation programs in a handful of cities,<sup>37</sup> and Seattle's University of Washington is already a collaborator in the NCSS.<sup>38</sup> According to a local NRCS soil scientist, "The last time [The King County soil map dataset] was updated the city was excluded due to the amount of urbanization. There is an interest [in producing] a soil survey for Seattle and NRCS recognizes the need for mapping in urbanized areas...it will still be years (3-4) before it would get started."<sup>39</sup>

According to my research, the cheapest way for Seattle residents to test for heavy metals in their soil is to send soil samples to The University of Massachusetts. UMass' routine analysis costs \$10 and includes agronomic parameters as well as arsenic and lead concentration.<sup>40</sup> There are other heavy metals like cadmium that are also likely to be present in some urban soils<sup>41</sup> and can negatively impact plant growth.<sup>42</sup> Further research is necessary to clarify when those substances are likely to be a problem and how to make testing more readily available.

## Interventions

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37 Urban Conservation Programs | NRCS Soils. (n.d.). Retrieved February 22, 2013, from <http://soils.usda.gov/use/urban/conservation.html>

38 List of Universities | NRCS Soils. (n.d.). Retrieved February 22, 2013, from <http://soils.usda.gov/partnerships/universities/#wa>

39 Personal communication, 22 February 2013.

40 UMass Soil and Plant Tissue Testing Laboratory. "Services." <http://soiltest.umass.edu/services>.

41 "Cadmium occurs naturally in ores together with zinc, lead and copper. Cadmium compounds are used as stabilizers in PVC products, colour pigment, several alloys and, now most commonly, in re-chargeable nickel-cadmium batteries. Metallic cadmium has mostly been used as an anticorrosion agent (cadmiation). Cadmium is also present as a pollutant in phosphate fertilizers." -from Jarup, L. (2003). Hazards of heavy metal contamination. *British Medical Bulletin*, 68(1), 167-182.

42 Zaman, M. S., & Zereen, F. (1998). "Growth responses of radish plants to soil cadmium and lead contamination." *Bulletin of environmental contamination and toxicology*, 61(1), 44-50.

After testing soil or researching site history, communities may be interested in finding strategies for using the site that limit the negative impacts of soil lead. This section discusses strategies that can be used by community garden groups. Excavating contaminated soil, disposing of it off site, and importing clean topsoil is not discussed because it is financially unrealistic for most community gardens. Similarly, phytoremediation of lead contamination is not discussed because the process takes years,<sup>43</sup> making it unsuitable for use in community gardens.

### *Raised Beds*

Growing food in raised beds filled with clean imported soil is a standard way of dealing with soil contamination.<sup>44</sup> There are a number of important considerations in the design and construction of raised beds to enable healthy and abundant plant growth.

When constructing raised beds, it is important to avoid materials for the sides that will leach new contaminants into the soil. Many of the chemical treatments used to make wood rot resistant, such as creosote or chromated copper arsenate, are not suitable for use in gardens due to negative health impacts. Alkaline copper quaternary is an alternative treatment that the EPA has approved for use in gardens.<sup>45</sup> It is also possible to use types of wood like redwoods that

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43 David J. Butcher, et al. "Phytoremediation of Arsenic and Lead in Contaminated Soil Using Chinese Brake Ferns (*Pteris vittata*) and Indian Mustard (*Brassica juncea*)."  
*International Journal Of Phytoremediation* 5, no. 2 (June 2003): 89-103.

44 For example:

Peryea, F. J. (1999). "Gardening on Lead and Arsenic Contaminated Soils." *Washington State University Cooperative Extension*.

Penn State Extension: Crop Management Extension Group. (n.d.). "Lead in Residential Soils: Sources, Testing, and Reducing Exposure." *Penn State Cooperative Extension*.

Wieland, B., Leith, A., & Rosen, C. (n.d.). "Urban Gardens and soil Contaminants: A Gardener's Guide to Healthy Soil." *University Of Minnesota Extension*.

45 Lerner, BR. 1986. "Container and Raised Bed Gardening." HO-Purdue University, Cooperative Extension Service: 1-3.

are naturally resistant to rot.<sup>46</sup> Other material choices include concrete, stone, wood/plastic composites, and recycled rubber. Concrete may not be suitable for use with soils that have higher pH, as it will leach lime over time.<sup>47</sup>

Installing a bottom to the raised bed as a boundary between native and imported soil prevents contamination from entering the raised bed. Without such a boundary, contamination may be brought up into the raised bed by the activity of worms or by overzealous digging by gardeners. In addition, plant roots may extend into native soil below bottomless raised beds. The boundary can consist of gravel, landscape cloth, or anything else that allows proper drainage.

Another consideration in designing and building raised beds with bottoms is the depth of imported soil, which must be adequate for healthy root development. While 6-8" of depth is sufficient for many annual vegetable crops, root crops like carrots require at least 1 foot of depth. Trees and perennials, which over time establish more extensive root systems than annual vegetables do, require more depth.

### *Rock Phosphate*

The Connecticut Agricultural Experiment Station explored the possibility of adding phosphorous to lead-contaminated soil to reduce the levels of available lead.<sup>48</sup> In this method, phosphorous binds to lead, making it less soluble. Soil contents that are less soluble are less likely to enter plant roots, limiting their impact on plant growth. Interestingly, the study team found significant differences in the success of this technique depending on the type of phosphate they added. Because there is concern that this strategy would create additional ecological problems

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46 US EPA, Office of Pesticide Programs. "Alternatives to Pressure-Treated Wood | Pesticides | EPA." [http://www.epa.gov/oppad001/reregistration/cca/pressuretreatedwood\\_alternatives.htm](http://www.epa.gov/oppad001/reregistration/cca/pressuretreatedwood_alternatives.htm).

47 Oregon State University Extension. (2003). "Raised Bed Gardening."

48 Stilwell, D. E., & Ranciato, J. F. (2008). "Use of Phosphates to Immobilize Lead in Community Garden Soils." The Connecticut Agricultural Experiment Station.

by increasing the amount of phosphate in runoff, the team also compared how much additional phosphate was leached from the different amendments. They found that rock phosphate was the optimal form for stabilizing lead while minimizing phosphate runoff. However, the researchers emphasize that this study was done in a greenhouse, and more research is needed to determine if phosphate amendment could be used in field conditions to stabilize lead. This topic is well suited for investigation with a citizen science initiative: the study could be designed by soil scientists at UW, data could be collected by p-patch gardeners, and data could be analyzed at The King Conservation District's lab.

## Conclusion

Given the negative impacts and prevalence of heavy metal contamination in urban soils, looking into contamination through site history research and/or soil testing should be a standard component of site analysis for designers working on urban agricultural projects. When contamination is identified, designers can play a key role in working with the community to identify effective remedial strategies that fit within the available budget.

Designers can also work with communities to frame projects as experiments that generate information. Details about existing conditions, the design process, remedial strategies and materials used, and results can all be compiled and shared with other groups. Results may include follow-up soil tests, observations on raised bed drainage, remarks about material durability, or data on crop yields. While it may not be possible for the designer to compile this information, the designer may help organize a group of volunteers to undertake the project. Designers may also facilitate partnerships with other groups who may be interested in the community's findings.

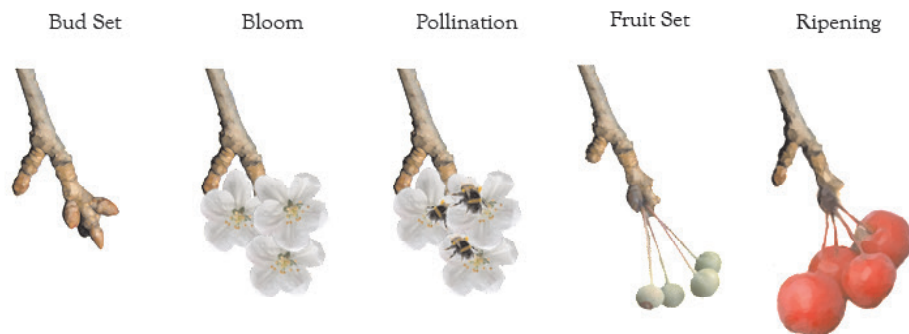


## Case Study 2: Pollinators

For crops such as tomatoes, pears, and almonds, which are cultivated for their fruits and nuts, pollinators are fundamental to productivity. The existing body of scientific research on pollination provides information about how pollination can help increase yields in urban community gardens and what kinds of site interventions would support local pollinator populations.

### Background

Pollination happens when pollen is brought from the male anther, where it is produced, to a female stigma, either of the same or of a different flower. Pollen can be transported by a variety of means, with bees being the most important pollinator for the plant types cultivated in Seattle's community gardens.<sup>49</sup>



*The Role of Pollination in Fruit Formation*  
 Source: Katherine Jacobs, 2013

The diagram above illustrates the role of pollination in creating fruit. After flowers bloom, they must be pollinated in order for fertilization, fruit set, and ultimately fruit ripening to be possible. Without robust pollinators, even the healthiest crops make relatively little fruit.

<sup>49</sup> Crops like wheat are wind-pollinated, but since they are not commonly cultivated in Seattle's community gardens, I focus on bees.

Many studies have compared the productivity of plants with all variables equal except exposure to pollinators, and consistently found that plants isolated from pollinators yield less fruit.<sup>50</sup>

Researchers also have found that there are differences in the efficiency of pollinators on different plant species. For example, researchers observed bees pollinating faba bean fields (*Vicia faba*) and found that almost all flowers visited by the bee *Eucera numida* were successfully pollinated, while a third of the European honeybee visits observed removed nectar in a way that did not pollinate the flowers.<sup>51</sup> Another experiment compared fruit set of greenhouse tomatoes pollinated by two different bee species and found interesting differences in their pollination efficiency depending on climatic conditions.<sup>52</sup> Much of this research on pollinator species specificity aims to identify the most efficient pollinators to pair with large commercial monocultures. However, for the diversity of plant species cultivated in community gardens, differences in pollinator efficiency makes it important to support diversity in pollinator species.

In addition, there is evidence that pollinator species diversity may increase overall yields, even in monocultures. Observations of bee activity suggest that having multiple bee species changes their behavior, making them more effective pollinators and increasing yields.<sup>53,54</sup> These findings

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50 For example:

Hikawa, M., & Miyanaga, R. (2009). "Effects of pollination by *Melipona quadrifasciata* (Hymenoptera: Apidae) on tomatoes in protected culture." *Applied Entomology and Zoology*, 44(2), 301–307

Holzschuh, A., Dudenhöffer, J.-H., & Tschardtke, T. (2012). "Landscapes with wild bee habitats enhance pollination, fruit set and yield of sweet cherry." *Biological Conservation*, 153, 101–107.

51 Benachour, K., Louadi, K., & Terzo, M. (2007). "Role of wild and honey bees (Hymenoptera : Apoidea) in the pollination of *Vicia faba* L. var. major (Fabaceae) in Constantine area (Algeria)." *Annales de la Societe Entomologique de France*, 43(2), 213–219.

52 Hikawa, M., & Miyanaga, R. (2009). "Effects of pollination by *Melipona quadrifasciata* (Hymenoptera: Apidae) on tomatoes in protected culture." *Applied Entomology and Zoology*, 44(2), 301–307.

53 Brittain, C., Williams, N., Kremen, C., Klein, A., & B, P. R. S. (2013). "Synergistic effects of non-*Apis* bees and honey bees for pollination services." *Proceedings of the Royal Society*, 280(20122767).

54 Klein, A.-M., et al. (2003). "Fruit set of highland coffee increases with the diversity of pollinating bees." *Proceedings of the Royal Society of Biological Sciences*. 270(1518): 955–61.

provide more support to the idea that supporting the health, quantity, and diversity of pollinators increases yields. The following sections discuss how community gardens can support a diverse population of pollinators with diverse habitat and food sources.

## Interventions

The preceding discussion showed that an abundant and diverse bee population in community gardens can increase yields. This section discusses physical site elements that would support such a population and thereby increase yields in Seattle's community gardens.

### *Supporting a Diverse Population of Pollinators: Habitat*

Because this discussion focuses on how community gardens can support a diverse bee population, it is not necessary to review the particular habits of the many species found in Seattle. Instead, I review the range of needs found in local bee populations. First, I discuss the three different nesting styles: hives, ground nests, and hole nests.<sup>55</sup>

While honeybees can live without human stewards, managed apiaries for honeybees are popular assets for community gardens. These bee hives produce honey in addition to pollination services. On siting new hives, The University of Missouri Extension advises,

"The apiary should face southeast or south with a windbreak behind it. The location should be well drained. The south face of a hillside is ideal, but bees will adapt to less-than-ideal locations. Deciduous trees that shade the colony in summer afternoons and allow the sun to penetrate in winter are desirable...A platform on the roof of a house or other building is a good place to keep hives."<sup>56</sup>

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55 Moisset, B. B., & Buchmann, S. (2011). "Bee Basics: An Introduction to Our Native Bees." USDA Forest Service and Pollinator Partnership Publications.

56 The University of Missouri Extension. (n.d.). "Beekeeping Tips for Beginners." Retrieved February 28, 2013, from <http://extension.missouri.edu/publications/DisplayPub.aspx?P=G7600>

This latter recommendation may be particularly useful in community gardens, where well-drained, south-facing ground is in demand for growing plants.

Ground nesting bees, including some bumble bees, need dry, bare, preferably sunny ground space that will remain undisturbed by foot/vehicle traffic, digging, or flooding year round. Their sites must be dry and protected throughout the rainy winter, while they are dormant, to support the following year's bee population. Some bees dig their own holes, while others use holes dug by mice or other subterranean creatures.<sup>57</sup> Thick layers of mulch make it difficult for ground-nesting bees to reach the ground.<sup>58</sup> Areas of nutrient-poor, compacted, sandy soil that would not readily support plant growth are actually ideal for ground nesting bees.

It could be possible for roofs covered with a layer of soil to provide habitat for ground nesting bees in a way that makes efficient use of space. Roofs would be ideal for bee nests in that they are elevated away from disturbance by humans. Slanted roofs could also provide good drainage. Because such designs would encourage rapid drainage, they would be much lighter than water-heavy green roofs. As a result, retrofitting roofs for bee habitat would be an option for existing structures that could not support green roofs. South facing roofs could also be beneficial in being warm and sunny, but more research needs to be done into the maximum temperature tolerable by ground nesting bees, since roofs get hotter than soil does.

Other bees, like mason bees, are hole nesters. These bees either create nests in existing holes in wood or may burrow their own holes. So-called carpenter bees avoid painted or finished wood, so they are fairly easy to dissuade from nesting in necessary structures.<sup>59</sup> Communities

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57 Moisset, B. B., & Buchmann, S. (2011). *Bee Basics: An Introduction to Our Native Bees*. Washington, DC: USDA Forest Service and Pollinator Partnership Publications.

58 Vaughan, M., & Hoffman Black, S. (2006). "Improving Forage for Native Bee Crop Pollinators." *USDA Agroforestry Notes*, 33, 1-4.

59 Moisset, B. B., & Buchmann, S. (2011). "Bee Basics: An Introduction to Our Native Bees." *USDA Forest Service and Pollinator Partnership Publications*.

wanting to attract hole nesters can construct attractive, sculptural bee nests with pre-drilled holes. According to Washington State University Extension,

... placement of the block is the most important consideration in successful mason bee culture. The bees require a warm, dry, wind-protected place for their nests. The best place is usually on the side of a house, shed, or other large structure, ideally facing east or south to catch the morning sun, and under an eave to deflect rain. The bees will avoid nesting in blocks placed out in the open.<sup>60</sup>

These nests can be managed, which increases likelihood of yearly population growth and allows continued reuse of the same nest, or unmanaged, in which case the nests will only last a few years.<sup>61</sup>

Since bees travel away from their nests for food, it may not always be beneficial to provide all of these habitat types in every garden. Instead, it may be helpful to evaluate what bee habitat types are lacking in the surrounding area and would also be feasible to provide with available space, resources, and with the cultural or aesthetic needs of the community.

#### *Supporting a Diverse Population of Pollinators: Food Sources*

The nectar and pollen provided from crops may not be enough to support a diverse bee population due to the timing of most blooms. Some bees, particularly bumble bees, emerge very early in the growing season, before most crops are in flower. Providing them with flowering plants in this period helps them establish healthy and abundant colonies. In the fall, after the flowering of most crops is complete, late-season bloomers provide food for queen bees to prepare for hibernation. In addition to these temporal considerations, the USDA Agroforestry Center points

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60 Washington State University King County Extension. (n.d.). "Orchard Mason Bees." Community Horticulture Fact Sheet, (83), 3-6.

61 Ibid.

out that “because native bees come in a range of sizes, it is important to provide flowers of various sizes, shapes, and colors.”<sup>62</sup>

## Conclusion

Scientific research on the impact of pollinators on agricultural yields indicates that supporting a diverse local pollinator population would support higher yields. This information may expand the programmatic foci of communities that had not previously considered the role of pollinators in agricultural production or communities that had previously focused on honeybees. Designers may play a key role in educating communities on the benefits of creating habitat and food sources for pollinators. In addition, scientific information on the habitat and food needs of pollinators enables designers to make interventions that are effective in supporting pollinator populations and, ultimately, higher yields.

## Case Study 3: Club Root

Club Root, or *Plasmodiophora brassicae*, is a pathogenic protist<sup>63</sup> that is currently plaguing many of Seattle’s community gardens.<sup>64</sup> The pathogen has a negative impact on brassica yields, so design strategies that eliminate it or reduce its severity would increase yields. Scientific research executed to support large-scale farming provides key insights into what club root is, how it spreads, and what design strategies would be effective in managing club root in Seattle’s community gardens.

## Background

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62 USDA National Agroforestry Center. (2006). “Agroforestry: Sustaining Native Bee Habitat For Crop Pollination.”

63 It is interesting to note that *Plasmodiophora brassicae* does respond to some fungicides, even though it is not a fungus (Potential biological control of clubroot on canola and crucifer vegetable crops, Peng et al).

64 The prevalence of club root in Seattle’s community gardens was brought to my attention by Julie Bryan, a P-Patch Site Coordinator.

Plants infected with *Plasmodiophora brassicae* have visibly enlarged, deformed roots. *Plasmodiophora brassicae* prevents plants in the *Brassica* (cabbage) family from taking up nutrients properly, stunting their growth and ultimately killing the plant.<sup>65</sup> Lacking effective methods for eradicating club root, some community gardeners are currently dealing with the problem by



Cabbage Seedlings Infected with Club Root

Source: Western Committee on Plant Disease Digital Image Collection, photograph by R. Howard.

harvesting the plants young.<sup>66</sup> Doing so provides *Plasmodiophora brassicae* with new generations of hosts, contributing to the continued expansion of the local *Plasmodiophora brassicae* population. In addition, gardeners are getting much less edible biomass for the same inputs of time, energy, seeds, and water. A systemic change that dealt with *Plasmodiophora brassicae* would therefore increase yields on gardening that is already happening.

Seattle gardens are more susceptible to *Plasmodiophora brassicae* than others in the nation because it thrives in moist, temperate climates.<sup>67</sup> In addition, climatic conditions during the winter in the Seattle region are favorable to growing Brassicas and little else. As a result, gardeners often grow Brassicas all year round. Since Brassicas are hosts to *Plasmodiophora brassicae*, year-round cultivation supports rapid expansion of the parasite's population.

65 Hwang, Sheau-Fang, Stephen E Strelkov, Jie Feng, Bruce D Gossen, and Ron J Howard. "Plasmodiophora Brassicae: a Review of an Emerging Pathogen of the Canadian Canola (*Brassica Napus*) Crop." *Molecular Plant Pathology* 13, no. 2 (February 2012): 105–13. <http://www.ncbi.nlm.nih.gov/pubmed/21726396>.

66 Julie Bryan (P-Patch site coordinator), in discussion with the author, February 2013.

67 Thuma, BA, et al. "Relationships of Soil Temperature and Moisture to Clubroot (*Plasmodiophora Brassicae*) Severity on Radish in Organic Soil," *Plant Disease*. 67, no 2 (1983): 758-762.

Sharma, Kalpana, et al. (2011). "Effect of Temperature on Cortical Infection by *Plasmodiophora Brassicae* and Clubroot Severity," *Phytopathology*, 101(12): 1424-1432.

## Interventions

The preceding section discussed what *Plasmodiophora brassicae* is and how eliminating or reducing infections in community gardens would increase yields. The following sections review physical site interventions that would reduce or eliminate *Plasmodiophora brassicae* and thereby increase yields.

### *Reducing Infection: Tool Sanitation and Testing Methods*

Community gardens are vulnerable to pathogens because of the many opportunities for small organisms to enter and move around. Gardeners often share tools,<sup>68</sup> which can bring the problem from one infected plot to the rest of the plots in the garden. A system of tool sanitation that killed *Plasmodiophora brassicae* and was easy enough to be used consistently would help limit movement of the pathogen within community gardens. Pathogens can also enter a site through infected seeds, soil, and compost. Affordable methods for testing these materials for *Plasmodiophora brassicae* would therefore be extremely helpful in controlling its spread.

### *Crop Rotation and Fallowing*

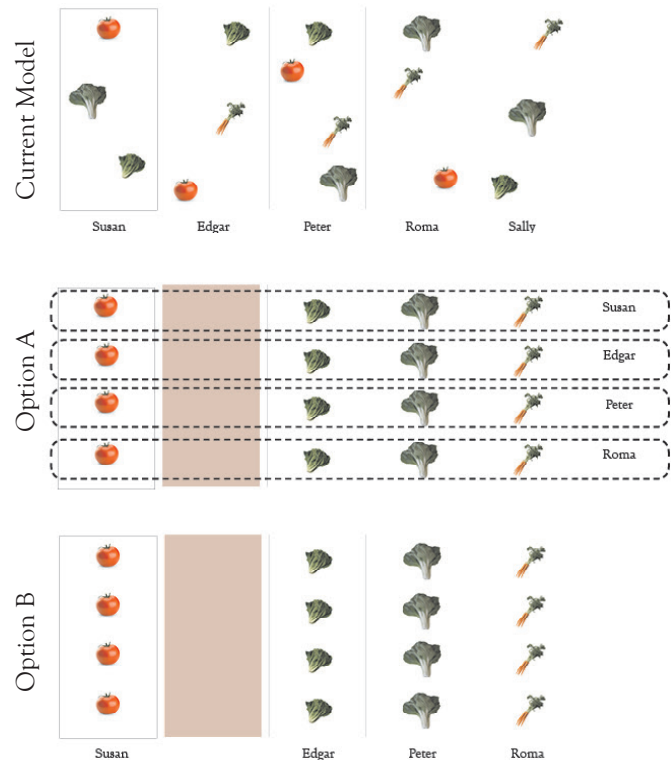
Before the advent of chemical pesticides, many cultures used crop rotation and field fallowing as effective strategies for controlling pest populations. Community gardeners are in a tricky situation: community rules usually do not allow the use of chemical pesticides, yet the small plot sizes do not allow for effective crop rotation or fallowing. In general, there is a need for organic community gardens to develop strategies that would enable these methods for pest population control. An alternative model (Option A) that would allow for crop rotation and fallowing is to devote each plot to a particular crop instead of to a particular person. Crops could therefore be effectively rotated, and it would be possible to include a fallow plot (or plots) in

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<sup>68</sup> Julie Bryan (P-Patch site coordinator), in discussion with the author, February 2013.



that rotation. Perhaps in this model each crop-plot would be divided into rows, which can be designated for different gardeners. Alternatively, gardeners could be in charge of tending one crop all season (Option B), and the gardeners would share their produce. The latter model, in particular, would require a tight-knit and trusting community with effective organization to ensure equitable sharing of the harvest. Another challenge is that there is currently pressure for space in Seattle's P-Patch program, which makes it very difficult politically to implement a system that includes fallowing. However, current trends of intensive cultivation may render plots un-usable for gardening, which would further compound the problem of limited space.



Crop Rotation in Allotment Garden  
Source: Katherine Jacobs, 2013

The discussion of fallowing and crop rotation as a method of controlling *Plasmodiophora brassicae* is complicated by the tenacity of this particular pest, which can remain dormant in soil without host Brassicas for more than 10 years.<sup>69</sup> Although a fallowing period that long is clearly out of the question in urban settings, where space is limited, fallowing for shorter periods may be helpful in preventing the concentration of *Plasmodiophora brassicae* from increasing. In addition, it might be possible to declare infected sites as “no Brassica zones,” which could still be used for a variety of other crops. Non-host plants may actually induce germination in the club root spores,

69 “in a field with 100% infestation, the level of infestation declined to below the detection level after a period of 17-3 years.” From Wallenhammar, A. “Prevalence of *Plasmodiophora Brassicae* in a Spring Oilseed Rape Growing Area in Central Sweden and Factors Influencing Soil Infestation Levels.” *Plant Pathology* 45 (1992): 710.

potentially reducing the concentration of dormant spores over time, but the results of this research is not conclusive.<sup>70</sup> If fallowing is used as a method for controlling *Plasmodiophora brassicae*, it is important to monitor the site and remove any weeds in the Brassica family, which would act as hosts.

### *Altering Soil pH*

Currently, the most useful strategy for dealing with club root involves altering the pH of the soil. *Plasmodiophora brassicae* does not thrive above pH of 7.2,<sup>71</sup> while most Brassicas thrive up to a pH of 8. Therefore, soil between 7.2 and 8 can support healthy Brassicas, but not *Plasmodiophora brassicae*. This can be achieved with careful application of basic (high pH) soil amendments. Because this strategy involves a limited pH window, it can be challenging to amend the soil to the ideal pH. Affordable and widely available litmus tests can be very helpful for gardeners trying to amend their soil to this precise pH range.

Another challenge in raising soil pH is doing so without creating other imbalances in soil composition. Agricultural lime (pulverized limestone) and dolomite lime (calcium magnesium carbonate) are commonly used to raise pH and supplement soil levels of calcium and magnesium. Unfortunately, addition of lime may increase magnesium levels beyond what is safe for plants. Therefore, gardeners struggling with club root should test magnesium levels before using lime to make sure that it's safe. If existing magnesium levels are adequate or high, dried ground eggshells, hardwood ash, ground oyster shells, or calcite are alternative materials for raising soil pH without

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70 Friberg, Hanna, Jan Lagerlöf, and Birgitta Rämert. (2005). "Germination of *Plasmodiophora Brassicae* Resting Spores Stimulated by a Non-host Plant." *European Journal of Plant Pathology* 113 (3): 275–281.

Murakami, H., S. Tsushima, T. Akimoto, K. Murakami, I. Goto, and Y. Shishido. (2000) "Effects of Growing Leafy Daikon (*Raphanus Sativus*) on Populations of *Plasmodiophora Brassicae* (clubroot)." *Plant Pathology* 49 (5): 584–589.

71 Dobson, R.L., R.L. Gabrielson, A.S. Baker, and L. Bennett. 1983. "Effects of Lime Particle Size and Distribution and Fertilizer Formulation on Clubroot Disease Caused by *Plasmodiophora Brassicae*." *Plant Disease* 67 (1): 50–52.

altering magnesium levels.

## Conclusion

Because club root is a barrier to productivity in Seattle's community gardens, design strategies that prevent club root infection support higher levels of productivity. Designs that facilitate sanitation of shared tools would be effective in preventing infection in new areas. Site design that enables crop rotation and fallowing would be instrumental in preventing new infections and managing infections of club root as well as other pathogens. It will be important for designers to work with administrators in the P-Patch Program to balance the need for crop rotation and fallowing with the pressure for space in the P-Patch Program. It is possible that designing community gardens in a way that enables crop rotation may be more easily achieved in community gardens outside the P-Patch program, if those communities have less pressure for gardening space.

## Discussion

Although productivity is the focus of the preceding case studies, it is one among many benefits of urban community gardens. While some community gardens like Thistle P-Patch are designed primarily to maximize productivity,<sup>72</sup> many of Seattle's community gardens are designed to support other goals such as creating opportunities for urban dwellers to connect with natural processes, building community, and education.<sup>73</sup> Even in projects that are not primarily focused on productivity, landscape architects can identify strategies that support higher yields along with other project goals. This section discusses how the previously identified opportunities for increasing productivity could have additional layers of benefit for community gardens.

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72 Hou, Jeffrey, Julie Johnson, and Laura J. Lawson. 2009. *Greening cities, growing communities: learning from Seattle's urban community gardens*. Washington, D.C.: Landscape Architecture Foundation in association with University of Washington Press, Seattle. 85.

73 Ibid. 25-27.

Because looking into soil contamination can potentially support human health as well as higher yields, it is a strategy that would likely be encouraged by communities that are not primarily concerned with productivity. Designers might also see this stage of the design process as a rich opportunity to engage volunteers in researching site history. This process could be a valuable educational experience for members of the community, potentially deepening their sense of place. Younger volunteers might conduct interviews with elderly members of the community about their memories of the site, generating useful information in a way that creates a meaningful role for an oft-neglected group.

Similarly, design strategies that support higher pollinator populations provide benefits beyond higher yields. Apiaries of honeybees provide honey and beeswax, which could be enjoyed by the community or sold in order to generate income. The process of collecting honey could also be a catalyst for a community festival. Other strategies for supporting bees could provide opportunities for engaging with local schools and educating children about pollination.

While community members may not seek help from landscape architects to help avoid infestations in the planning of new community gardens, preventing infestations of things like club root is important in achieving other goals like education and community building. Infestations can ultimately reduce yields to the point of making gardeners frustrated and disenchanted with the project. In addition to the fact that preventing infestations supports other goals, communities may be interested in taking advantage of methods like crop rotation as educational tools to teach about traditional agricultural practices. The alternatives to traditional allotment gardening that I suggest in the section on club root may be exciting to some communities for exactly the same reasons they would be impossible for other communities. Designating one person (or family) to grow all the tomatoes for the community, and likewise for other crops, might be a burdensome amount of coordination, but it might also create a welcome sense of mutual support and collaboration. Even

for such mundane-seeming strategies as application of lime for management of club root might involve educational workshops that are also opportunities for bringing the community together; it could also be an opportunity for a local school to do a lesson on soil acidity.

In addition to these specific design opportunities, my research revealed opportunities for expanding the practice of grounding landscape architectural design for urban agriculture in scientific research. The Landscape Architecture Foundation (LAF) Landscape Performance Series database provides case studies of designs intended to provide a variety of sustainability benefits.<sup>74</sup> These case studies describe design features, provide information on design process, and supply detailed performance metrics. As a central hub for information about landscape designs that contribute to sustainability goals, this database is an opportunity for designers of urban agricultural spaces to share design strategies and compare productivity outcomes. The four food-related projects found in the Landscape Performance Series database at the time of writing quantify food production in various ways, often using formulas for average production that do not capture the impact that the design has on agricultural processes in that space.<sup>75</sup> Developing a consistent method for measuring production that is able to capture those impacts might better enable designers to compare the efficacy of different design strategies, though it would also be necessary to account for climatic differences.

A different set of opportunities are apparent in Landscape Architecture Magazine, which “is the magazine of record for the landscape architecture profession in North America, reaching more than 60,000 readers who plan and design projects valued at over \$140 billion each year.”<sup>76</sup> Since this publication spans all of landscape architectural practice in North America, it is not a suitable venue for sharing the depth of information that is possible in the Landscape Performance

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74 Landscape Architecture Foundation. “Landscape Performance Series.” <http://www.lafoundation.org/research/landscape-performance-series>. Accessed 27 May 2013.

75 Ibid.

76 <http://landscapearchitecturemagazine.org/about-us>. Accessed 9 June 2013.

Series database. Instead, Landscape Architecture Magazine is an opportune venue for spreading the story of urban agricultural designs that are informed by scientific research on agricultural processes, and thus inspiring designers to seek out that information.

## Reflections

The findings of this thesis are framed by the scope I established. In this section, I reflect on opportunities for future research on this subject, applied with a different scope. By expanding the geographic scope of my research beyond Seattle to include nearby rural areas, this project could have included a range of agricultural modes, including intentional communities, permaculture homesteads, mainstream farms, organic farms, biodynamic farms, and more. Comparing the work of landscape architects on urban community agriculture to the work of other professionals in agriculture would have revealed a different set of opportunities for landscape architects. In addition, working with a geographic scope that included a range of agricultural modes and practices would have enabled a comparison of the greenhouse gas efficiencies associated with each type.

In the course of my research, I was surprised to find that there is no comprehensive data on the greenhouse gas emissions associated with the United States' food system, much less Seattle's food system. This is a significant area for future research on food systems. Without such data, it is unclear what parts of our food system are most detrimental or what strategies for changing our food system would be most effective at reducing emissions. I continued with my project based on the logic that urban agriculture should reduce greenhouse gas emissions by reducing large scale transport of food in vehicles that run on fossil fuels as well as the use of nitrogen fertilizers, but data would be necessary to pursue systemic changes that are effective at reducing food-related emissions.

In demonstrating the potential for designers to enhance yields in community gardens, this project suggests some flexibility in the landscape architect's role. Many of the strategies identified in the case studies could be implemented by a designer who is engaged with the design of a community garden through a traditional design contract. In order for designers of urban community gardens to ground their design in scientific research to the extent suggested in this paper, however, designers would either need to develop a special knowledge base for this type of design or consult with experts on agricultural process. Other strategies suggested in this project are implemented over time, and would therefore be more appropriately implemented by a site coordinator. While site coordination involves skills that differ from those of a landscape architect, the understanding of site design and landscape systems developed through studying landscape architecture may be beneficial to a site coordinator.

As a burgeoning design professional, developing this thesis has been a valuable process for cultivating my approach to design. I am primarily interested in landscape architecture as a way of curating relationships between humans and natural systems, and thus working toward a more sustainable way of life in my community. Urban agriculture is one arena for this kind of work, in which design can enable lower greenhouse gas emissions and support other sustainability goals. In order for design work to realize the intended sustainability benefits, it is important to ground this work in scientific research.

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# Introduction

## *Overview*

This thesis focuses on opportunities for landscape architects to help reduce food-related emissions through designs that increase urban agricultural production. Such a design approach necessitates a science-based understanding of the processes that underlie food production. This approach is demonstrated in three case studies of particular relevance to urban agriculture in Seattle, Washington.

## *Background*

There is broad consensus in the international scientific community that human activities are contributing to unprecedented changes in the earth's climate.<sup>1</sup> Among other impacts, these changes threaten human health and safety in the form of extreme weather events, loss of arable land, loss of fresh water resources, and sea level rise. In order to sustain a population that is expected to reach 8.1-10.6 billion by 2050,<sup>2</sup> global socio-economic systems must shift to ways of functioning that are less detrimental to long term survival. The task of changing how our global social, economic, and political structures work will require numerous strategies, working across scales and disciplines.

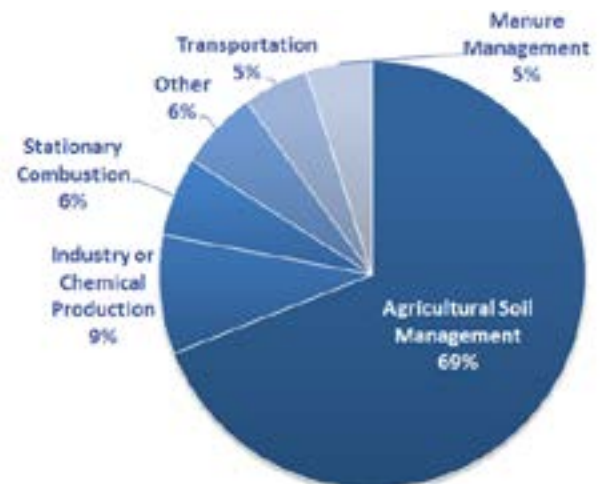
In the United States, local food production is a strategy for reducing greenhouse gas emissions that has recieved significant popular attention in the last few years, evidenced by increasing numbers of farmers markets across the country<sup>3</sup> and an urban agriculture topic page

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- 1 Metz, B., OR Davidson, PR Bosch, R Dave, and LA Meyer. (2007). *Contribution of Working Group III to the Fourth Assessment Report of the IPCC*. New York.
  - 2 The United Nations Population Division. (2011). "World Population to Reach 10 Billion by 2100 If Fertility in All Countries Converges to Replacement Level."
  - 3 USDA Marketing Services Division. (2012). "Farmers Market Growth: 1994-2012." <http://www.ams.usda.gov>. Accessed 20 April 2013.

on NYTimes.com. Since the majority of the average American diet is transported long distances to get from the point of production to the consumer<sup>4</sup> and current transportation methods emit greenhouse gasses,<sup>5</sup> producing food closer to consumers would reduce greenhouse gas emissions and thus mitigate for potential climate change.

In addition to reducing emissions associated with transport of food, urban agriculture is often associated with a reduction in the use of synthetic fertilizers. Urban settings provide opportunities for gardeners to take advantage of on-site or nearby waste streams as nutrient inputs. Furthermore, it is common for community gardening organizations like Seattle's P-Patch Program to forbid the use of chemical fertilizers.<sup>6</sup>

Synthetic nitrogen fertilizers make a significant contribution to national emissions of nitrous oxide ( $\text{N}_2\text{O}$ ) by creating imbalances in the naturally occurring nitrogen cycle.<sup>7,8</sup> In the absence of human activities, processes that changed elemental nitrogen ( $\text{N}_2$ ) into reactive forms (inorganic reduced forms, oxidized forms like  $\text{N}_2\text{O}$ , and organic compounds) and processes that change reactive forms of nitrogen into



$\text{NO}_2$  Emissions in the US by Source  
Source: EPA Climate Change Division

elemental nitrogen occurred at roughly the same rate. Human activities now transform elemental

- 4 Canning, Patrick, Ainsley Charles, Sonya Huang, Karen R Polenske, and Arnold Waters. (2010). "Energy Use in the U . S . Food System." Economic Research Report, 94.
- 5 Metz, B., OR Davidson, PR Bosch, R Dave, and LA Meyer. (2007). *Contribution of Working Group III to the Fourth Assessment Report of the IPCC*. New York.
- 6 P-Patch Community Gardening Program. "P-Patch Community Gardening Program Rules For Participants." [http://www.seattle.gov/neighborhoods/ppatch/documents/2013RULESStandard\\_121113\\_000.pdf](http://www.seattle.gov/neighborhoods/ppatch/documents/2013RULESStandard_121113_000.pdf). Accessed 22 April 2013.
- 7 US EPA, Climate Change Division. (2013). "Nitrous Oxide Emissions." <http://epa.gov/climatechange/ghgemissions/gases/n2o.html>.
- 8 Galloway, James N., et al. (2003). "The Nitrogen Cascade." *Bioscience* 53 (4): 341.



nitrogen into reactive forms more rapidly than atmospheric and ecosystem processes do the inverse, resulting in higher concentrations of reactive nitrogen.  $N_2O$  is the most concerning form of reactive nitrogen because it has a 100 year residence in the troposphere.<sup>9</sup>

Agricultural practices that transform elemental nitrogen into reactive forms include practices that promote nitrogen-fixing bacteria, fossil fuel combustion, and the Haber-Bosch process,<sup>10</sup> with the latter being the most significant factor.<sup>11</sup> Since 85% of the reactive nitrogen produced globally by the Haber-Bosch process is used for fertilizer, food production systems that recycle nitrogen from waste streams rather than depending on synthetic fertilizers derived through the Haber-Bosch process would significantly reduce  $N_2O$  emissions.

In the interest of reducing food-related greenhouse gas emissions, this thesis discusses opportunities for landscape architects to support urban food production. The following sections, “Critical Stance” and “Scope,” further articulate the purpose and parameters of this project. “Methods” reviews my interview and research process, and “Connections Between Agricultural Research and Community Agriculture” provides an overview of how information about agricultural processes reaches the people involved in urban agriculture. The subsequent three chapters provide a detailed exploration of processes that impact agricultural production, describing how landscape designs that are informed by an understanding of these processes would support higher urban agricultural yields. I conclude with reflections on the implications of these opportunities and the questions that remain unanswered.

## Critical Stance

One might expect landscape architects to play a key role in work on urban agriculture.

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9 Ibid.

10 The Haber-Bosch process is an industrial method for reacting nitrogen gas with hydrogen gas to produce ammonia ( $N_2 + 3H_2 \rightarrow 2NH_3$ ), thereby transforming elemental nitrogen into a reactive, bio-available form.

11 Ibid.

Definitions of landscape architecture generally involve negotiating or curating the relationship between humans and natural systems.<sup>12</sup> Agriculture is an ancient and fundamental component of that relationship, making it a realm that is theoretically significant to the work of landscape architecture. In their expertise working with plants, community process, temporal processes, ecological systems, site analysis, and site planning, landscape architects thus have a skill set that lends itself to work in urban agriculture.

In landscape architectural design for urban agriculture, there are several standard design elements that respond to the processes that will take place on the site.<sup>13</sup> Several of these elements, like gathering spaces, kiosks, and ornamental buffers between gardens and the surrounding neighborhood, anticipate the social processes that are integral to success in urban agriculture. Other standard elements like compost and irrigation systems anticipate the agricultural process that will take place on site and are therefore extremely relevant to this project. This thesis proposes going a step beyond incorporation of these standard elements by exploring other agricultural processes that can be enhanced through design, and by basing this design work in scientific research.

In order to discuss the subject in depth, this project focuses on one of the many ways urban community gardens are beneficial. As noted in *Greening Cities, Growing Communities: Learning from Seattle's Urban Community Gardens*, these urban spaces can provide a wide variety of environmental, social, economic, and health benefits.<sup>14</sup> Some benefits include horticultural therapy, contact with nature, education, and community building. *Greening Cities, Growing Communities* also points out that these benefits vary in importance depending on the community involved: the design of

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12 Foster, Kelleann. (2010). *Becoming a Landscape Architect : a Guide to Careers in Design*. Hoboken, N.J.: Wiley.

13 Hou, Jeffrey, Julie Johnson, and Laura J. Lawson. 2009. *Greening cities, growing communities: learning from Seattle's urban community gardens*. Washington, D.C.: Landscape Architecture Foundation in association with University of Washington Press, Seattle. 36.

14 Ibid, 3.

Bradner Gardens allocates more space to community gathering than the design of Thistle P-Patch does, which reflects differences in the two communities' goals. While food production varies in its relative importance, it is a goal that community gardens share.

By exploring how design interventions can support cultivation, this thesis transcends any division between the physical designed landscape and the processes that it enables. According to the *Oxford English Dictionary*, a process is “A continuous and regular action or succession of actions occurring or performed in a definite manner, and having a particular result or outcome; a sustained operation or series of operations.”<sup>15</sup> Since these actions or operations are shaped by their physical surroundings, the design of a site's physical characteristics has a direct and significant impact on the processes that take place there.

The idea that good site design intentionally engages site processes for a desired outcome is a cornerstone of the University of Washington's Landscape Architecture program and is demonstrated in Nancy Rottle and Ken Yocom's 2010 book, *Ecological Design*. This book provides a detailed conceptual framework for design that engages with ecological processes and case studies that demonstrate the prevalence of ecological design in landscape architectural practice. One characteristic of ecological design is that interventions enable a variety of ecological processes.

Design for urban agriculture enables a variety of processes, including those that are involved in food production. The critical stance of this thesis is that there are opportunities for designers to play a more significant role in supporting urban agriculture by delving into agronomic research and engaging with agricultural processes.

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15 <http://www.oed.com/view/Entry/151794?rkey=vU92YK&result=1&isAdvanced=false#eid>. Accessed 11 June 2013.

## Scope

I limited the geographic scope of my research to Seattle did for several reasons. First, I live here. I began my research already having a basic familiarity with the climate and culture. Living here also enabled interviews that might not have been possible if I were researching different cities.

Second, Seattle is an ideal city to study in this particular project because it is home to an active urban agricultural scene, as surveyed by Magdalena Celinska in 2011 for *Productive Neighborhoods: A Case Study Based Exploration of Seattle Urban Agriculture Projects*.<sup>16</sup> There are a variety of institutions supporting urban agriculture in Seattle, including municipal efforts, non-profit organizations, and for-profit businesses. There is also a strong legacy and culture of community action in Seattle, supported institutionally by the City of Seattle, The P-Patch Program, The Department of Neighborhoods, Sustainable Seattle, Interim Community Development Association, and many other non-profits. As a result, there is significant institutional support for urban agriculture projects undertaken by communities (henceforth referred to as community agriculture) compared to food production in yards and on for-profit farms. The institutional and cultural support for community agriculture make it a rich area of focus for this project.

Finally, community gardens are more significantly shaped by landscape architects than privately owned urban agriculture. Therefore, focusing on community agriculture enables me to identify ways designers in my field can work in the existing professional structure to create more productive spaces.

## Methods

Initially, the methods for this project were structured to explore how designers of Seattle's urban agriculture spaces used scientific information to inform their work. I expected that the

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16 Celinska, Magdalena. (2011). "Productive Neighborhoods: A Case Study Based Exploration of Seattle Urban Agriculture Projects." Seattle.

designs would focus on food production among other project goals, and I was curious about what kind of research design professionals did to inform the design of spaces that would produce food.

I set out to interview urban agriculture professionals including, but not exclusively, trained designers. I was interested in comparing the work of landscape architects to that of urban agricultural professionals who are not trained in design. I anticipated that differences in approach and practice would reveal something about landscape architectural training.

However, I was not able to compare the work of these two groups due to lack of data. My sample size was limited due to time constraints and by my choice to conduct interviews rather than surveys. I was only able to interview four designers trained in landscape architecture, one permaculture designer, one community garden coordinator, and no professional urban farmers. This unequal representation began in the group of people I initially contacted: seven with degrees in landscape architecture, one permaculture designer, one community garden coordinator, and two professional urban farmers. One factor that influenced this bias was my own situation in the world of landscape architecture studies, which exposes me to the work of local professionals in my field. Although I am involved in local urban agriculture organizations, I am not in any urban agriculture professional networks; ultimately, my exposure to these professionals did not match my exposure to professionals in my own field. Another factor that contributed to the imbalance was my decision to limit the pool of possible interviewees to professionals based in Seattle. If my primary goal had been to compare how landscape architects and small scale farmers differed in their use of scientific research, I could have expanded my scope to include all the small farms in King County.<sup>17</sup>

However, as I explain further in “Initial Findings,” I quickly realized in the course of conducting interviews with designers that their work for urban agricultural spaces was not based in

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17 Washington Tilth Producer’s directory supports the idea that there are more small farms outside the city in that it lists 8 in the county and 0 in Seattle. <http://tilthproducers.org/washington-organic/directory/> accessed 12 April 2013.

any scientific research. I therefore decided that my thesis would be more useful as a presentation of the idea that urban agricultural yields can be increased through design that is informed by research on agricultural processes. This possibility is explained through three subject-based case studies: lead-contaminated soil, pollinators, and club root (*Plasmodiophora brassicae*). These three case studies were selected based on their relevance to community agriculture in Seattle, the availability of scientific information, and the opportunities they reveal for increasing yields through design. I also selected these topics to represent the breadth of opportunities for supporting agricultural processes with design.

Julie Bryan, a P-Patch staff member and one of my interviewees, brought my attention to soil contamination and several pathogens as issues that are relevant to Seattle's community gardens. I chose club root, which Julie Bryan assessed to be the most prevalent pathogen, to demonstrate that design based in research can help reduce infections. I also chose to research soil contamination because it is extremely prevalent in urban settings. Lead in particular is a contaminant that historically originated from non-industrial sources, lead paint and leaded gas, which gives lead contamination a broad significance to a wide variety of urban sites.

While those two case studies demonstrate the potential for design to reduce or eliminate barriers to productivity, I developed the third case study to demonstrate the potential for design to support higher productivity, even in the absence of barriers. To demonstrate this idea, I chose to look at pollinators. Pollinators emerged as a good subject to study that was relevant to urban agriculture in Seattle through two projects that are ongoing at the time of this writing: The Pollinator Pathway,<sup>18</sup> a project in Seattle's Capitol Hill neighborhood that creates a corridor of pollinator-friendly plantings on parking strips; and the Urban Pollinator Project,<sup>19</sup> a citizen science initiative coordinated by researchers at The University of Washington that is evaluating the impact

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18 <http://www.pollinatorpathway.com/>

19 <http://nwpollination.org/>

of pollination by bumble bees on tomato production.

### *Initial Findings*

My interviews with designers trained in landscape architecture showed similarities in the type of work they did that challenged the initial premise of my research. First, I realized through the course of my interviews that the majority of landscape architectural design work in support of urban agriculture was in community gardens. I also found that the programmatic elements interviewees focused on were circulation, access to water, proper site drainage, and gathering areas. None of the designers interviewed worked addressed plant choices or pest control in their work. In other words, the designers I interviewed were not concerned with shaping the site to directly enable food production, but with shaping the site to enable the work of community members. In this approach, things like pest management belong in the hands of the community. Since I was interested in the potential for scientific research to inform design solutions for things like pest management, this warranted re-thinking of my focus.

Design for communities involves a risk that the designer's work may disempower the community. My understanding is that more in-depth design strategies to support food production are considered overstepping the appropriate role of the designer, taking away the community's self-determination. An example would be a landscape architect who is contracted for the design of a public orchard, and creates a design with apple trees. If there is a significant immigrant population in the local community that doesn't use apples in their cuisine, this orchard design might be useless to that community. Further, the act of self-determination in itself is valuable- even if the landscape architect used culturally appropriate trees, the community wouldn't feel as much ownership over the space as they would if they select and plant the trees themselves.

While these considerations are absolutely vital, the current boundaries between the work

of the landscape architect and the work of the community make it impossible to use some design strategies that would further the goal of urban food production. There is potential in combining a scientific understanding of agricultural processes with a designer's perspective to create highly productive urban agricultural systems that are sustainable economically, ecologically, and socially. However, it is clear that this kind of work is not enabled by the current structure of how landscape architects work with community gardens, and redefining that relationship would be beyond the scope of this thesis.

### Connecting Agricultural Research and Community Agriculture

Before delving into my case studies, I discuss existing connections between agricultural research and community agriculture in Seattle. This context is significant to my project because these resources can be useful for a landscape architect engaging with agricultural research for the design of community agriculture, and because landscape architects can become another point of contact between scientific research and the community.

As stated, Seattle residents are fortunate to have extensive organizational infrastructure supporting community agriculture. For example, the active and visible non-profit Seattle Tilth lists 50 other local urban agriculture organizations on the "Our Community" section of their website.<sup>20</sup> This list includes a number of blogs, Facebook pages, Google groups, and listserves that help connect Seattle's urban agriculture community. These social network platforms are well-suited for peer-to-peer sharing of information. Gardeners are constantly doing informal experiments inspired by questions like: "Is it better to put my squash on the side of the house that gets direct sun in the morning, or on the side that gets sun in the afternoon?" Existing social network platforms are useful in enabling exchange of information gleaned from these informal experiments, but they are limited in two major ways. The first limitation is that it can be extremely difficult to locate

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<sup>20</sup> <http://seattletilth.org/our-community>, accessed 24 March 2013.



information. This difficulty is in part because the information is very decentralized, and it is often organized chronologically rather than by subject matter. Another limitation is that people don't necessarily describe all the variables that were important in determining the outcome they had.

Classes and workshops led by community members, non-profits, and small businesses are another forum for people in Seattle's urban agriculture community to share knowledge. Especially when it involves hands-on learning, this can be one of the most enjoyable and effective methods of sharing information. These classes can be a useful point of connection between the community and scientific research, particularly if teachers have scientific backgrounds and stay up to date on relevant research.

There are also local programs that use classes and workshops to transform community members into educators, including the Master Gardener and Master Composter programs. These community teachers have the potential to be liaisons between the urban agriculture community and the scientific community.

Master Gardeners are especially well positioned to connect the community to the world of scientific research because they are affiliated with Washington State University, an agricultural research institution, via Washington's Cooperative Extension Service. For the 2014 training session, people interested in becoming Master Gardeners will pay \$275 for 84 hours of training, including homework and open book assessments.<sup>21</sup> The training is taught by specialists on a variety of topics, including one session on the scientific method.<sup>22</sup> After their initial training, Master Gardeners have a continuing education requirement, which keeps them informed of ongoing research.<sup>23</sup> In the two years after completing training, Master Gardeners each spend 90 hours

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21 <http://county.wsu.edu/king/gardening/mg/Pages/Apply.aspx> Accessed 28 March 2013.

22 <http://www.mgfk.org/wp-content/uploads/2013/01/2013-MGTraining-Open-to-Visitors.pdf> Accessed 28 March 2013.

23 <http://county.wsu.edu/king/gardening/mg/Pages/Apply.aspx> Accessed 28 March 2013.

educating the community. They reach out to the community through Garden clinics, located throughout Seattle in farmers markets and stores; an online e-clinic; presentations to groups; a children's garden; and demonstration gardens, one of which is connected to the Picardo P-Patch.<sup>24</sup>



*Picardo P-Patch and Master Garden Demonstration Garden*  
 Source: Google Earth. Accessed 28 April 2013.

Due to its size and proximity to a large and well-established P-Patch, the 5,000 square foot demonstration garden adjacent to the Picardo P-Patch is an exceptional opportunity for Master Gardeners to connect community gardeners to scientific research.

<sup>24</sup> <http://county.wsu.edu/king/gardening/Pages/default.aspx> Accessed 28 March 28, 2013.



*Demonstration Garden Kiosk*  
 Source: photo by Katherine Jacobs, March 2013

The site's kiosk could provide gardeners with any number of the well-researched and informative brochures developed by Washington State University extension on subjects related to growing food plants, but in early 2013 it proffered a single leaflet on "Fantastic Foliage." Given that their mission is not limited to edible plants, it is appropriate for the Master Gardeners to use this space to educate people about ornamental plants as well as edible ones. However, the proximity of this demonstration garden to the Picardo P-Patch warrants some emphasis on cultivation of edible plants. In the kiosk in particular, it is clear that it would be possible to provide more information about cultivating edible plants without removing information about ornamentals.

There are many informative and useful brochures developed by Washington State University as well as other extension offices that summarize scientific research in a concise format and in language that is accessible to a wide audience. The P-Patch website also has links to a

number of similar resources. These are available for free to anyone with internet access.

It would also be possible to layer additional information in the planting design. Currently, there are thematic beds showcasing techniques such as esplanade, perennial borders, and the bed shown above/below: bulbs for summer and autumn bloom. Without compromising the existing messages, Master Gardeners could amend plant selections and/or signage to instruct visitors about additional topics such as nitrogen fixation, companion planting, or plant choices for pollinators. This bed that showcases summer and autumn blooming bulbs could include edible plant choices like chives, onions, and Jerusalem artichoke.



*Summer and Autumn Blooming Bulbs (Existing)*  
Source: Katherine Jacobs, Photo taken March 2013



*Summer and Autumn Blooming Bulbs, Proposed*  
Source: Katherine Jacobs

Community garden site coordinators and Master Gardeners can be instrumental in helping gardeners identify the name of a problem plant or pest, without which it may be difficult to research. These leaders are also important in finding resources for gardeners who don't speak English and/or don't have internet access.

In summary, there are many existing pathways for scientific research to reach Seattle's urban agriculture community. Many of the existing resources and institutions are quite useful as they are, and there are a variety of ways they can be altered to become even more so. Designers can play a role in connecting community members to scientific research through the community design process or through educational design elements. In addition, designers can make use of this existing body of agricultural research to inform designs that support abundant yields. The following three case studies explore particular issues that highlight the utility of scientific

information in increasing community agricultural yeilds.

## Case Study 1: Lead-Contaminated Soil

According to ecologist Richard Pouyat and colleagues (2010), “elevated heavy metal concentrations are almost universally reported [in urban soils], although often with high variances.”<sup>25</sup> While there is an emerging discourse about the human health impacts of such contamination,<sup>26</sup> there has been relatively little discussion for how soil contamination impacts the productivity of urban agriculture. In this section, I discuss lead contamination as an illustrative example, demonstrating that contamination of urban soils can negatively impact crop yields. Designers for urban agriculture can therefore support higher yields by exploring the possibility of soil contamination during site analysis and initiating appropriate steps toward remediation.

### Background

Researching a site’s history through municipal records, historical maps, or interviews with elderly residents can reveal possible sources of contamination. This research may reveal that contamination is quite unlikely, indicating that soil testing is unnecessary. In other cases, research into site history may reveal which contaminants are likely to be present on the site. Because testing for all possible contaminants is inhibitive expensive, site history research enables soil testing that is targeted to contaminants that are most likely present. For community groups with limited funds, site history research may provide enough evidence of contamination to move ahead with remedial strategies without soil testing.

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25 Pouyat, R., Szlavacz, K., Yesilonis, I., Groffman, P., Schwarz, K. (2010). “Chemical, Physical, and Biological Characteristics of Urban Soils.” In J. Aitkenhead-Peterson & A. Volder (Eds.), *Urban Ecosystem Ecology* (pp. 119–152). Madison, WI: American Society of Agronomy, Crop Science Society of America, Soil Science Society of America. P 124.

26 A collection of research on lead and its health impacts can be found at <http://www2.epa.gov/lead/technical-studies>.



The two main sources of lead contamination are lead paint and leaded gasoline. Use of lead paint was standard in the United States before 1940, after which residential use declined, and was banned in 1978.<sup>27</sup> Soil near painted structures that were built before 1978 may therefore be contaminated with lead. Leaded gasoline was another important historical contributor to lead in urban soils. Engines that ran on leaded gas emitted leaded exhaust, which would settle on nearby surfaces and accumulate over time.<sup>28</sup> Because Seattle's comprehensive street grid was fully developed by the time lead was outlawed in 1995, there is likely some lead contamination everywhere in the city, with higher concentrations near older and more heavily-used roadways.<sup>29</sup>

Some sources indicate that "the quantities of lead found in most lead-contaminated soils typically are not high enough to reduce plant growth and yield."<sup>30</sup> However, research on the impact of lead on plants seems to disprove that claim. One laboratory experiment compared the growth of Scarlet White Tip radishes (*Raphanus sativus* L.) grown in soil with 100ppm-2000ppm lead ( $\text{Pb}(\text{NO}_3)_2$ ) with radishes grown in uncontaminated soil. This experiment found higher dry weight in the radishes grown in uncontaminated soil.<sup>31</sup> Another study found that all of the five plant species they used were stunted at 500ppm of lead compared to 0.<sup>32</sup>

To frame these experiments in reference to lead concentrations that might be found in an urban environment, soil samples taken from the Leo Street P-Patch were found to contain 700 - 2400 ppm of lead.<sup>33</sup> Based on the experiments referenced above, that range of concentration may have a negative impact on plant growth.

### *Soil Testing*

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- 27 Peryea, F. J. (1999). "Gardening on Lead and Arsenic Contaminated Soils." Washington State University Cooperative Extension. Retrieved February 19, 2013, from [http://www.ecy.wa.gov/programs/tcp/area\\_wide/AW/AppK\\_gardening\\_guide.pdf](http://www.ecy.wa.gov/programs/tcp/area_wide/AW/AppK_gardening_guide.pdf)
  - 28 Ibid.
  - 29 Ibid.
  - 30 Ibid.
  - 31 Zaman, M. S., & Zereen, F. (1998). "Growth responses of radish plants to soil cadmium and lead contamination." *Bulletin of environmental contamination and toxicology*, 61(1), 44-50.
  - 32 Begonia, G. B. (1997). "Comparative Lead Uptake and Responses of Some Plants Grown on Lead Contaminated Soils." *Journal of the Mississippi Academy of Sciences*, 42(2).
  - 33 Phillip Defoe. Personal Communication. 17 May 2013.

Soil testing for heavy metal contamination is the most direct and definitive way to determine soil contents. Unfortunately, it is far from standard practice. According to the EPA,

“Many community gardening ... organizations test for agronomic parameters – nitrogen, phosphorus, and potassium (N-P-K) as well as pH and organic content. [However,] A recent compendium of urban agriculture practice and planning by the American Planning Association ... noted few local requirements for soil testing [for contaminants] and very few examples of locally driven testing on behalf of community organizations.”<sup>34</sup>

Consistent with the EPA’s findings, The King Conservation District, an agency funded by Washington State, currently has a free soil testing program for King County residents that only tests for agronomic parameters.<sup>35</sup> Expanding its services to test for heavy metals would support food production in the county and would further their mission of resource conservation. The King Conservation District could get support for such an expansion from other existing institutions in the region that would be interested in having the lab as a resource, for example: The King County Board of Public Health, Seattle’s Office of Sustainability and Environment, Seattle’s Food Interdepartmental Team, and various entities within the University of Washington like the Food Studies Program. Examining precedents for municipal support of heavy metal testing, such as the City of Minneapolis, which offers free soil tests for lead,<sup>36</sup> could provide insights into how such a program might work.

Another institution that would be a useful part of this effort is the National Resources Conservation Service (NRCS), originally The National Soil Conservation Service. The NCRS is

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34 EPA. (2011). “Brownfields and Urban Agriculture: Interim Guidelines for Safe Gardening Practices.” p2.

35 King Conservation District Soil Testing Service. (n.d.). Retrieved February 24, 2013, from [http://www.kingcd.org/pro\\_far\\_soi.htm](http://www.kingcd.org/pro_far_soi.htm)

36 Wieland, B., Leith, A., & Rosen, C. (n.d.). “Urban Gardens and soil Contaminants: A Gardener’s Guide to Healthy Soil.” University Of Minnesota Extension. Retrieved February 19, 2013, from [http://www.misa.umn.edu/prod/groups/cfans/@pub/@cfans/@misa/documents/asset/cfans\\_asset\\_287228.pdf](http://www.misa.umn.edu/prod/groups/cfans/@pub/@cfans/@misa/documents/asset/cfans_asset_287228.pdf)

a federal entity that does soil research and provides information on soil quality for agriculture. Although urban soils and heavy metal contamination are currently peripheral to their work, the NRCS has an existing structure for soil research in the National Cooperative Soil Survey (NCSS) that could be expanded to do more work evaluating urban soil contamination. The NRCS currently has soil conservation programs in a handful of cities,<sup>37</sup> and Seattle's University of Washington is already a collaborator in the NCSS.<sup>38</sup> According to a local NRCS soil scientist, "The last time [The King County soil map dataset] was updated the city was excluded due to the amount of urbanization. There is an interest [in producing] a soil survey for Seattle and NRCS recognizes the need for mapping in urbanized areas...it will still be years (3-4) before it would get started."<sup>39</sup>

According to my research, the cheapest way for Seattle residents to test for heavy metals in their soil is to send soil samples to The University of Massachusetts. UMass' routine analysis costs \$10 and includes agronomic parameters as well as arsenic and lead concentration.<sup>40</sup> There are other heavy metals like cadmium that are also likely to be present in some urban soils<sup>41</sup> and can negatively impact plant growth.<sup>42</sup> Further research is necessary to clarify when those substances are likely to be a problem and how to make testing more readily available.

## Interventions

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37 Urban Conservation Programs | NRCS Soils. (n.d.). Retrieved February 22, 2013, from <http://soils.usda.gov/use/urban/conservation.html>

38 List of Universities | NRCS Soils. (n.d.). Retrieved February 22, 2013, from <http://soils.usda.gov/partnerships/universities/#wa>

39 Personal communication, 22 February 2013.

40 UMass Soil and Plant Tissue Testing Laboratory. "Services." <http://soiltest.umass.edu/services>.

41 "Cadmium occurs naturally in ores together with zinc, lead and copper. Cadmium compounds are used as stabilizers in PVC products, colour pigment, several alloys and, now most commonly, in re-chargeable nickel-cadmium batteries. Metallic cadmium has mostly been used as an anticorrosion agent (cadmiation). Cadmium is also present as a pollutant in phosphate fertilizers." -from Jarup, L. (2003). Hazards of heavy metal contamination. *British Medical Bulletin*, 68(1), 167-182.

42 Zaman, M. S., & Zereen, F. (1998). "Growth responses of radish plants to soil cadmium and lead contamination." *Bulletin of environmental contamination and toxicology*, 61(1), 44-50.



After testing soil or researching site history, communities may be interested in finding strategies for using the site that limit the negative impacts of soil lead. This section discusses strategies that can be used by community garden groups. Excavating contaminated soil, disposing of it off site, and importing clean topsoil is not discussed because it is financially unrealistic for most community gardens. Similarly, phytoremediation of lead contamination is not discussed because the process takes years,<sup>43</sup> making it unsuitable for use in community gardens.

### *Raised Beds*

Growing food in raised beds filled with clean imported soil is a standard way of dealing with soil contamination.<sup>44</sup> There are a number of important considerations in the design and construction of raised beds to enable healthy and abundant plant growth.

When constructing raised beds, it is important to avoid materials for the sides that will leach new contaminants into the soil. Many of the chemical treatments used to make wood rot resistant, such as creosote or chromated copper arsenate, are not suitable for use in gardens due to negative health impacts. Alkaline copper quaternary is an alternative treatment that the EPA has approved for use in gardens.<sup>45</sup> It is also possible to use types of wood like redwoods that

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43 David J. Butcher, et al. "Phytoremediation of Arsenic and Lead in Contaminated Soil Using Chinese Brake Ferns (*Pteris vittata*) and Indian Mustard (*Brassica juncea*).*" International Journal Of Phytoremediation* 5, no. 2 (June 2003): 89-103.

44 For example:

Peryea, F. J. (1999). "Gardening on Lead and Arsenic Contaminated Soils." *Washington State University Cooperative Extension*.

Penn State Extension: Crop Management Extension Group. (n.d.). "Lead in Residential Soils: Sources, Testing, and Reducing Exposure." *Penn State Cooperative Extension*.

Wieland, B., Leith, A., & Rosen, C. (n.d.). "Urban Gardens and soil Contaminants: A Gardener's Guide to Healthy Soil." *University Of Minnesota Extension*.

45 Lerner, BR. 1986. "Container and Raised Bed Gardening." HO-Purdue University, Cooperative Extension Service: 1-3.

are naturally resistant to rot.<sup>46</sup> Other material choices include concrete, stone, wood/plastic composites, and recycled rubber. Concrete may not be suitable for use with soils that have higher pH, as it will leach lime over time.<sup>47</sup>

Installing a bottom to the raised bed as a boundary between native and imported soil prevents contamination from entering the raised bed. Without such a boundary, contamination may be brought up into the raised bed by the activity of worms or by overzealous digging by gardeners. In addition, plant roots may extend into native soil below bottomless raised beds. The boundary can consist of gravel, landscape cloth, or anything else that allows proper drainage.

Another consideration in designing and building raised beds with bottoms is the depth of imported soil, which must be adequate for healthy root development. While 6-8" of depth is sufficient for many annual vegetable crops, root crops like carrots require at least 1 foot of depth. Trees and perennials, which over time establish more extensive root systems than annual vegetables do, require more depth.

### *Rock Phosphate*

The Connecticut Agricultural Experiment Station explored the possibility of adding phosphorous to lead-contaminated soil to reduce the levels of available lead.<sup>48</sup> In this method, phosphorous binds to lead, making it less soluble. Soil contents that are less soluble are less likely to enter plant roots, limiting their impact on plant growth. Interestingly, the study team found significant differences in the success of this technique depending on the type of phosphate they added. Because there is concern that this strategy would create additional ecological problems

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46 US EPA, Office of Pesticide Programs. "Alternatives to Pressure-Treated Wood | Pesticides | EPA." [http://www.epa.gov/oppad001/reregistration/cca/pressure-treated-wood\\_alternatives.htm](http://www.epa.gov/oppad001/reregistration/cca/pressure-treated-wood_alternatives.htm).

47 Oregon State University Extension. (2003). "Raised Bed Gardening."

48 Stilwell, D. E., & Ranciato, J. F. (2008). "Use of Phosphates to Immobilize Lead in Community Garden Soils." The Connecticut Agricultural Experiment Station.

by increasing the amount of phosphate in runoff, the team also compared how much additional phosphate was leached from the different amendments. They found that rock phosphate was the optimal form for stabilizing lead while minimizing phosphate runoff. However, the researchers emphasize that this study was done in a greenhouse, and more research is needed to determine if phosphate amendment could be used in field conditions to stabilize lead. This topic is well suited for investigation with a citizen science initiative: the study could be designed by soil scientists at UW, data could be collected by p-patch gardeners, and data could be analyzed at The King Conservation District's lab.

## Conclusion

Given the negative impacts and prevalence of heavy metal contamination in urban soils, looking into contamination through site history research and/or soil testing should be a standard component of site analysis for designers working on urban agricultural projects. When contamination is identified, designers can play a key role in working with the community to identify effective remedial strategies that fit within the available budget.

Designers can also work with communities to frame projects as experiments that generate information. Details about existing conditions, the design process, remedial strategies and materials used, and results can all be compiled and shared with other groups. Results may include follow-up soil tests, observations on raised bed drainage, remarks about material durability, or data on crop yields. While it may not be possible for the designer to compile this information, the designer may help organize a group of volunteers to undertake the project. Designers may also facilitate partnerships with other groups who may be interested in the community's findings.

## Case Study 2: Pollinators

For crops such as tomatoes, pears, and almonds, which are cultivated for their fruits and nuts, pollinators are fundamental to productivity. The existing body of scientific research on pollination provides information about how pollination can help increase yields in urban community gardens and what kinds of site interventions would support local pollinator populations.

### Background

Pollination happens when pollen is brought from the male anther, where it is produced, to a female stigma, either of the same or of a different flower. Pollen can be transported by a variety of means, with bees being the most important pollinator for the plant types cultivated in Seattle's community gardens.<sup>49</sup>



*The Role of Pollination in Fruit Formation*  
Source: Katherine Jacobs, 2013

The diagram above illustrates the role of pollination in creating fruit. After flowers bloom, they must be pollinated in order for fertilization, fruit set, and ultimately fruit ripening to be possible. Without robust pollinators, even the healthiest crops make relatively little fruit.

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<sup>49</sup> Crops like wheat are wind-pollinated, but since they are not commonly cultivated in Seattle's community gardens, I focus on bees.

Many studies have compared the productivity of plants with all variables equal except exposure to pollinators, and consistently found that plants isolated from pollinators yield less fruit.<sup>50</sup>

Researchers also have found that there are differences in the efficiency of pollinators on different plant species. For example, researchers observed bees pollinating faba bean fields (*Vicia faba*) and found that almost all flowers visited by the bee *Eucera numida* were successfully pollinated, while a third of the European honeybee visits observed removed nectar in a way that did not pollinate the flowers.<sup>51</sup> Another experiment compared fruit set of greenhouse tomatoes pollinated by two different bee species and found interesting differences in their pollination efficiency depending on climatic conditions.<sup>52</sup> Much of this research on pollinator species specificity aims to identify the most efficient pollinators to pair with large commercial monocultures. However, for the diversity of plant species cultivated in community gardens, differences in pollinator efficiency makes it important to support diversity in pollinator species.

In addition, there is evidence that pollinator species diversity may increase overall yields, even in monocultures. Observations of bee activity suggest that having multiple bee species changes their behavior, making them more effective pollinators and increasing yields.<sup>53,54</sup> These findings

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50 For example:

Hikawa, M., & Miyanaga, R. (2009). "Effects of pollination by *Melipona quadrifasciata* (Hymenoptera: Apidae) on tomatoes in protected culture." *Applied Entomology and Zoology*, 44(2), 301–307

Holzschuh, A., Dudenhöffer, J.-H., & Tschardtke, T. (2012). "Landscapes with wild bee habitats enhance pollination, fruit set and yield of sweet cherry." *Biological Conservation*, 153, 101–107.

51 Benachour, K., Louadi, K., & Terzo, M. (2007). "Role of wild and honey bees (Hymenoptera : Apoidea) in the pollination of *Vicia faba* L. var. major (Fabaceae) in Constantine area (Algeria)." *Annales de la Societe Entomologique de France*, 43(2), 213–219.

52 Hikawa, M., & Miyanaga, R. (2009). "Effects of pollination by *Melipona quadrifasciata* (Hymenoptera: Apidae) on tomatoes in protected culture." *Applied Entomology and Zoology*, 44(2), 301–307.

53 Brittain, C., Williams, N., Kremen, C., Klein, A., & B, P. R. S. (2013). "Synergistic effects of non-*Apis* bees and honey bees for pollination services." *Proceedings of the Royal Society*, 280(20122767).

54 Klein, A.-M., et al. (2003). "Fruit set of highland coffee increases with the diversity of pollinating bees." *Proceedings of the Royal Society of Biological Sciences*. 270(1518): 955–61.

provide more support to the idea that supporting the health, quantity, and diversity of pollinators increases yields. The following sections discuss how community gardens can support a diverse population of pollinators with diverse habitat and food sources.

## Interventions

The preceding discussion showed that an abundant and diverse bee population in community gardens can increase yields. This section discusses physical site elements that would support such a population and thereby increase yields in Seattle's community gardens.

### *Supporting a Diverse Population of Pollinators: Habitat*

Because this discussion focuses on how community gardens can support a diverse bee population, it is not necessary to review the particular habits of the many species found in Seattle. Instead, I review the range of needs found in local bee populations. First, I discuss the three different nesting styles: hives, ground nests, and hole nests.<sup>55</sup>

While honeybees can live without human stewards, managed apiaries for honeybees are popular assets for community gardens. These bee hives produce honey in addition to pollination services. On siting new hives, The University of Missouri Extension advises,

"The apiary should face southeast or south with a windbreak behind it. The location should be well drained. The south face of a hillside is ideal, but bees will adapt to less-than-ideal locations. Deciduous trees that shade the colony in summer afternoons and allow the sun to penetrate in winter are desirable...A platform on the roof of a house or other building is a good place to keep hives."<sup>56</sup>

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55 Moisset, B. B., & Buchmann, S. (2011). "Bee Basics: An Introduction to Our Native Bees." USDA Forest Service and Pollinator Partnership Publications.

56 The University of Missouri Extension. (n.d.). "Beekeeping Tips for Beginners." Retrieved February 28, 2013, from <http://extension.missouri.edu/publications/DisplayPub.aspx?P=G7600>

This latter recommendation may be particularly useful in community gardens, where well-drained, south-facing ground is in demand for growing plants.

Ground nesting bees, including some bumble bees, need dry, bare, preferably sunny ground space that will remain undisturbed by foot/vehicle traffic, digging, or flooding year round. Their sites must be dry and protected throughout the rainy winter, while they are dormant, to support the following year's bee population. Some bees dig their own holes, while others use holes dug by mice or other subterranean creatures.<sup>57</sup> Thick layers of mulch make it difficult for ground-nesting bees to reach the ground.<sup>58</sup> Areas of nutrient-poor, compacted, sandy soil that would not readily support plant growth are actually ideal for ground nesting bees.

It could be possible for roofs covered with a layer of soil to provide habitat for ground nesting bees in a way that makes efficient use of space. Roofs would be ideal for bee nests in that they are elevated away from disturbance by humans. Slanted roofs could also provide good drainage. Because such designs would encourage rapid drainage, they would be much lighter than water-heavy green roofs. As a result, retrofitting roofs for bee habitat would be an option for existing structures that could not support green roofs. South facing roofs could also be beneficial in being warm and sunny, but more research needs to be done into the maximum temperature tolerable by ground nesting bees, since roofs get hotter than soil does.

Other bees, like mason bees, are hole nesters. These bees either create nests in existing holes in wood or may burrow their own holes. So-called carpenter bees avoid painted or finished wood, so they are fairly easy to dissuade from nesting in necessary structures.<sup>59</sup> Communities

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57 Moisset, B. B., & Buchmann, S. (2011). *Bee Basics: An Introduction to Our Native Bees*. Washington, DC: USDA Forest Service and Pollinator Partnership Publications.

58 Vaughan, M., & Hoffman Black, S. (2006). "Improving Forage for Native Bee Crop Pollinators." *USDA Agroforestry Notes*, 33, 1-4.

59 Moisset, B. B., & Buchmann, S. (2011). "Bee Basics: An Introduction to Our Native Bees." *USDA Forest Service and Pollinator Partnership Publications*.

wanting to attract hole nesters can construct attractive, sculptural bee nests with pre-drilled holes. According to Washington State University Extension,

... placement of the block is the most important consideration in successful mason bee culture. The bees require a warm, dry, wind-protected place for their nests. The best place is usually on the side of a house, shed, or other large structure, ideally facing east or south to catch the morning sun, and under an eave to deflect rain. The bees will avoid nesting in blocks placed out in the open.<sup>60</sup>

These nests can be managed, which increases likelihood of yearly population growth and allows continued reuse of the same nest, or unmanaged, in which case the nests will only last a few years.<sup>61</sup>

Since bees travel away from their nests for food, it may not always be beneficial to provide all of these habitat types in every garden. Instead, it may be helpful to evaluate what bee habitat types are lacking in the surrounding area and would also be feasible to provide with available space, resources, and with the cultural or aesthetic needs of the community.

#### *Supporting a Diverse Population of Pollinators: Food Sources*

The nectar and pollen provided from crops may not be enough to support a diverse bee population due to the timing of most blooms. Some bees, particularly bumble bees, emerge very early in the growing season, before most crops are in flower. Providing them with flowering plants in this period helps them establish healthy and abundant colonies. In the fall, after the flowering of most crops is complete, late-season bloomers provide food for queen bees to prepare for hibernation. In addition to these temporal considerations, the USDA Agroforestry Center points

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60 Washington State University King County Extension. (n.d.). "Orchard Mason Bees." Community Horticulture Fact Sheet, (83), 3-6.

61 Ibid.



out that “because native bees come in a range of sizes, it is important to provide flowers of various sizes, shapes, and colors.”<sup>62</sup>

## Conclusion

Scientific research on the impact of pollinators on agricultural yields indicates that supporting a diverse local pollinator population would support higher yields. This information may expand the programmatic foci of communities that had not previously considered the role of pollinators in agricultural production or communities that had previously focused on honeybees. Designers may play a key role in educating communities on the benefits of creating habitat and food sources for pollinators. In addition, scientific information on the habitat and food needs of pollinators enables designers to make interventions that are effective in supporting pollinator populations and, ultimately, higher yields.

## Case Study 3: Club Root

Club Root, or *Plasmodiophora brassicae*, is a pathogenic protist<sup>63</sup> that is currently plaguing many of Seattle’s community gardens.<sup>64</sup> The pathogen has a negative impact on brassica yields, so design strategies that eliminate it or reduce its severity would increase yields. Scientific research executed to support large-scale farming provides key insights into what club root is, how it spreads, and what design strategies would be effective in managing club root in Seattle’s community gardens.

## Background

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62 USDA National Agroforestry Center. (2006). “Agroforestry: Sustaining Native Bee Habitat For Crop Pollination.”

63 It is interesting to note that *Plasmodiophora brassicae* does respond to some fungicides, even though it is not a fungus (Potential biological control of clubroot on canola and crucifer vegetable crops, Peng et al).

64 The prevalence of club root in Seattle’s community gardens was brought to my attention by Julie Bryan, a P-Patch Site Coordinator.

Plants infected with *Plasmodiophora brassicae* have visibly enlarged, deformed roots. *Plasmodiophora brassicae* prevents plants in the *Brassica* (cabbage) family from taking up nutrients properly, stunting their growth and ultimately killing the plant.<sup>65</sup> Lacking effective methods for eradicating club root, some community gardeners are currently dealing with the problem by



Cabbage Seedlings Infected with Club Root

Source: Western Committee on Plant Disease Digital Image Collection, photograph by R. Howard.

harvesting the plants young.<sup>66</sup> Doing so provides *Plasmodiophora brassicae* with new generations of hosts, contributing to the continued expansion of the local *Plasmodiophora brassicae* population. In addition, gardeners are getting much less edible biomass for the same inputs of time, energy, seeds, and water. A systemic change that dealt with *Plasmodiophora brassicae* would therefore increase yields on gardening that is already happening.

Seattle gardens are more susceptible to *Plasmodiophora brassicae* than others in the nation because it thrives in moist, temperate climates.<sup>67</sup> In addition, climatic conditions during the winter in the Seattle region are favorable to growing Brassicas and little else. As a result, gardeners often grow Brassicas all year round. Since Brassicas are hosts to *Plasmodiophora brassicae*, year-round cultivation supports rapid expansion of the parasite's population.

65 Hwang, Sheau-Fang, Stephen E Strelkov, Jie Feng, Bruce D Gossen, and Ron J Howard. "Plasmodiophora Brassicae: a Review of an Emerging Pathogen of the Canadian Canola (*Brassica Napus*) Crop." *Molecular Plant Pathology* 13, no. 2 (February 2012): 105–13. <http://www.ncbi.nlm.nih.gov/pubmed/21726396>.

66 Julie Bryan (P-Patch site coordinator), in discussion with the author, February 2013.

67 Thuma, BA, et al. "Relationships of Soil Temperature and Moisture to Clubroot (*Plasmodiophora Brassicae*) Severity on Radish in Organic Soil," *Plant Disease*. 67, no 2 (1983): 758-762.

Sharma, Kalpana, et al. (2011). "Effect of Temperature on Cortical Infection by *Plasmodiophora Brassicae* and Clubroot Severity," *Phytopathology*, 101(12): 1424-1432.

## Interventions

The preceding section discussed what *Plasmodiophora brassicae* is and how eliminating or reducing infections in community gardens would increase yields. The following sections review physical site interventions that would reduce or eliminate *Plasmodiophora brassicae* and thereby increase yields.

### *Reducing Infection: Tool Sanitation and Testing Methods*

Community gardens are vulnerable to pathogens because of the many opportunities for small organisms to enter and move around. Gardeners often share tools,<sup>68</sup> which can bring the problem from one infected plot to the rest of the plots in the garden. A system of tool sanitation that killed *Plasmodiophora brassicae* and was easy enough to be used consistently would help limit movement of the pathogen within community gardens. Pathogens can also enter a site through infected seeds, soil, and compost. Affordable methods for testing these materials for *Plasmodiophora brassicae* would therefore be extremely helpful in controlling its spread.

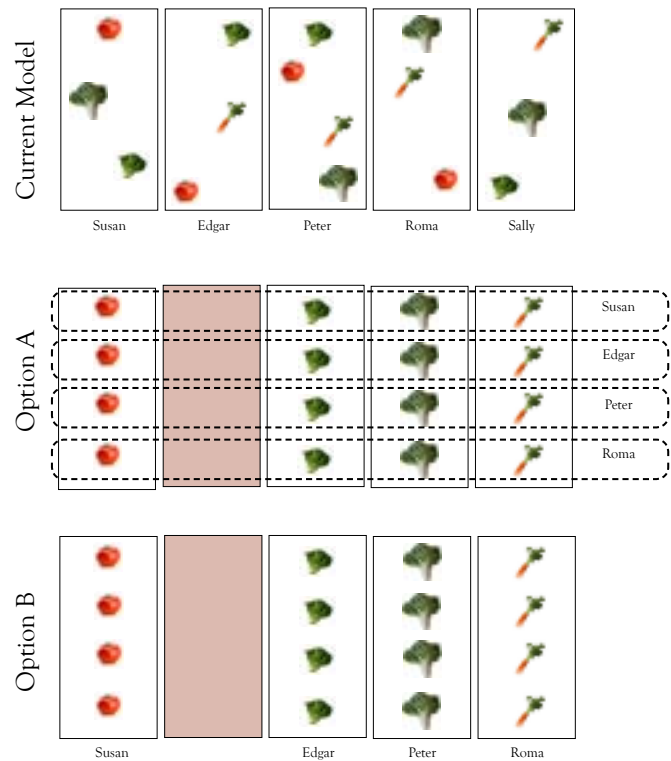
### *Crop Rotation and Fallowing*

Before the advent of chemical pesticides, many cultures used crop rotation and field fallowing as effective strategies for controlling pest populations. Community gardeners are in a tricky situation: community rules usually do not allow the use of chemical pesticides, yet the small plot sizes do not allow for effective crop rotation or fallowing. In general, there is a need for organic community gardens to develop strategies that would enable these methods for pest population control. An alternative model (Option A) that would allow for crop rotation and fallowing is to devote each plot to a particular crop instead of to a particular person. Crops could therefore be effectively rotated, and it would be possible to include a fallow plot (or plots) in

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<sup>68</sup> Julie Bryan (P-Patch site coordinator), in discussion with the author, February 2013.

that rotation. Perhaps in this model each crop-plot would be divided into rows, which can be designated for different gardeners. Alternatively, gardeners could be in charge of tending one crop all season (Option B), and the gardeners would share their produce. The latter model, in particular, would require a tight-knit and trusting community with effective organization to ensure equitable sharing of the harvest. Another challenge is that there is currently pressure for space in Seattle's P-Patch program, which makes it very difficult politically to implement a system that includes fallowing. However, current trends of intensive cultivation may render plots un-usable for gardening, which would further compound the problem of limited space.



*Crop Rotation in Allotment Garden*  
Source: Katherine Jacobs, 2013

The discussion of fallowing and crop rotation as a method of controlling *Plasmodiophora brassicae* is complicated by the tenacity of this particular pest, which can remain dormant in soil without host Brassicas for more than 10 years.<sup>69</sup> Although a fallowing period that long is clearly out of the question in urban settings, where space is limited, fallowing for shorter periods may be helpful in preventing the concentration of *Plasmodiophora brassicae* from increasing. In addition, it might be possible to declare infected sites as “no Brassica zones,” which could still be used for a variety of other crops. Non-host plants may actually induce germination in the club root spores,

<sup>69</sup> “in a field with 100% infestation, the level of infestation declined to below the detection level after a period of 17-3 years.” From Wallenhammar, A. “Prevalence of *Plasmodiophora Brassicae* in a Spring Oilseed Rape Growing Area in Central Sweden and Factors Influencing Soil Infestation Levels.” *Plant Pathology* 45 (1992): 710.

potentially reducing the concentration of dormant spores over time, but the results of this research is not conclusive.<sup>70</sup> If fallowing is used as a method for controlling *Plasmodiophora brassicae*, it is important to monitor the site and remove any weeds in the Brassica family, which would act as hosts.

### *Altering Soil pH*

Currently, the most useful strategy for dealing with club root involves altering the pH of the soil. *Plasmodiophora brassicae* does not thrive above pH of 7.2,<sup>71</sup> while most Brassicas thrive up to a pH of 8. Therefore, soil between 7.2 and 8 can support healthy Brassicas, but not *Plasmodiophora brassicae*. This can be achieved with careful application of basic (high pH) soil amendments. Because this strategy involves a limited pH window, it can be challenging to amend the soil to the ideal pH. Affordable and widely available litmus tests can be very helpful for gardeners trying to amend their soil to this precise pH range.

Another challenge in raising soil pH is doing so without creating other imbalances in soil composition. Agricultural lime (pulverized limestone) and dolomite lime (calcium magnesium carbonate) are commonly used to raise pH and supplement soil levels of calcium and magnesium. Unfortunately, addition of lime may increase magnesium levels beyond what is safe for plants. Therefore, gardeners struggling with club root should test magnesium levels before using lime to make sure that it's safe. If existing magnesium levels are adequate or high, dried ground eggshells, hardwood ash, ground oyster shells, or calcite are alternative materials for raising soil pH without

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70 Friberg, Hanna, Jan Lagerlöf, and Birgitta Rämert. (2005). "Germination of *Plasmodiophora Brassicae* Resting Spores Stimulated by a Non-host Plant." *European Journal of Plant Pathology* 113 (3): 275–281.

Murakami, H., S. Tsushima, T. Akimoto, K. Murakami, I. Goto, and Y. Shishido. (2000) "Effects of Growing Leafy Daikon (*Raphanus Sativus*) on Populations of *Plasmodiophora Brassicae* (clubroot)." *Plant Pathology* 49 (5): 584–589.

71 Dobson, R.L., R.L. Gabrielson, A.S. Baker, and L. Bennett. 1983. "Effects of Lime Particle Size and Distribution and Fertilizer Formulation on Clubroot Disease Caused by *Plasmodiophora Brassicae*." *Plant Disease* 67 (1): 50–52.

altering magnesium levels.

## Conclusion

Because club root is a barrier to productivity in Seattle's community gardens, design strategies that prevent club root infection support higher levels of productivity. Designs that facilitate sanitation of shared tools would be effective in preventing infection in new areas. Site design that enables crop rotation and fallowing would be instrumental in preventing new infections and managing infections of club root as well as other pathogens. It will be important for designers to work with administrators in the P-Patch Program to balance the need for crop rotation and fallowing with the pressure for space in the P-Patch Program. It is possible that designing community gardens in a way that enables crop rotation may be more easily achieved in community gardens outside the P-Patch program, if those communities have less pressure for gardening space.

## Discussion

Although productivity is the focus of the preceding case studies, it is one among many benefits of urban community gardens. While some community gardens like Thistle P-Patch are designed primarily to maximize productivity,<sup>72</sup> many of Seattle's community gardens are designed to support other goals such as creating opportunities for urban dwellers to connect with natural processes, building community, and education.<sup>73</sup> Even in projects that are not primarily focused on productivity, landscape architects can identify strategies that support higher yields along with other project goals. This section discusses how the previously identified opportunities for increasing productivity could have additional layers of benefit for community gardens.

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72 Hou, Jeffrey, Julie Johnson, and Laura J. Lawson. 2009. *Greening cities, growing communities: learning from Seattle's urban community gardens*. Washington, D.C.: Landscape Architecture Foundation in association with University of Washington Press, Seattle. 85.

73 Ibid. 25-27.

Because looking into soil contamination can potentially support human health as well as higher yields, it is a strategy that would likely be encouraged by communities that are not primarily concerned with productivity. Designers might also see this stage of the design process as a rich opportunity to engage volunteers in researching site history. This process could be a valuable educational experience for members of the community, potentially deepening their sense of place. Younger volunteers might conduct interviews with elderly members of the community about their memories of the site, generating useful information in a way that creates a meaningful role for an oft-neglected group.

Similarly, design strategies that support higher pollinator populations provide benefits beyond higher yields. Apiaries of honeybees provide honey and beeswax, which could be enjoyed by the community or sold in order to generate income. The process of collecting honey could also be a catalyst for a community festival. Other strategies for supporting bees could provide opportunities for engaging with local schools and educating children about pollination.

While community members may not seek help from landscape architects to help avoid infestations in the planning of new community gardens, preventing infestations of things like club root is important in achieving other goals like education and community building. Infestations can ultimately reduce yields to the point of making gardeners frustrated and disenchanted with the project. In addition to the fact that preventing infestations supports other goals, communities may be interested in taking advantage of methods like crop rotation as educational tools to teach about traditional agricultural practices. The alternatives to traditional allotment gardening that I suggest in the section on club root may be exciting to some communities for exactly the same reasons they would be impossible for other communities. Designating one person (or family) to grow all the tomatoes for the community, and likewise for other crops, might be a burdensome amount of coordination, but it might also create a welcome sense of mutual support and collaboration. Even

for such mundane-seeming strategies as application of lime for management of club root might involve educational workshops that are also opportunities for bringing the community together; it could also be an opportunity for a local school to do a lesson on soil acidity.

In addition to these specific design opportunities, my research revealed opportunities for expanding the practice of grounding landscape architectural design for urban agriculture in scientific research. The Landscape Architecture Foundation (LAF) Landscape Performance Series database provides case studies of designs intended to provide a variety of sustainability benefits.<sup>74</sup> These case studies describe design features, provide information on design process, and supply detailed performance metrics. As a central hub for information about landscape designs that contribute to sustainability goals, this database is an opportunity for designers of urban agricultural spaces to share design strategies and compare productivity outcomes. The four food-related projects found in the Landscape Performance Series database at the time of writing quantify food production in various ways, often using formulas for average production that do not capture the impact that the design has on agricultural processes in that space.<sup>75</sup> Developing a consistent method for measuring production that is able to capture those impacts might better enable designers to compare the efficacy of different design strategies, though it would also be necessary to account for climatic differences.

A different set of opportunities are apparent in Landscape Architecture Magazine, which “is the magazine of record for the landscape architecture profession in North America, reaching more than 60,000 readers who plan and design projects valued at over \$140 billion each year.”<sup>76</sup> Since this publication spans all of landscape architectural practice in North America, it is not a suitable venue for sharing the depth of information that is possible in the Landscape Performance

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74 Landscape Architecture Foundation. “Landscape Performance Series.” <http://www.lafoundation.org/research/landscape-performance-series>. Accessed 27 May 2013.

75 Ibid.

76 <http://landscapearchitecturemagazine.org/about-us>. Accessed 9 June 2013.



Series database. Instead, Landscape Architecture Magazine is an opportune venue for spreading the story of urban agricultural designs that are informed by scientific research on agricultural processes, and thus inspiring designers to seek out that information.

## Reflections

The findings of this thesis are framed by the scope I established. In this section, I reflect on opportunities for future research on this subject, applied with a different scope. By expanding the geographic scope of my research beyond Seattle to include nearby rural areas, this project could have included a range of agricultural modes, including intentional communities, permaculture homesteads, mainstream farms, organic farms, biodynamic farms, and more. Comparing the work of landscape architects on urban community agriculture to the work of other professionals in agriculture would have revealed a different set of opportunities for landscape architects. In addition, working with a geographic scope that included a range of agricultural modes and practices would have enabled a comparison of the greenhouse gas efficiencies associated with each type.

In the course of my research, I was surprised to find that there is no comprehensive data on the greenhouse gas emissions associated with the United States' food system, much less Seattle's food system. This is a significant area for future research on food systems. Without such data, it is unclear what parts of our food system are most detrimental or what strategies for changing our food system would be most effective at reducing emissions. I continued with my project based on the logic that urban agriculture should reduce greenhouse gas emissions by reducing large scale transport of food in vehicles that run on fossil fuels as well as the use of nitrogen fertilizers, but data would be necessary to pursue systemic changes that are effective at reducing food-related emissions.

In demonstrating the potential for designers to enhance yields in community gardens, this project suggests some flexibility in the landscape architect's role. Many of the strategies identified in the case studies could be implemented by a designer who is engaged with the design of a community garden through a traditional design contract. In order for designers of urban community gardens to ground their design in scientific research to the extent suggested in this paper, however, designers would either need to develop a special knowledge base for this type of design or consult with experts on agricultural process. Other strategies suggested in this project are implemented over time, and would therefore be more appropriately implemented by a site coordinator. While site coordination involves skills that differ from those of a landscape architect, the understanding of site design and landscape systems developed through studying landscape architecture may be beneficial to a site coordinator.

As a burgeoning design professional, developing this thesis has been a valuable process for cultivating my approach to design. I am primarily interested in landscape architecture as a way of curating relationships between humans and natural systems, and thus working toward a more sustainable way of life in my community. Urban agriculture is one arena for this kind of work, in which design can enable lower greenhouse gas emissions and support other sustainability goals. In order for design work to realize the intended sustainability benefits, it is important to ground this work in scientific research.

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