

Harvest Pierce County as a Model for Community Garden Programs: Analysis of a County-Level Collaborative Effort to Reduce Waste, Build Soil, and Connect to Community.

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Abstract

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Past community garden research focused on benefits without consideration of garden usage. However, garden usage has implied weight on benefits provided by gardens. The Harvest Pierce County Community Garden Program is integrated with municipal departments and provides material resources to assist gardeners. This inclusive program provides a controlled study program to assess usage of gardens by internal structural differences and socioeconomic differences of surrounding census tracts. A survey of this program found that larger gardens are used more intensively than smaller gardens; whereas the number and size of individual plots does not significantly predict how well a garden is used. While community gardens are well-distributed across communities of color the diversity of the census tract does not predict garden usage. Overall gardens are well-used across the program.

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Chapter 1: Literature Review – What do we know about community gardens so far?

What are community gardens?

Community gardens are a type of urban agriculture (Lawson, 2005). Unlike urban farms, community gardens involve multiple individuals, working separately or as a group in a shared space. The goal of each community garden reflects the people who use the garden (S. Brown et al., 2016). Some gardens are used to intensively produce food for personal consumption or to sell but others are places for people to gather and spend time learning, teaching, sharing, connecting, and forming a community (Draper & Freedman, 2010). Management and structure of gardens differ from garden to garden, but a typical garden structure has the large garden area subdivided into individual plots with democratic management and elements of public ownership or access (Ferris et al., 2001). Individual community members choose to grow produce, herbs, flowers, shrubs, bushes, and sometimes trees (Bos, n.d.). For most community gardens in the US, the communities do not own the land, and instead it is leased from public or private organizations (Borrelli, 2008). Garden managers have limited power and require government and policy support for community gardens for the long-term success of a garden (Diaz et al., 2018).

Community gardens come in all shapes and sizes with different numbers and sizes of garden plots, different requirements for participation, rules for what can and cannot be used in the garden, and connections to organizations or overarching garden programs (Armstrong, 2000). Some gardens have areas for compost production, tool sheds, decorative fencing or pathways, areas for children to play, educational displays, native plant or pollinator plots, and wheelchair accessible raised plots. Other gardens more closely resemble urban farms with no visible separation of families' plots and neat rows of highly managed crops (S. Brown et al., 2016). How, what, and who grows when are all unique to the garden (Borrelli, 2008; S. Brown et al., 2016; Ferris et al., 2001).

A few categories of community gardens include: leisure gardens, child and school gardens, entrepreneurial gardens, crime division gardens/work and training gardens, healing and therapy gardens/quiet gardens, neighborhood pocket parks, ecological restoration gardens/parks, and demonstration gardens (Borrelli, 2008; Ferris et al., 2001). Neighborhood community gardens are typically when a lot is divided among households who then tend small plots of land for their own use. School gardens are located on school lots where parts of garden maintenance can be incorporated into the curriculum (Morris & Zidenberg-Cherr, 2002). Intensive entrepreneurial gardens are used to produce vegetables, herbs, flowers, and sometimes raise animals for wholesale and retail markets (Bos, 2017). On the whole, urban agriculture is mostly limited to plant-related endeavors and industries and only rarely does it include raising and processing livestock or fish (K. H. Brown & Jameton, 2000).

Despite the diversity of community garden types and analysis of general community garden systems little research has been done into the intensity of community garden usage. The gap in understanding how different types of community gardens are used limits further discussion on community access and efficacy of garden programs.

What is the history of community gardens – how did we get here?

United States' community gardens tend to increase in number during times of recession when food is expensive and the number of vacant lots in a city increases. The popularity of gardens reflects the socio-economic or political climate of the country (Draper & Freedman,

2010).) The original community garden movement began in the 1890s as a result of the social, environmental and economic climates of the time. The community gardens were usually school gardens and vacant-lot cultivation projects to produce food for local communities. The initial garden movement targeted immigrants, children and the poor. However, widespread economic hardship associated with the World Wars and the Great Depression increased universal interest and participation in community gardens (Lawson, 2005). During WWII the US Department of Agriculture reported that national health as well as personal well-being were dependent on the consumption of fresh vegetables. This in part led to the Victory Gardens Program which developed an estimated 20 million gardens across the US that in turn produced approximately 40% of the fresh vegetables consumed. These programs enabled communities to produce an independent food source in a national climate of gross shortages. The increase in food supplies was especially important because it required minimal transporting and use of other limited resources (Armstrong, 2000).

The Work Projects Administration designated city lands for community gardens during the Great Depression to assist the unemployed and impoverished. As the US recovered following WWII, the number and use of community gardens diminished, but made a comeback in the 1970s when food prices increased and a broadening environmental consciousness arose (Lawson, 2005). While some individuals settled in rural areas to experiment with “living off the land,” many young urban gardeners used community gardens and gardening in general as a political expression of environmental stewardship. Others looked to urban gardens as a community organizing tool to combat poverty and provide a collective response to blighted city neighborhoods. The gardens also increased the amount of locally-grown produce to offset the cost of purchasing highly-priced food. (K. H. Brown & Jameton, 2000). Following the recession of 2009, there was a 19% increase in what are called ‘recession gardens’, to decrease individual and family food bills while providing more self-sufficiency (Draper & Freedman, 2010). First Lady Michelle Obama broke ground on a garden located at the White House on March 20, 2009. She used this garden to educate as well as to produce herbs, fruits and vegetables that were donated to local soup kitchens or used in the meals prepared for the family and visitors to the White House. The White House Kitchen Garden inspired other communities and the number of gardens are on the rise across the country (Draper & Freedman, 2010).

Although gardens have long been recognized as a method to improve local access to less expensive fresh food, recent policies and programs also promote gardens as community recreational and leisure opportunities. According to surveys conducted by the National Gardening Association, the number of people engaged in urban gardening increased by 29 percent between 2008 and 2013. The number of households participating in community gardening specifically, increased by 200 percent to over three million during the same time period (National Gardening Association, 2014; (Iuliano et al., 2017). There are over 4,000 community gardens listed as of August 1, 2020 (American Community Garden Association, 2020). However, the number of gardens does not accurately account for the usage of each garden. More information is needed to describe garden characteristics and patterns in how each garden is used. With an increase in the number and popularity of community garden programs there is a current opportunity to describe the variability in garden use as a proportion of total numbers and more accurately account for benefits associated with participation in these gardens.

Why do gardens matter—what are the benefits of community gardens?

Community gardens are used by, and beneficial for, individuals of any age, race, ethnicity, and socioeconomic status, as well as the disabled and nondisabled alike (Draper & Freedman, 2010). Four overarching reasons for promoting garden use include: increased education and access to nutrition and environmental health, social stability for surrounding community, economic strength of neighborhood, and public health for participants and people appreciating greenspace (Egli et al., 2016).

Community gardens encourage sustainable and positive economic development and can provide employment and educational opportunities (Ackerman et al., 2014). They represent a form of greening and beautification in areas that often severely lack existing open spaces, parks, and trees (Litt et al., 2011). Gardening teaches participants about nature, science, and the environment (Armstrong, 2000). Gardens also provide a space for people of all ages to gather (Image 1). Local increases in food production results in improving diets and the alleviation of problems such as poor-quality inner-city grocery stores and expensive food costs (Borrelli, 2008). Observational findings suggest that food production increases with more intensive use and over time as garden experience increases (Meadow, 2013).

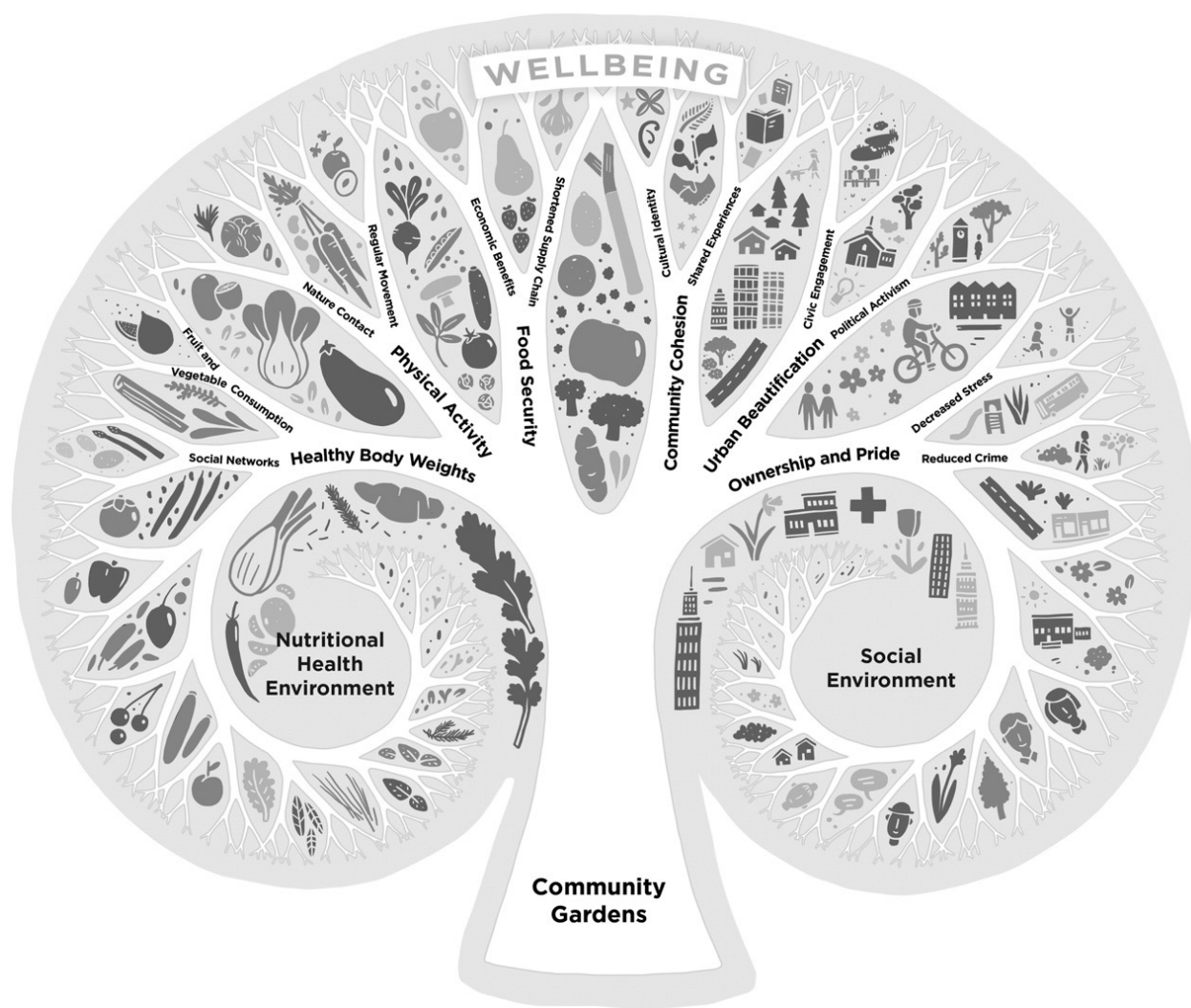
Image 1 : Garden Playground

Gardens provide opportunities to meet community needs, such as a space for engaging with children of all ages.



Benefits of community gardens have been summarized into three sub-sections benefits for people, benefits for community, and benefits for the larger environment (Figure 1). The benefits for garden users and larger communities are dependent on the quality and quantity of garden usage. **However, current studies of garden benefits have not included quantitative measures of use to inform the measured benefits.**

Figure 1: Multiple Facets of Wellbeing
 Egli et al. described multiple interrelated facets of wellbeing that are commonly associated with community gardens (Egli et al., 2016).



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Individual Benefits

Gardens act as open spaces that promote nutrition and education, subsidize household income, enable recreation, and provide psychological benefits (Ferris et al., 2001). Egli et al. (2016) visualized the many elements of wellbeing that community gardens provide to people (Figure 1). Community gardens improve the local social environment and nutritional health environment of people who directly participate. There are also more nuanced improvements feeding into the larger benefits (Egli et al., 2016). Some social benefits may be experienced without direct use of the garden. However, observations from case studies indicate that the most

intensively used gardens maximize community cohesion, ownership and pride, and provide direct individual health benefits (S. Brown et al., 2016).

The nutritional health benefits are due to the changes in gardener's diets, increase in physical activity, neurological stimulation, and stress reduction. An increase in use of community gardens leads to increased consumption of fruits and vegetables among urban adults (Alaimo et al., 2008) and rural adults (Barnidge et al., 2013). This increase in consumption of fruits and vegetables is due in part to an increased awareness or knowledge of different fruits and vegetables as well as due to increased availability through garden production. Psychological benefits can be related to the enhanced neighborhood aesthetics, community garden participation with others, and social involvement with community efforts (Litt et al., 2011). Community gardening also has beneficial impacts on the diets of children. Children who participated in garden programming demonstrated a greater familiarity with and knowledge of vegetables and fruits (Morris & Zidenberg-Cherr, 2002). The increase in knowledge translated to an increase in preference and children asking for vegetables at home. Youth gardening programs also improved academic and developmental measures (Ober Allen et al., 2008). The garden-enhanced nutrition programs also increased physical activity and children's self-efficacy for gardening methods (Draper & Freedman, 2010). These studies conclude that the beneficial effect on diet is due in part to recognition and ownership of food. This recognition and familiarity would increase with the frequency and intensity of use and future studies should include analyses of the program structure related to how each child uses the garden.

Participation in community gardens is beneficial for people of all ages and ability levels. Increased access to fresh fruits and vegetables has been associated with a reduced risk for cardiovascular disease, cancer, and ischemic stroke. These chronic diseases have the highest prevalence in urban populations and are the three leading causes of death in the US. The prevalence of these diseases in urban populations suggests that active urban agriculture and community gardening programs in cities can have a large impact on community health. Under average growing conditions in a 130 day growing season, a 10x10 m plot can provide a household's yearly requirements for vitamins A, C, and B complex and iron (K. H. Brown & Jameton, 2000).

In addition to lowering the risk of chronic diseases, gardening also has benefits for weight control, cardiac fitness, and fine motor movement (Zick et al., 2013). Gardening is one of the most commonly practiced types of exercise and is a recommended form of physical activity (Armstrong, 2000). A study found a significant change in total cholesterol, HDL cholesterol, and systolic blood pressure was associated with either walking or gardening (Caspersen et al., 1991). As with other forms of exercise, the frequency and total time spent completing gardening activities impact beneficial health outcomes.

In addition to benefiting measures of physical health, participation in community gardening has psychological benefits, such as a reduction in stress and anger (Hayashi et al., 2008). Working in the garden has benefits related to working in a natural environment and through the development of a sense of community. Gardening increases levels of neuroendocrine and reduces affective stress (Van Den Berg & Custers, 2011). Community gardens can provide a safe space for individuals and families to gather and relax, especially for those who would not otherwise have easy access to such areas. (Draper & Freedman, 2010)

The production of food in community gardens reduces an individual's or family's expenditures on food (K. H. Brown & Jameton, 2000). A one-acre vegetable garden, established as a component of a diabetes education program on an American Indian reservation produced

6,000 pounds of fresh produce, in 1 year, which was distributed primarily amongst tribal elderly (Draper & Freedman, 2010). Saldivar-Tanaka and Krasny (2004) estimated that in NYC, an investment of \$5 to \$10 in plants for a garden plot provides for a profit of \$500 to \$700 (Saldivar-Tanaka & Krasny, 2004). Gardeners consciously planted foods that were either unavailable or expensive in local stores. Thus, a small plot of land can yield large amounts of produce, equating to significant monetary value and savings if planted strategically (Hanna & Oh, 2000). Community garden participants can also use garden space to produce vegetables to sell. Gardeners in various studies enhanced their economic benefit from the garden by selling the produce to local markets or restaurants (Ferris et al., 2001). Besides nutritional value, gardeners can also enjoy fresh seasonal produce and preserve culturally relevant produce and recipes (Armstrong, 2000).

The most salient or impactful benefits of community gardens to an individual or family differ based on their health, age, or location. In urban areas, participants reported that the enjoyment of nature and open spaces, benefits to mental health, and a food source for low-income households were the most important benefits of community gardens. In contrast, rural community gardeners more often cited the practice of traditional culture as a benefit to garden participation (Armstrong, 2000). Initial motivations to garden may shift with sustained use and more intensive use of gardens can lead gardeners to appreciate other benefits of gardens such as community cohesion or community pride (Saldivar-Tanaka & Krasny, 2004)

Community Benefits

Community benefits are more difficult to quantify and vary depending on where the garden is, who participates in the garden, who manages the garden, and how the garden is used. Gardens provide community health benefits, exposure of urban populations to nature through gardening and greenery advances public social and psychological health (Kondo et al., 2020, 2020; Lawson, 2005). Both enhanced neighborhood beautification and an increased opportunity for leisure and outdoor recreation were listed as benefits for leisure gardens and food-producing gardens (Draper & Freedman, 2010). Community gardens can also improve the food security of the participants and neighborhood (Guitart et al., 2012). Some gardens donate portions of the produce to food banks (McIvor, 2011).

Community gardens have positive effects on the economic and social behaviors of the neighborhood. Having a community garden in a neighborhood was reported by garden coordinators in NYC to improve the attitudes of residents toward their neighborhood for 51% of gardens. These reported attitudes were supported by improvements in the maintenance of other properties in the neighborhood. Coordinators noted reduced littering and increased pride in the neighborhood (Armstrong, 2000). Qualitative reports taken from neighborhood residents who are garden participants describe a noticeable difference in the amount of crime in the surrounding area once a garden was established (Ferris et al., 2001; Ober Allen et al., 2008). Other studies support that how often city gardens and parks are frequented has been negatively correlated with local crime and that garden participation might be able to address surrounding issues that differentiate low- and higher-income neighborhoods (Saldivar-Tanaka & Krasny, 2004). More intensively used gardens have a larger impact on neighborhood safety. The presence of community gardens increases neighboring property values. The impact on property value is modified by the income level of the neighborhood as well as the age and quality of the garden (Been & Voicu, 2006). Perceived quality of garden increases with the frequency and intensity of

use (Brown et al., 2016). This connection between level of garden use and property value should be tied together more explicitly in future studies (S. Brown et al., 2016).

Community gardens also increase neighborhood cohesion (Teig et al., 2009). Latino community gardens in NYC were identified as the only open spaces available within the neighborhood (Saldivar-Tanaka & Krasny, 2004). Gardens can be used to preserve knowledge and practices as well as a space to host cultural events, and affirm traditions (Draper & Freedman, 2010). Community gardens have generated particularly strong local neighborhood involvement with the inclusion of music, theater and storytelling, by incorporating a community performance area and hosting such activities in the gardens (Armstrong, 2000).

One of the large differences between private and public gardens is the collective nature of the garden. A collective garden inherently has social interactions which can allow for the cultivation of meaningful relationships. These relationships are not isolated to interactions between garden participants, they also include interactions with entities outside of the immediate garden context. The collective garden and individual gardeners can network with universities, cooperative extension offices, summer youth programs, not-for profit organizations, banks and health centers (Draper & Freedman, 2010). Outside entities would be more willing to invest or connect with gardens that are used more intensively and would therefore maximize the return on investment.

Environmental Benefits

Gardens are often established on parcels that had been derelict. By restoring soils and plant growth to these sites a range of environmental benefits are appreciated. For example, one study quantified the stormwater collection benefits of community gardens in New York City as a diversion of 12 million gallons (Gittleman et al., 2017). In more general terms these sites restore soils to higher levels of function (Herrmann et al., 2017). Other studies value numerous ecosystem services associated with urban greening such as nutrient cycling, air purification, habitat for animal species, biomass production and carbon sequestration, genetic diversity, photosynthesis and evapotranspiration, and energy conversion into edible plants (Gómez-Baggethun & Barton, 2013). Costanza et al., valued urban ecosystem services at \$6,661 per hectare per year and this valuation can be applied to quantify the environmental impact of community gardens services (Costanza et al., 2014). Other studies have noted the importance of gardens as habitat for pollinators and birds (S. Brown et al., 2016). There may also be impacts on local climate (Borrelli, 2008). Finally the gardens can provide opportunities for beneficial end use of municipal residuals including municipal biosolids, food/yard waste composts and cardboard (S. Brown et al., 2016; McIvor, 2011). These benefit cities by reducing disposal costs of waste products and reducing load on wastewater infrastructure (S. Brown et al., 2016; Deelstra & Girardet, n.d.). Gardens have long-term benefits that increase the longer a garden is used. Environmental benefits are also theoretically increased with the intensity of use. So far, no studies have adjusted calculations based on intensity of use and assume gardens are well-used or do not include garden use as a relevant factor.

What limits community gardens?

Many of the requirements for a community garden are similar to privately-owned household gardens. These general requirements are related to the successful growth of plants.

These elements include: fertile and safe soil, tools and infrastructure (such as: netting, fencing, trellises, walls, path and irrigation materials), clean water, sunlight, seeds or plant starts, knowledge, sustained interest and time, and a space to cultivate. However, community gardens have additional requirements to be successful (Birky, 2017). Since community gardens function at both a collective and individual level there are requirements for making garden-wide decisions and protocols for acceptable individual behavior. Community gardens also require a system to generate revenue to support garden projects and costs, including the cost of leasing garden land (Lawson, 2005).

All gardens require permanence or a focus on long-term; plant and soil cultivation to improve with time. Amendments will improve soil health and therefore plant growth and food production. However, soil building techniques, especially biologically and ecologically appropriate methods can require multiple seasons to maximize effect (Mitchell et al., 2014). This long-term perspective on gardens includes a consideration of past use of land. Contamination of soil by heavy metals can persist and affect garden soils and accumulate in plant tissues. Soil testing is required to understand potential contaminants and to develop methods to overcome contaminants or to remediate soils (Cooper et al., 2020).

This need for a permanent space and time to cultivate soil and knowledge of successful techniques is particularly challenging to address for community gardens. (Borrelli, 2008; Lawson, 2005). Urban community gardens are usually developed on vacant or abandoned lots that are owned by a city or municipality. Communities and gardening associations either lease the land directly from the municipality or use the land under a conservation easement or a public park land designation. Other lands are privately owned, or owned by nonprofit organizations or land trusts (Borrelli, 2008). This leads to a unique management requirement for community gardens. Community gardens require policy protection, autonomous control over leased land, protection of long-term commitments for garden lands, and a central organizer to manage administrations such as leases, designations, and fee collection for rental payment (McCormack et al., 2010). Gardens meet these basic requirements in different ways. More information is needed to describe these differences and tie these differences to how the gardens are used and differences in garden performance.

Management and Leadership

Another limitation unique to community gardens compared to private gardens is management or community integration. The management of community gardens differs for different community garden programs (Egerer & Fairbairn, 2018). Some gardens are managed at the city or county level, as part of a network of individual gardens. These individual community gardens as well as other gardens that are not organized in a network usually have a garden coordinator that manages the operations and needs of the gardeners. Coordinators generally enroll and inform each garden participant about the rules and organization of a community garden (Aptekar, 2015). Coordinators may also obtain garden materials and organize cooperative activities. Both coordinators of free-standing gardens and those in a garden network routinely interact with town administrations and the broader community around the garden. Government administrations can donate services (e.g. install a water outlet or provide trash removal) and neighborhood organizations can help legitimize a community garden as a desirable community tradition (Armstrong, 2000).

Garden management may be cooperative or associated with a community organization. Churches, non-profits, children's organizations, hospitals, cooperatives, and municipal gardens

will operate gardens differently. The operations of the garden are affected by the organization's goals for the garden or the benefits that each managing structure is targeting. (George et al., 2015; Heise et al., 2017; Milliron et al., 2017). Garden program structure has qualitative impacts on the success of community gardens (S. Brown et al., 2016).

Poor or Contaminated Soil and Lack of Water

Basic requirements to grow plants include soil with adequate nutrition and organic matter to sustain a harvest. One of the concerns with growing plants in urban soils is contaminated or poor urban soil (S. Brown, 2018; Diaz et al., 2018; Laidlaw et al., 2017). Since many gardens are grown on abandoned lots or other sites that have not been developed, there is risk of historical contamination of the soil. Other sites may be paved, or have soil that is low in organic matter, eroded, or low in nutrients. Contamination can pose a danger to human health, while poor or absent soil can make successful yields a challenge and could lead to the failure of the community garden. Building or remediating soil is expensive and time-consuming, soil amendments also require knowledge to implement correctly, which is usually a product of gardening experience (Lee & Matarrita-Cascante, 2019).

Many community gardens overcome the obstacle of poor or contaminated soil by building raised plots filled with new soil from another site. The sourcing of soil could be the responsibility of the coordinators, individual gardeners, or the gardening program management. Similar obstacles exist for the sourcing of water for irrigation. Lots that do not have preexisting water must either pay for connection to water infrastructure, pay for the installation of a well, or organize onsite storage and access of other water. Convenient access to sufficient water is critical to the health and success of the plants, and thus the longevity of the garden (S. Brown et al., 2016; Lawson, 2005).

Garden Impermanence

Community gardens are generally located on land leased from a local government or organization or land that the garden has been granted access to under certain conditions. The lack of ownership over garden land can lead to issues related to garden permanence. Garden land can and often is repurposed for other city projects or sold to developers (Fox-Kämper et al., 2018). Since many of the benefits of community gardens are more salient with garden maturity, and garden success increases with time, the instability of land threatens community gardens. Securing land tenure, sustaining interest, developing the garden community, and long-term administrations are all factors that develop over time and are needed for garden success (Milburn & Vail, 2010).

There are a few general problems created by the short-term durations of gardens. Financial returns are limited in the short term since participants need time to prepare for each season and learn from successes from past years. There are gaps in time when the public becomes aware of, then interested, then involved in the project. The amount of time to maximize garden participation differs for each garden but generally increases over time (Borrelli, 2008). Additionally, initial crop yields tend to be low and time is necessary to encourage and properly train participants unfamiliar with gardening to increase yields. Gardening experience leads to emotional motivations to continue gardening, which creates a positive loop with gardeners who participate longer and gain more experience more motivated to continue gardening (Lee & Matarrita-Cascante, 2019)

Problems that contribute to garden impermanence include funding and legal problems including: liability issues, tax implications, nonprofit status and property ownership (Schukoske, 1999). Gardens also have high cost barriers related to garden establishment or large projects and barriers related to cost can prevent a garden from being established or prevent individuals from participating in gardens (Kingsley et al., 2019). Gardens that receive grants or donations to sustain garden functions are also in danger of funding streams drying up (Daftary-Steel et al., 2015).

Subjective Valuation of Garden Benefits

Garden benefits are difficult to document, verify, and accurately quantify. Most policy makers would prefer quantified data to give gardens legal protection and support. This is the case as garden programs can have large upfront costs to install infrastructure, access to water, and organization. Many politicians find it difficult to justify garden expenditures or the allocation of space when local and state governments are financially-stressed and have competing interests. Many gardens are established with specific goals, and due to the variety of benefits, it is easy to establish a garden as a cure-all for neighborhood issues. When multiple agendas are layered on gardens, it makes achievable objectives difficult to ascertain, much less prove to a skeptical land developer or policy maker. Other competing programs or problems such as homelessness or drugs can lead to dismissal of gardens as luxuries (Lawson, 2005).

Especially in urban settings, land quantity crises often lead to dispute over land. Elected officials have to decide how it is to be used, who gets to use it, the best use for the land, how to profit from the land, with pressure from the inevitable housing concerns. Projects and initiatives such as downtown revitalization and urban renewal efforts can lead to city planners and developers identifying garden space as available land. There is historic precedent of cities not renewing leases to gardens or repossessing and selling garden land to developers to fund other city projects (Borrelli, 2008). It is difficult to argue for the value 'undeveloped' garden land to administrators that are trying to get re-elected or stretch a limited budget. The nature of a garden's benefits makes it easy for people in different positions to value gardens differently (Borrelli, 2008; Lawson, 2005).

Garden benefits are only realized if the gardens are well-utilized. Participation in community gardens is a voluntary activity. Participation rates may vary over time or with factors associated with individual gardens. No academic studies have been completed to assess what predicts garden use or to survey the usage patterns of community gardens. Program evaluations of gardens depend on the management and program structure and largely remains unpublished. A better understanding of which characteristics are correlated with maximum usage of community gardens and therefore maximum benefit would better strengthen community gardens as policy alternatives. A minimum requirement for garden parameters such as size, management, soil, and plots would remove some of the perceived ambiguity. A recommendation that begins to quantify connections of use would be a step towards solidifying the value of community gardens in realms of government decision-making.

Chapter 2: Introduction to Program and Problem –

What is so special about Harvest Pierce County (HPC)?

The Harvest Pierce County Program is a county level urban agriculture program that aims to bring together resources and gardeners to provide access to local food. The program supplies local gardeners with materials and support while they build neighborhood gardens that reflect the needs and effort of a community. The program is run through the Pierce Conservation district with centralized program directors and coordinators who coordinate garden-level leaders. Harvest Pierce County currently has 83 gardens in the network. Prior to the development of Harvest Pierce County, Tacoma area had fewer than a dozen gardens. Community gardens in Tacoma were managed by the Metropolitan Park District as a recreational opportunity, not an urban agriculture focused initiative (K. McIvor, personal communication, 2020).

Although each garden is unique, all are built on an integrated foundation of city and county infrastructure, resources, and community interest. Harvest Pierce County works to provide these resources to interested residents as part of the Pierce County Conservation District. The community garden program is directly linked to the city's mission. When the program was created, then Mayor Strickland proclaimed that she wanted Tacoma to have the most community gardens per capita of any city in the US. The City of Tacoma has a published Memorandum of Understanding that outlines how the Pierce County Public Works Department, the City of Tacoma, the Metropolitan Park District of Tacoma and the Pierce Conservation District support a coordinated, regional, urban agriculture and local food access program. This has allowed for direct department collaboration with interested gardeners. Every garden is provided with as much residual based soil products or compost as are needed, as well as cardboard and wood chips for pathways, and access to water on site at no cost to the gardeners. The Wastewater Treatment and Biosolids Program, the Solid Waste Division, Recycling Program, and Public Works division all contribute to the program. This interdepartmental prioritization of growing Tacoma gardens gives every garden a strong base of support and increases the chance of success. For gardens on City of Tacoma property, there are financial resources provided to support them in building physical infrastructure in the gardens such as raised plots and fences, and all gardens in the city limits qualify to receive free fruit trees to plant within the gardens.

Public Works paid for the installation of water systems at the gardens, including the irrigation systems, so every garden has water onsite. The City provides cardboard and wood chips that are used as a base for garden paths and a mulch. These are supplied by the Solid Waste Division to the gardens. Wood mulch from the yard-waste recycling program enables gardeners to keep gardens tidy and suppresses weeds between plots. Every garden also has an unlimited supply of high-quality pathogen-free soil that gardeners can use in raised plots to avoid growing in potentially contaminated soil. The soil is produced from wastewater biosolids and yard waste compost-both by products of city departments. The city also provides free soil testing for each garden (McIvor & Brown, 2016).

Additionally, there are a wide range of programs, classes, resources, and giveaways coordinated by Harvest Pierce County to support the gardens as well as dedicated staff. Tacoma is a unique example of integration of urban agriculture into the municipal infrastructure. The Harvest Pierce County Urban Agriculture Program (HPC) provides gardeners with intensive logistical support and access to inter-departmental resources. (K. McIvor, personal communication, February 17, 2020). Initially, HPC serves as a centralized point of contact for interested community members. Individuals who are interested in starting or joining a garden can

contact dedicated program employees to get answers and a direction to move forward. Different garden heads can coordinate volunteers and plot allocation while overall program direction and the coordination with other city departments is handled by the centralized program staff at Harvest Pierce County. Furthermore, the current culture within Tacoma motivates interdepartmental cooperation, which translates to ease of resource acquisition for different gardens (K. McIvor, personal communication, February 17, 2020).

One of the most important resources that Tacoma provides to gardens is a quality growing medium. All gardeners have access to TAGRO. TAGRO is a high-quality topsoil made from Class A biosolids, the solid material left following waste-water treatment. This natural soil mix uses two streams of waste to create a valuable resource that is supplied to community gardens for free. This soil is used to fill raised plots and due to the nutrient rich properties of the soil many gardeners report success in growing produce even without knowledge of how to amend soil or previous growing experience. TAGRO reduces the learning curve for gardeners and the initial success and yields can sustain momentum and interest in the garden. Healthy soil compounds the benefits of community gardens, increasing yields and access to fresh produce, maintaining physical activity in the garden, improving the appearance of the garden, sustaining long-term interest and development of the neighborhood. HPC also provides soil testing instructions and capabilities to gardens. Tacoma residents are concerned about historical soil pollution and the access to soil testing and clean soil is pivotal for gardeners (S. Brown et al., 2016).

Harvest Pierce County also provides access to municipal water and information for rainwater collection systems. Regular educational series and occasional events such as seed swaps or entertainment activities sustain gardener interest and connect each garden into a larger program network. Opportunities to socially connect are identified as important motivations for garden participation and HPC helps structure events to meet these needs. Each garden receives attention from program coordinators and each garden has access to the resources of the larger urban agriculture program (K. McIvor, personal communication, February 17, 2020).

How does HPC compare to other garden programs?

Other community garden programs have different numbers of gardens, different purposes for the program, and provide different resources and support to gardeners. A few cities that also have active community garden programs and have different support or resources are Toronto, New York City, and Seattle. A summary of garden programs is included in Table 1.

Toronto, Canada

Surveys of Toronto community gardens from 1987 to 1997 show the number of gardens increasing from fourteen to sixty-nine gardens. To monitor and organize the gardens, the Toronto Community Garden Network was formed in 1999 by a coalition of NGOs working on urban gardening and food-security. As of 2004 there were 110 community gardens, tended by 3,300 gardeners (Wakefield et al., 2007). The city program provides minimal resources or support and encourages gardeners to partner with non-profit organizations such as Toronto Urban Growers to fundraise or share resources. This is unlike Harvest Pierce County which provides significant material and administrative support.

The gardens are used for a variety of purposes and organization differs between gardens. Many gardens are started and coordinated by different groups and organizations such as:

neighborhood community groups, women's shelters, public-housing staff and nonprofit organizations. The gardens serve as spaces for recreational gardening, to cultivate food for personal consumption or community kitchens, or to sell as part of microenterprise projects. The gardens also provide social and recreational opportunities, supplement nutrition, educate the public about food production and preparation, are part of community-development strategies, offset income needs, and 'green' the urban environment (Wakefield et al., 2007). Gardens associated with senior centers, particularly those seniors who immigrated to Toronto, enable residents to grow culturally appropriate foods for traditional dishes while maintaining garden techniques. Many immigrants can find a place of familiarity and community in gardens that support diverse traditions. This community formation is similar to the experience of many immigrant communities throughout Harvest Pierce County (S. Brown et al., 2016).

The Toronto Community Garden Network emphasizes important aspects of the community food-security movement as it has developed over the past decade through community gardening and urban agriculture. The movement advocates for, develops, and promotes alternative food networks to improve access to food outside of corporate food systems. The network works to increase awareness of where food comes from through food systems education, to encourage diversity and cooperation, and to promote consumption of locally grown food (Toronto Community Garden Network). Currently, there is no information publicly available to describe the intensity of use for this program.

New York, NY

New York City is the most populous city in the United States with over eight million residents. The New York City Parks Department established the Green Thumb Program in 1995 to consolidate over 500 gardens under one management structure. The Green Thumb Program requires a garden liaison but program staff coordinates permits, resource allocation, mediation, and site development. Topsoil and building materials can be delivered through the Green Thumb Program, and when funding and sites allow, the city departments can install water outlets or coordinate trash removal. However, soil and building materials are not sourced through the garden program and must be arranged through outside sources. Partnerships with GrowNYC enable gardens to obtain or build rainwater capture systems (Green Thumb NYC).

Garden structure, crop plantings, and priorities are as diverse as the neighborhoods the gardens are located in. Gardens serve as spaces for communities to gather, sources of food for food pantries, opportunities to educate participants on garden components, and methods to engage with cultural traditions (Armstrong, 2000). The Green Thumb Gardening Program has funding to coordinate frequent events and regular newsletters due to the consistent funding through the Parks Department budget. Even though gardens are extremely diverse, the centralized support and community organization provided by the city allows for extensive garden growth (GrowNYC). This level of resource support and the central coordination of numerous gardens is highly similar to Harvest Pierce County but at a different municipal level and population scale. The Green Thumb Gardening Program and GrowNYC work at the city level whereas Harvest Pierce County is a county-level program with fewer gardens in a less dense region (Table 1). The per capita garden ratio of the Green Thumb Program is only 16% of the per capita ratio of Harvest Pierce County.

Seattle, WA

Seattle is a city of over 700,000 people in the Pacific Northwest with a mild maritime climate. The Community Garden (P-Patch) program began in 1973 with the first P-Patch Garden. The name, P-Patch, originated from the first community garden, Picardo Farm. Gardens come in many shapes, sizes, and ownerships. Today, the P-Patch Community Gardening Program, in conjunction with P-Patch Trust, a nonprofit organization, oversees 87 P-Patches distributed throughout the city. The city and non-profit together support the cultivation of over 25 acres of gardens that produce food for over 2,000 households. The P-Patch Community Garden Program is managed by the Seattle Department of Neighborhoods P-Patch Community Gardening Program (City of Seattle, P-Patch Program).

Similar to Harvest Pierce County, individual gardens are shaped by the neighborhood participants according to the needs of the community and founding members. Although there are garden liaisons that provide small amounts of coordination, management of the program is highly centralized. Each garden appoints a volunteer site coordinator, but the P-Patch Community Gardening Program staff collect fees and assign plots, manage a waiting list, and assist with gardener disputes. City-wide outreach events are planned once a year by staff; staff also attend annual gardener-gathering meetings in the spring. The location of the community garden program within the City of Seattle's Department of Neighborhoods sets an explicit priority of community building and community relationships, in addition to providing an affordable source of fresh produce and access to land.

The City of Seattle commits at least six full time staff and an annual budget of over \$800,000 to the garden program. Having a full-time staff gives the program a capacity to work with their gardeners and support the building of relationships within the garden. The program also aids with soil testing through labs associated with King County. The program does not directly provide topsoil, water infrastructure, or other building resources but by partnering with non-profits can provide funds for gardens to acquire materials. This program does not allow the use of biosolids in the gardens and has specific requirements for which soil amendments can be used in gardens. The P-Patch Program does have extensive education resources available for gardeners and holds occasional education events.

P-Patch will also remove inactive gardeners from the program and the waiting list is extensive (K. McIvor, personal communication, February 17, 2020). The P-Patch Program does not report on the use of their gardens. However, the program does control for use by telling gardeners to leave if their plots are consistently unused, this maintains all gardens at a relatively high use level.

<i>Table 1: Summary of Program Differences</i>				
<i>A summary of differences between garden programs according to geography, population served and resource availability from programs.</i>				
	Toronto	New York	Seattle	Tacoma
Population	2.93 million	8.33 million	753,675	198,397
Number of Gardens	250	550	87	83
Per Capita Gardens	0.000085	0.000066	0.00012	0.00042
Program Name	City of Toronto Parks	NYC Parks Green Thumb	P-Patch Community Gardening	Harvest Pierce County
Oversight Level	City	City	City	County
Management	Garden Supervisor	Dispersed with Garden Liaison	Site Leaders	Garden Leaders
Education	Limited Resources Available	Resources Available; Regular Events	Extensive Resources Available; Occasional Events	Extensive Resources Available; Occasional Events
Access to Free Soil or Compost	No	When Available	No	Yes
Access to Water	No	No	No	Yes
Access to Building Materials	When Available	When Available	No	Yes
Access to Soil Testing	No	Yes	Yes	Yes
Permitting Support	No	No	No	Yes
Garden Planning and Leadership Support	No	No	No	Yes
Free Pathway Materials	No	When available	No	Yes
Resource Coordination	No	No	No	Yes
Land Security	No	No	No	Yes
Active Intervention when Needed	No	No	No	Yes

Where does this program and research fit in?

This study was conducted to survey the community gardens within the Harvest Pierce County program to quantify the number of plots and area allocated to cultivation. The intensity of use was also evaluated. Finally, by using garden and community specific data, we aimed to understand what elements are associated with a garden being highly used and what elements are associated with unused gardens. Harvest Pierce County serves as an important study system to begin correlating garden characteristics with how gardens are used. Harvest Pierce County addresses all perceived obstacles and requirements for gardens. The homogenous access to resources and the structured initiation process for each garden control for effect of these external obstacles on level of use. Each garden has access to high quality soil, building materials, pathways mulch, and water and thus controls for the effect of these internal requirements on use. Since each garden is established to meet neighborhood needs there are internal differences that can be quantified and related to intensity and timing of use. This study allows us to describe how gardens are used when there are no limitations to resources.

The main questions that this study addresses are:

1. How many people are directly impacted by the Harvest Pierce County program?
2. How much land is under cultivation as part of this program?
3. How well used are the community gardens?
4. Does intensity of use vary equally between and within gardens?
5. Are there factors in garden design (such as plot size or number of plots) that impact intensity of use?
6. Do cultural, geographic, or socioeconomic factors impact garden usage?
7. Are there successful or failing gardens that can provide recommendations for future programs and policies?

Policies or programs that promote community gardens for any combination of benefits to the community are based on the assumptions that people will actively participate in the gardens. Any investment of public funds into a public resource should aim to maximize the benefits in relation to cost. Community gardens can provide significant benefits, but only if the gardens are used. This assumption holds true for the multiple types of benefits. For example, physical and mental health benefits associated with community gardens are only realized if people actively use their plots. Similarly, when accounting for food security or access to fresh produce the food is only be produced in a garden where the plots are actively tended. Although this assumption is intuitive it is absent from many cost-benefit analysis accounting or case studies of gardens. A quantification of intensity of use is critical from multiple perspectives. It can provide justification for continued support of a program, and it can allow for a more quantitative estimate of the program's benefits. Additionally, measuring use in different gardens can create more nuanced recommendations for community garden programs on how to maximize the use and therefore the associated benefits of gardens. The findings from this survey can be used for municipalities or other agencies interested in either starting a program or strengthening an existing program.

Chapter 3: Garden Census – Methods

How were the gardens surveyed?

All community gardens listed with the Harvest Pierce County Program were mapped on Google Maps and the location of the gardens was confirmed using the satellite imagery of the neighborhoods. Harvest Pierce County has 83 gardens registered with their organization (Harvest Pierce County, 2021). All registered gardens that could be identified from satellite map software and located by the survey teams were selected for surveying. In total 67 gardens were surveyed. Confirmed garden locations were added to a Google map and coded into batches based on proximity. A batch of six to eight gardens was surveyed per sampling day, surveys were completed two to three times a week. Sampling was completed batch by batch to complete a census across Pierce County. The survey was conducted in the summer of 2018 between June and August when peak garden usage was expected. A subset of the gardens was surveyed across multiple years and multiple seasons to estimate usage over time. The subsample was completed from November 2017 to June 2019.

Gardens were surveyed to measure number and dimensions of plots. Intensity of use was also measured based on a qualitative ranking. Each garden was measured by a minimum of two individuals. The initial batches were surveyed by the same two-member team to establish standard procedures for rankings. Each garden was visited by at least one of these foundational team members for all subsequent surveys. Any discrepancies were discussed as a team and a consensus reached for the dimensions of each plot and ranking of use (Image 2). Total garden area was calculated by summing the working area of each plot within a garden.

For each garden the team systematically measured each garden plot that was used to produce fruits, vegetables, or flowers. Any decorative plots, educational plots, or demonstration projects were noted but not measured. If a garden plot or planting area was split into smaller plots with fences, denoting multiple users, these smaller plots were measured as individual plots. Plots were identified and measured with the intention of measuring each user's efforts so that the number of plots counted reflected the approximate number of gardeners. Generally garden plots were differentiated by styles of materials or plantings, fences, pathways, numbers, or by following the perimeter of raised plot materials. Once the boundaries of a garden plot were identified, the team of researchers used a meter tape to measure the perimeter of rectangular or square plots or to measure the diameter of circular plots. The dimensions of each plot were

*Image 2: Collaborative Census of Each Plot
Dr. Sally Brown discusses her assessment of plant health and other indications of use.*



recorded and then the researchers would rank the use of each plot. In cases of irregular plot shapes, size was estimated to the nearest circle or rectangle.

Intensity of Garden Plot Use

The intensity of use was ranked on a numerical scale from zero to three. The rankings were based on the following criteria:

<i>Table 2: Plot Use Ranks and Examples</i>	
<i>0: A rank of zero indicated an abandoned plot with no evidence of effort. These plots were overgrown with weeds or completely barren. Examples of plots with a zero rank are shown below</i>	
Ex 0:	
<i>1: A rank of one indicates that there was minimal effort put in at some point during the growing season. Examples indicate clear evidence of plantings that have not been maintained. Plants have gone to seed or are overtaken by weeds. This ranking was also used for plots where only a small portion of the plot area showed any evidence of effort. Examples of plots with a one rank are shown below.</i>	
Ex 1:	
<i>2: A plot ranked at two is used at a moderate level of effort. There is evidence of semi-regular use and maintenance but there may be some weeds and untended crop plants. A portion of the plot remains unused. These plots would be expected to provide some amount of edible harvest for the gardener. Examples of plots with a two rank are shown below.</i>	



Factors that influenced the ranking included: the number, size, and types of plants, how much infrastructure was installed in the garden plot, how much weeding and watering was evident, whether there were cover crops or other soil-building practices, how much recent maintenance had been performed on plants or infrastructure, and whether appropriate modifications such as mulching, or frost protection were present. The ranking was meant to estimate the level of effort spent on the plot, not necessarily the success of the plantings. Plots were not penalized for lack of growth unless it could be attributed to lack of regular watering or attention. Examples of ranked gardens are listed in Table 2. Researchers would each rank the plot then discuss until consensus was reached. After the systematic survey the number of plots was tallied from rankings and confirmed by counting all the plots, regardless of size.

Size of Plot or Garden Plot

After the survey was completed the size of each plot was calculated from the dimensions recorded in the field. Within a garden the individual plots can be similar or very different in sizes. In some gardens there are many garden plots that were planned and installed at the same time and these often were all of the same size. In other gardens there was natural merging of neighboring plots into a double-wide or triple plot that was managed by one gardener. When

plots are added on later or in the area that was remaining after the main plots have been laid out there tend to be more irregular or different sized plots used to maximize the growing area in the garden. Within a garden, the size and shape of plots often varies. There is also no standard or convention between gardens. In this program, the responsibility for garden design falls to the individual gardens.

Growing Area in Each Garden

The area of each plot within a garden was combined into a measure of the total growing area for each garden. For this survey the total area only includes the working plots. Measures of the total gardening area did not include pathways, decorative plots, or space dedicated to other uses such as children play areas. The total area is directly related to the size of the lot, either public or private, that has been dedicated to the garden but does not reflect the working space. Other land uses can include picnic benches, tool storage sheds, children play areas, pathways wide enough to move wheelbarrows or carts down, compost bins, instructional displays, pollinator support plots, teaching plots, rainwater catchment systems, and other educational or community-driven infrastructure. While these areas can be critical to the success of the garden, they do not provide information on number of people involved in the garden or potential productivity of the garden (Image 3).

Number of Plots or Garden Plots

Gardens vary in how many plots or gardens plots are in each garden. In most gardens, each plot is used by a different participant in an allotment style. Some plots are community donation plots where many gardeners volunteer time to maintain one plot and donate the produce. In general, the number of plots can be interpreted as an indirect measure of how many individual gardeners work in the garden. The number of plots is constrained by the total area of the garden. However, there are instances where gardens are of similar size but divide the same area into fewer larger or many smaller plots. The number of plots is independent from the size of each plot but based on the logic outlined above, is correlated if the total garden area is held constant. For the purpose of the analysis, the number of plots was treated as independent of both the total garden growing area and the size of each individual plot (Appendix 1 and Table 6).

Image 3: Example of Garden Area

Plots used to grow crops are separated by pathways with raised platforms and benches used as spaces to gather. The total growing area is a measure of just the space dedicated to growing vegetables or other crops.



What additional variables were collected?

Besides variables that are all internal to each garden there are contextual or external factors that can influence gardens. Each garden that was included in the survey was located within a census tract from the 2016 US Census. Data considered from the Census included the median income of residents, the percentage of white respondents, and the number of racial groups self-identified by respondents. These factors were considered in the analysis of intensity of use for the different gardens.

Median Income

While HPCP does provide free soil, soil testing, materials for raised plots and pathways, and water access, there are costs associated with gardening that HPCP does not provide. Trellises, plants and seeds, tools, hoses, fencing, mulch, specific soil amendments, frost protector are all resources that the gardeners must provide. Maintaining a garden also requires a significant time commitment. Communities where resources are limited may find it difficult to maintain a garden.

Property Value

Active and well-used gardens improve the aesthetics of the neighborhood and provide a neighborhood amenity in the form of a gathering space (Saldivar-Tanaka & Krasny, 2004). In other cities the presence of community gardens has been correlated with an increase in the surrounding property value. This benefit may already be reflected in the current valuation of the property or it could be limited by the age of the garden since it would take time for the property value to be impacted by the presence of a community garden. This metric did not look at the change over time since the individual property values over time have not been documented. Instead, the median home value of homes within the two blocks around each garden were checked at one point in time using the estimation of a free property value software online. This variable also assumes that a garden's impact on property value is consistent and has the greatest impact right next to the garden. Understanding the spatial impacts or how far a garden affects the property value is beyond this metric. Understanding the median home value around gardens in the present moment gives a better understanding of where these gardens are located economically.

Deliveries of TAGRO

In previous research TAGRO dramatically increases the yield of vegetables and the water holding capacity of the soil (S. L. Brown et al., 2016; McIvor & Brown, 2016). This suggests that gardeners that use TAGRO put less time and energy into tending the soil and reap higher yields compared to gardeners that use conventional fertilizers or do not alter the soil. As it is a single amendment with multiple benefits, using this product can lower the knowledge barrier related to gardening. Many first-time gardeners do not have any knowledge of soils or soil fertility and can become frustrated by poor plant growth. Here the number of deliveries of TAGRO to a garden was considered as a potential predictive measure of the success of the garden (S. Brown et al., 2016; McIvor & Brown, 2016).

Percentage of White or Diversity of Garden

In previous surveys and with qualitative observational data gardens are heavily shaped by the culture of the gardeners (Ackerman et al., 2014; Daftary-Steel et al., 2015). Gardens can be places of information/ knowledge exchange (McIvor, 2011; McIvor & Brown, 2016). Maintenance practices, crop choices, materials used for plots, soil tending practices, crop layout, and even intensity of crop production are all related to the cultural context of the garden. In certain cases, gardens are started and used primarily by specific immigrant groups such as the Viet Huong Community Garden which is used primarily by Vietnamese immigrants (McIvor & Brown, 2016). These gardens can serve as a community gathering space where people who speak the same languages and cook similar foods can celebrate their culture. Each garden was located within a census tract and the percentage of white residents within the tract was assigned to the garden. This metric assumes that the people using the garden reside within the same census tract where the garden is located.

What statistical analyses were completed?

Descriptive statistics were used to provide basic information on the gardens in the program. The mean, median, and standard deviation were calculated for the following variables:

Per garden:

- Number of plots
- Size of plots
- Arable garden area
- Median income
- Median home value
- Diversity of area

Program total

- Number of plots
- Total area under cultivation
- Estimate of individuals directly impacted

The intensity of use measure was the primary metric used to quantify the success of gardens. Both ANOVA statistical analyses and regression analyses were completed to check for significance of per garden variables on the intensity of use (Appendix 1).

ANOVA analyses were completed to look for significant differences in the mean use of gardens that could be attributed to the 'per garden' variables listed above. To account for the different number of plots in each garden the dataset was weighted to normalize the data and prevent garden-level parameters from being skewed by total number of plots. I did not complete a sensitivity analysis on the linear regressions or ANOVA analyses. Without weighting, gardens with more plots would heavily skew analyses compared to gardens with fewer plots. Each variable was tested with an ANOVA to determine if each variable alone was significant.

A linear mixed model was completed to determine which of the measured variables had a positive or negative effect on intensity of use (Appendix 2). The size of each positive and negative effect may not be accurate when using a mixed linear model on ordinal data and so the value of each coefficient will not be discussed, only whether it was positive or negative. Although all identified gardens were surveyed, some gardens were excluded from the analysis as outliers. Gardens were excluded if they were used as urban farms or urban orchards and tended as a collective production effort rather than with individual plots. Of the total gardens surveyed-four fell into this grouping. These outliers had large total growing areas, typically had the highest use rating, and often were cultivated as a unit or with fewer and larger plots or a few plots. These extreme values would significantly skew the analyses and were excluded. After outliers were omitted, there were 63 gardens within the dataset.

Intensity of use was the primary outcome variable. The data that was collected would be defined as ordinal variable but for ease of analysis was treated as a continuous variable. This violation of the assumptions in the model prevents accurate interpretation of coefficients. The model results would provide directional relationships, but the coefficient values are not accurate. The same researchers determined level of use for all plots therefore plots are consistently ranked for outcome and no bias was introduced by researcher. The predictive variables considered as

potentially impacting intensity of use included the garden specific measures (size and number of plots, as well as the total garden area, and the number quantity of TAGRO delivered) as well as information related to the community surrounding each garden (median income, neighborhood (geographic area), percentage of white residents and median home value).

For predictors, garden-level factors include the number of plots in the garden, the total size growing area of each garden, the median income of the surrounding census tract, the geographic area, the percentage of white residents around each garden, the median home value of the houses around each garden, and the amount of TAGRO delivered to each garden. The only plot-level predictor is the size of each individual plot. The distribution of each predictor was checked for skewness and kurtosis using R (RStudio Team, 2020). Appropriate transformations were applied to correct for skewness and kurtosis when needed. The transformations applied are included in Table 3. All predictors were tested for correlation using pairwise correlation tests. When sets of variables were highly correlated, one of the correlated variables was selected for the model. Highly correlated variables were not used in the same model to avoid violating statistical assumptions.

All analyses were completed using the statistical software R and packages ('readr', 'MASS', 'fBasics', 'car', 'MuMIn', 'fmsb', 'gss', 'spatstat', 'ncf', 'sp', 'gstat', 'quantreg', 'DAAG', 'mcsM', 'ggplot2', 'dplyr', 'cglm', and 'lme4') (RStudio Team, 2020).

What subgroup statistical analysis was completed?

I also created groupings of the gardens to facilitate analysis. Gardens were manually selected as 'high-use' or 'low-use' based on the proportion of individual plots of different use intensities. If a garden plot had 50% or greater of the beds used only at level 0 or 1 then they were grouped into the low-use group. If a garden had 80% or more individual plots used at level 3 then the garden was grouped into the highly-used category. These two groups represented the extremes of the distribution of intensity of use. The remaining gardens were then divided into a 'mid-high' and 'mid-low' to create four groups of 17 high-use, 20 mid-high use, 13 mid-low use, and 12 low-use gardens. The range, median, and average of intensity of use was calculated in each group. Then I used an ANOVA to compare the four different groups on each of the predictor variables. This sub analysis approximated an experimental assignment of use and then looked at the other variables means to see if there was a significant difference in the means of total area, number of plots, plot size, median income, property value, and diversity between groups.

<i>Table 3: Summary of Variables Collected</i>		
Variable	Description	Transformation
Garden Name	The name of a Community Garden in Pierce County, mostly within Tacoma city limits	none
Plot Size	The area of each individual plot used to grow produce	log10
Total Garden Growing Area	The total area of all plots in the garden; the total farmable area or the sum of all individual plots	log10
Number of Plots	The total number of plots in each garden, a count of individual plots	none
Intensity of Use	The qualitative ranking of plot according to level of effort. no effort or abandoned (0), little or infrequent effort (1), occasional or moderate effort (2), consistent or high levels of effort (3). See Table 2 for examples.	none
Median Income	Median household income based on the 2016 census tract in which each garden is located	none
Property Value	The median home value in 2 blocks (0.5 mile radius) of each garden	log10
TAGRO deliveries	The quantity in yards of TAGRO delivered to the garden	log10 + 1
Percentage of White Residents	The percent of white respondents from the 2016 census in which each garden is located	none
Neighborhood	A geographic designation of plots	none

Chapter 4: Census Results –

Overview of the Harvest Pierce County Program

Data from 63 of the 66 gardens surveyed were included in this analysis. The three gardens that were excluded did not follow the typical allotment-style use structure and were typically better classified as urban farms. The Franklin Pierce Farm, Blueberry Park Farm, and Curran Apple Orchard had large total growing areas, were highly used (use-level 3) and often were cultivated as a unit or with fewer and larger plots or just a few plots. The Curran Apple Orchard had only one large plot, while the Blueberry Park Farm had seven plots that were 4,460 m² each. The Franklin Pierce Farm did have plots that were used at a lower intensity with an average use of 2.29; however, the collective management of large plots justified its designation as an outlier.

Across the gardens included in the analyses, there were 1,960 plots. The number of plots in a garden ranged from 81 plots to 2 plots. University Place Community Garden, Shepherd's Field, and Salishan Community Garden were the three gardens with the most plots with 81, 73, and 72 plots in each garden respectively. Mountain View in Eatonville, Graham Lutheran, and Lincoln High School Community Garden were the three gardens with the fewest plots with 2, 5, and 5 plots respectively. The mean and median number of plots across all gardens was 31.6 and 25 plots. Total plot area covered 24,133 m² or 2.4 ha of land across Pierce County. The smallest garden, 48th and Yakima, had 12.9 m² of

working space and the largest garden, Abundance Community Garden, had 3,441 m² or 0.34 ha of arable space. This total area does not include the 81,359 m² (8.1 ha) of land used as urban farms which were counted as outliers. The Harvest Pierce County Program has over 26 acres or 10.5 hectares of growing area in both urban farms and community gardens. An example of a large garden with divided plots is shown in Image 4.

The average plot size across the entire program was 25.6 m². The gardens with the largest plots were the Salvation Army Community Garden which averaged 228 m² plots, the Gallucci Learning Garden with plots that averaged 183 m², and Abundance Community Gardens which had plots that averaged 114 m². University Place, Shepherd's Field, 48th and Yakima, and Bonney Lake Community Garden all had an average plot size of less than a square meter. The measured variables are compared and reviewed with more detail in later sections.

Image 4: Large Garden with Infrastructure

Fences divide individual plots that are further divided or infrastructure as the gardener chooses.



How are gardens used generally?

In general, gardens were well used. Across all gardens, the average intensity of use was 2.26 with a standard deviation of 0.55 and the median intensity of use of all gardens was 2.37. Most plots are highly used. Across all gardens surveyed 194 plots were found to be unused (use-level 0), 233 plots were of low use (use-level 1), 403 plots were well-used (use-level 2), and 1,154 plots were highly-used (use-level 3). There were 1,960 plots in total, likely representing approximately as many families participating in the program and using the gardens. There were six gardens in which all plots were highly used (use-level 3). These gardens were: Springbrook Park, St. John Bosco Food Bank, Lincoln Community Garden, Lincoln High School, Abundance Gardens, and Kandle Community Garden. No gardens were entirely abandoned, but Mountain View (Eatonsville) and the YMCA Garden in West End averaged only low-use across all plots (use-level 1).

About half of the gardens, 35 out of 63, were directly associated with churches, schools, non-profits, and other community-driven organizations. Garden use was not predicted by association with an organization. Five of the most highly used gardens as well as some of the lowest use gardens are associated with formalized organizations. The St. John Bosco Food Bank (use-level 3) and Abundance Gardens (use-level 3) both have a portion of the garden dedicated to growing food that is donated to local charities. Both gardens are affiliated with religious congregations and volunteers can have their own plot and or work in the donation plots. The volunteers and community take pride in the gardens efforts to increase food security (“Abundance Garden,” n.d.; “Food Bank Garden,” n.d.). Springbrook Park (use-level 3) is similarly managed to produce food for donation into the community but does not have an affiliation to an organized religion and instead is maintained and managed by the Springbrook Connections volunteer group (“Springbrook Park Community Garden,” n.d.). The Lincoln Community Garden (use-level 3) and the Lincoln High School Community Garden (use-level 3) are associated with the Lincoln High School Garden Project which is a formalized organization of students and volunteers. The Lincoln High School Garden Project, also known as Abe’s Golden Acres is integrated into curricula, used as a life skills program, and can provide fundraising opportunities for students and the garden (Hemmann, n.d.).

Some of the least used gardens are also associated with organizations. The Boze Neighbor’s Community Garden (use-level 1.07) and the Mountain View Community Garden (use-level 1) both are associated with community organizations. The Boze Elementary School and the Boze Neighbors Organization share use of the garden space which has recently received reconstruction to make the garden safer and capitalize on its accessibility to the community (Ushka, 2020). The Mountain View Community Garden (use-level 1) is managed by a Co-Op with regular events and learning opportunities alongside the Gallucci Learning Garden (*Mountain Community Garden - Home*, n.d.). Gardens are associated with organizations either through direct management or as a tangential resource across the distribution of use. Mid- range gardens are similarly associated with organizations. However, this association does not evaluate the level of support provided by the organization.

The six highest and lowest use gardens are shown in Table 4. The different measured variables including number of plots, plot size, total area along with community measures are also included. Each of the variables that I measured and collected were analyzed to identify any predictors that contribute more to increasing the intensity of use. Each variable is described in more detail in following sections.

Table 4: Summary of Example Gardens
A comparison of the six highest and six lowest used gardens on survey variables.

Garden	Intensity of Use (0 to 3)	Number of Plots (count)	Total Area (meters ²)	Average Plot Size (meters ²)	Percent White (%)	Median Income (USD)	Median Value	Neighborhood
Abundance Gardens	3	30	3,441	115	91%	\$63,385	\$356,906	New Tacoma
Lincoln High School	3	5	327	65	93%	\$71,536	\$517,495	South End
Kandle Park	3	13	139	11	52%	\$17,105	\$246,455	University
St. John Bosco food bank garden	3	66	520	8	67%	\$44,621	\$247,946	Gig Harbor
Lincoln	3	14	71	5	90%	\$82,417	\$440,114	Gig Harbor
Springbrook Park	3	21	36	2	70%	\$51,895	\$249,786	Sumner
8th and I/Neighbor's Park	1.41	49	95	2	48%	\$50,734	\$233,955	Eastside
Green Thumb	1.23	44	230	5	86%	\$66,859	\$326,547	Graham
Stewart Middle School	1.13	8	84	11	42%	\$24,581	\$189,893	Lakewood
Boze Neighbors Community Garden	1.07	27	45	1	84%	\$67,870	\$259,440	Elk Plain
Mountain View (Eatonville)	1	2	737	368	54%	\$41,689	\$219,853	North End
YMCA	1	12	49	4	85%	\$67,364	\$423,736	60700

What were the statistical results?

Statistical analyses were used to see if any of the variables included in this analysis would be predictive of the intensity of use of the different gardens. I found only one significant predictive relationship between variables measured and increased use of gardens at an alpha level of 0.1. Most ANOVAs to compare the variation of the measured variables with the variation in use did not result in significant relationships. However, the total area of the garden had a p-value of 0.085 which is significant at an alpha level of 0.1 (Table 5). This means that the larger gardens were used more intensively than the gardens with less area available for cultivation. None of the socioeconomic or internal variables were significantly related to use. This can be seen with the examples of gardens selected in Table 4. For the most used community gardens number of plots varied from 5 to 66 with an average of 24.8 plots per garden. The least

used gardens had a total number of plots that varied from 2 to 49 with an average of 23.7. Apart from Abundance Gardens which is the largest garden in the dataset, the total plot area of the most used gardens averaged 212.4 m² and the least used gardens averaged 206.4 m². The percent white, median income, and median home value are similarly close in value. The residents around the most used gardens were 77% white with a median income of \$55,160 and a home value of \$343,117. The residents around the least used gardens were 67% white with a median income of \$53,183 and a home value of \$275,570. Although not significantly, higher used gardens tend to be larger with more plots and in richer whiter census tracts. However, the gardens overall are well-used across the range of communities and shapes and sizes.

<i>Table 5: ANOVA Results Summary</i>					
<i>A summary of results from ANOVA analysis of different predictors on the average use recorded per garden with reported p-values and other relevant values.</i>					
Predictor	Df	Sum Sq	Mean Sq	F Value	Pr(>F)
Total area (log 10)	1	0.923	0.9226	3.068	0.0852
Number of plots	1	0.362	0.3619	1.204	0.2772
Percent white	1	0.170	0.1701	0.566	0.4550
Interventions	1	0.277	0.2768	.921	0.3414
Residuals	57	17.139	0.3007		

What are the general trends we see across all the different variables?

Although gardeners have little control over the size of the community garden, each garden as a community divides the arable area into plots. Dividing the garden into many smaller plots enables more individuals to participate in the garden but provides less space for a family to grow produce. Larger plots have the potential for larger yields of produce but mean that fewer individuals can have their own plots in the garden. Here I considered the impact of internal variables on use intensity of the gardens. Internal variables were the size of each plot, the number of plots in a garden, and the size of the garden. The size of the plots and the size of the arable area in the garden were correlated. This means that the larger gardens tended to have larger individual plots than the smaller gardens.

Table 6: Correlation of Internal Variables and TAGRO

The correlation table shows the significant correlations between structural variables and TAGRO which is correlated with structural variables. Variables that have a positive or negative correlation greater than the absolute value of 0.6 are considered significantly correlated.

	Total Area	Plot Size	TAGRO	Total Plots
Total Area	1	0.677	0.831	0.445
Plot Size		1	0.616	-0.016
TAGRO			1	0.309
Total Plots				1

The correlation of total garden area with the size of plots, suggests that larger gardens tend to have larger plot sizes (0.68). There was also a strong relationship between TAGRO deliveries and larger gardens since more TAGRO is needed to cover larger gardens (0.83). TAGRO is considered an external variable but was included in this table due to the high correlations with garden area and plot size. Structural variables are compared to use in later sections.

In addition to internal variables, contextual variables were added for each garden according to the census tract of the garden. These variables relate to the socioeconomic status of residents around each community garden and the assumed demographics of the garden participants. In general, the percentage of white residents, the number of racial groups reported, and the median income of the census tract are all correlated. Additionally, the median home value is correlated to the median income. As the percentage white residents of a census tract increases, the home value and median income also increase. Conversely, as the population of diverse groups increases, the median income and median home value decrease.

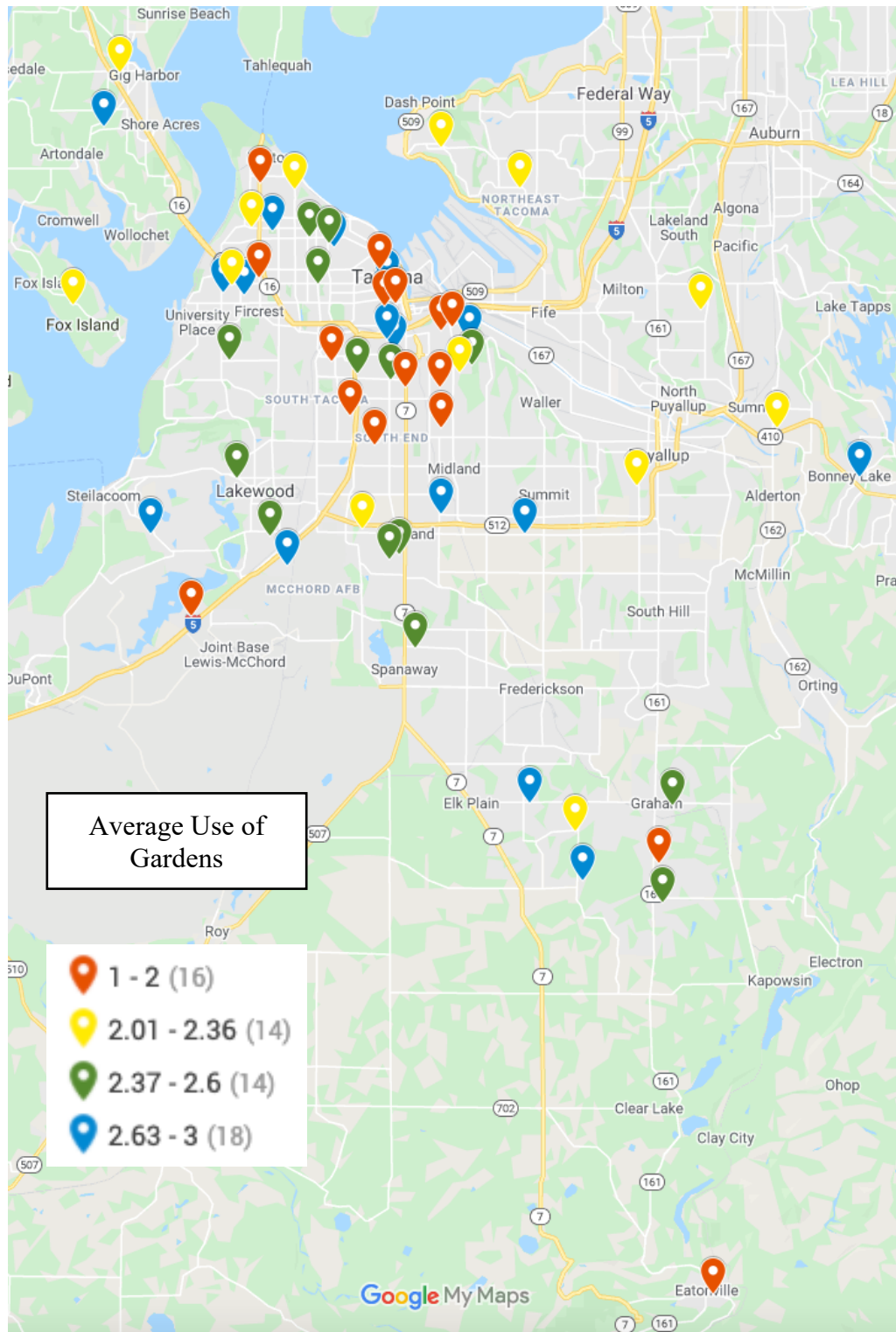
Table 7: Correlation of Socioeconomic Variables

The correlation table shows the significant correlations between socioeconomic variables. Variables that have a positive or negative correlation greater than the absolute value of 0.6 are considered significantly correlated.

	Percentage white	Diverse groups	Median income	Median home value
Percentage white	1	-0.628	0.781	0.713
Diverse groups		1	-0.653	-0.764
Median income			1	0.710
Median home value				1

Unsurprisingly, gardens in census tract with a higher reported income also have nearby houses with a higher home value (0.710). These census tracts also tend to be white neighborhoods, with a positive correlation of median income and the percentage of white resident respondents (0.781). As a confirmation of this sociodemographic trend, the more ethnic groups that responded during the census or the more diverse the neighborhood, the lower the median income and home value of the garden area (-0.653; -0.764). Socioeconomic variables are compared to use in later sections.

Figure 2: Map of Gardens by Average Use
A map of community gardens color-coded by use-level demonstrates the spatial variation in how gardens are used around Pierce County; in general, average use is well-distributed.



How does the geographic distribution impact gardens?

Harvest Pierce County groups gardens into eight areas based on location (K. McIvor, personal communication, February 17, 2020). The average use of the gardens in each area is listed in Table 8. The program designated areas reflect colloquial groupings of neighborhoods. Using the breakdown of zones given by HPC the average use of all gardens in each zone is relatively consistent. In general gardens within the East designation were used the least while gardens in the South area were used the most. Almost all Eastside gardens were used below the average garden intensity of 2.26 but other neighborhoods were not as consistent. The West End area had one of the lowest used gardens (YMCA 1) and one of the highest used gardens (Kandle 3). On average though the program and garden resources are well used across geographic areas.

The census tract of each garden is a geographic delineation associated with demographic parameters such as the median income, the diversity of residents, and the population density of an area. Based on the census tracts with gardens, the population density of areas with gardens ranges from 26 persons per square mile in the least dense region to 10,054 persons per square mile in New Tacoma. The average population density in the HPC zones was similar (Table 8). The area with the lowest density was closest to the Mountain View Garden in Eatonville which had lower use intensity (2) than the mean and median values. However, other gardens that are in less densely populated census tracts have above average use. For example, the Hosmer Tropical Park Community Garden (2.36) and 48th and Yakima Community Garden (2.43) are in census tracts with 88 and 357 people per square mile respectively but show use intensity close to the mean overall value. The densest census tract has 10,054 people per square mile and is home to many gardens. The gardens within this high-density tract cover a spectrum and include both high-use and low-use. Kandle Park CG (3), University of Puget Sound CG (2.53), Bethany Presbyterian Church CG (2.33), and Grace Baptist CG (2.28) were used at or above the average use intensity while YMCA (1) was one of the most poorly used gardens. The average population density around community gardens was 4,306 people per square mile with a standard deviation of 2,536 people per square mile. Each of the neighborhoods designated by HPC had an average population density within one standard deviation of the mean.

I analyzed the distribution of gardens across Tacoma Pierce County to see if garden locations were equally distributed across all neighborhoods (Figure 2). Differences in garden location distribution could result in masked impacts by the external variables included in the analysis. Additionally, garden neighborhood might be a predictor of the intensity of use. As part of this analysis, I plotted the gardens on a map of the area with coding to designate the intensity of use (Figure 2). There is not an immediately noticeable pattern of usage by area, but instead smaller clusters of gardens with similar use. The lowest used gardens (Mountain View in Eatonville, and YMCA on West End) were in different neighborhoods and the most highly used gardens were also in different areas (Springbrook Park, St. John Bosco Food Bank, Lincoln Community Garden, Lincoln High School, Abundance Gardens, and Kandle Community Garden). Garden neighborhood does not have significant predictive effect on intensity of use (F-value = 0.835, p-value = 0.668). Population density was similarly not predictive of intensity of use (F-value = 0.037, p-value = 0.849).

Table 8: Summary of HPC Geographic Groupings
Average use and associated demographic numbers for geographical grouping of gardens according to HPC service areas.

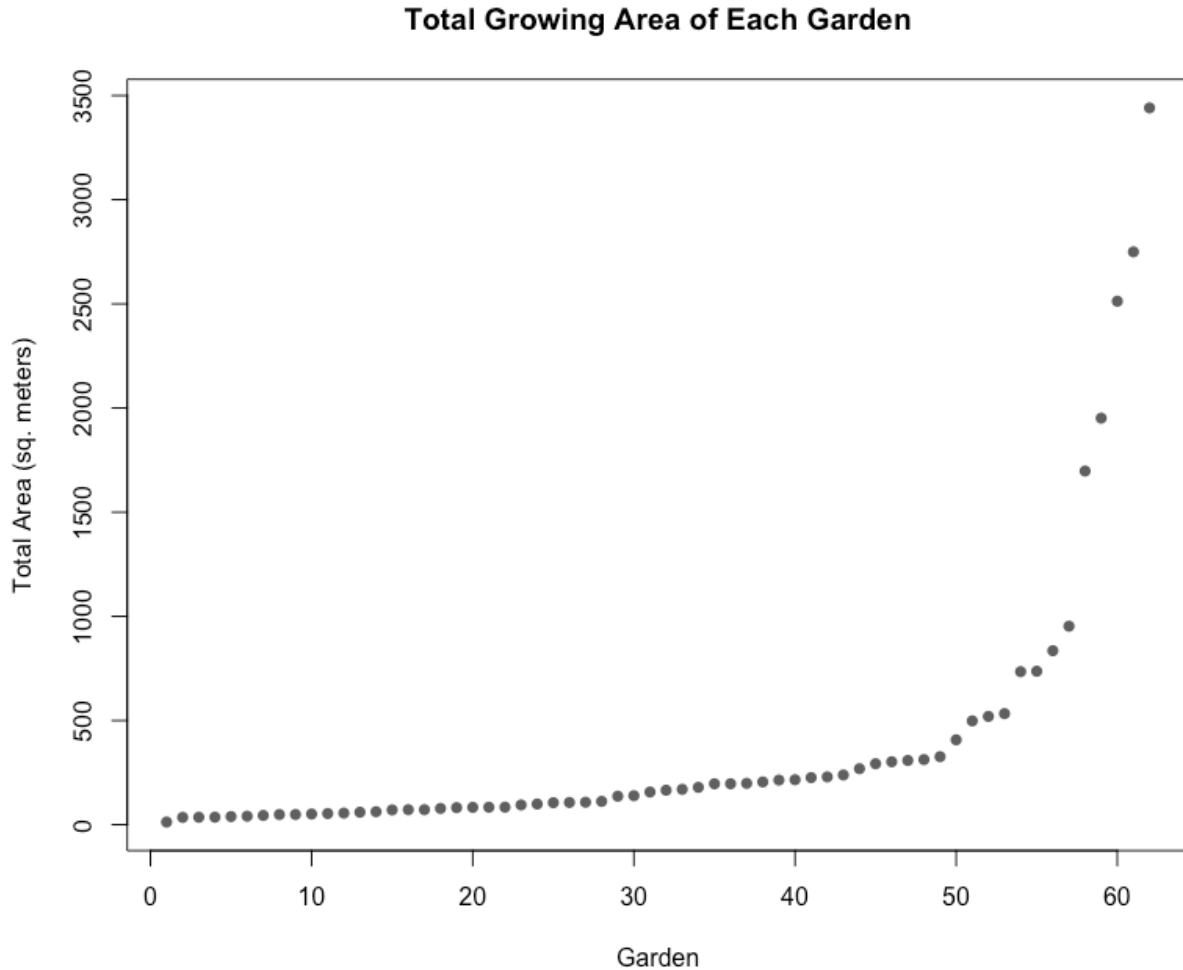
Area	Mean Use	SD	Median Use	Number of Gardens (n)	Average Population Density (people/mile ²)
Central	2.22	0.59	2.45	9	5,040
East	2.08	0.65	2.19	15	2,257
Key Peninsula	2.40	0.31	2.31	3	3,260
North	2.34	0.58	2.43	10	6,928
Northeast	2.28	0.26	2.21	5	4,527
Rainier	2.19	0.71	2.50	7	5,112
South	2.64	0.29	2.54	6	4,134
West	2.23	0.54	2.48	7	4,117

What is the total area used to grow produce across gardens?

Across the garden program, all the gardens surveyed totaled a growing area of 10.55 hectares. The distribution of each garden's size is shown in Figure 4. The mean size of each garden was 389 m² with a median size of 161.3 m² and a standard deviation of 671.1 m². Gardens used as urban farms had larger total areas and were excluded from the analysis. The smallest garden had 12.9 m² of working space and the largest garden had 3,441 m² of working space. The smallest garden was Graham Lutheran Community Garden with 5 smaller plots of about 3 m² and an average use intensity of 2.6. The next smallest garden at the YMCA was one of the least used gardens (use 1) and was 35 m² with 12 plots also with an average plot size of about 3 m². The largest garden, Shepherd's Field CG was slightly above average use at 2.36 and had 73 large plots of 48 m². While some gardens are almost 9 times larger than the average, such as the Shepherd's Field CG, only 11 out of 63 gardens exceed 500 m² of dedicated growing space [University Place (2.54), Bonney Lake Community Garden (2.68), Wapato Hills Community Garden (1.75), Lakeview Church of Christ (2.33), Kandle Community Garden (3), Viet Huong (2.83), Proctor Community Garden (2.56), Tacoma Community College (2.87), Franklin Park (2.74), Swan Creek Park Community Garden (2.38), and Shepherds Field (2.36)]. All except for Wapato Hills Community Garden had above average use, which supports the trend of larger gardens having higher use intensity.

Figure 3: Total Area of Each Garden

The distribution of total areas measured for each garden in order from the smallest area to the largest.

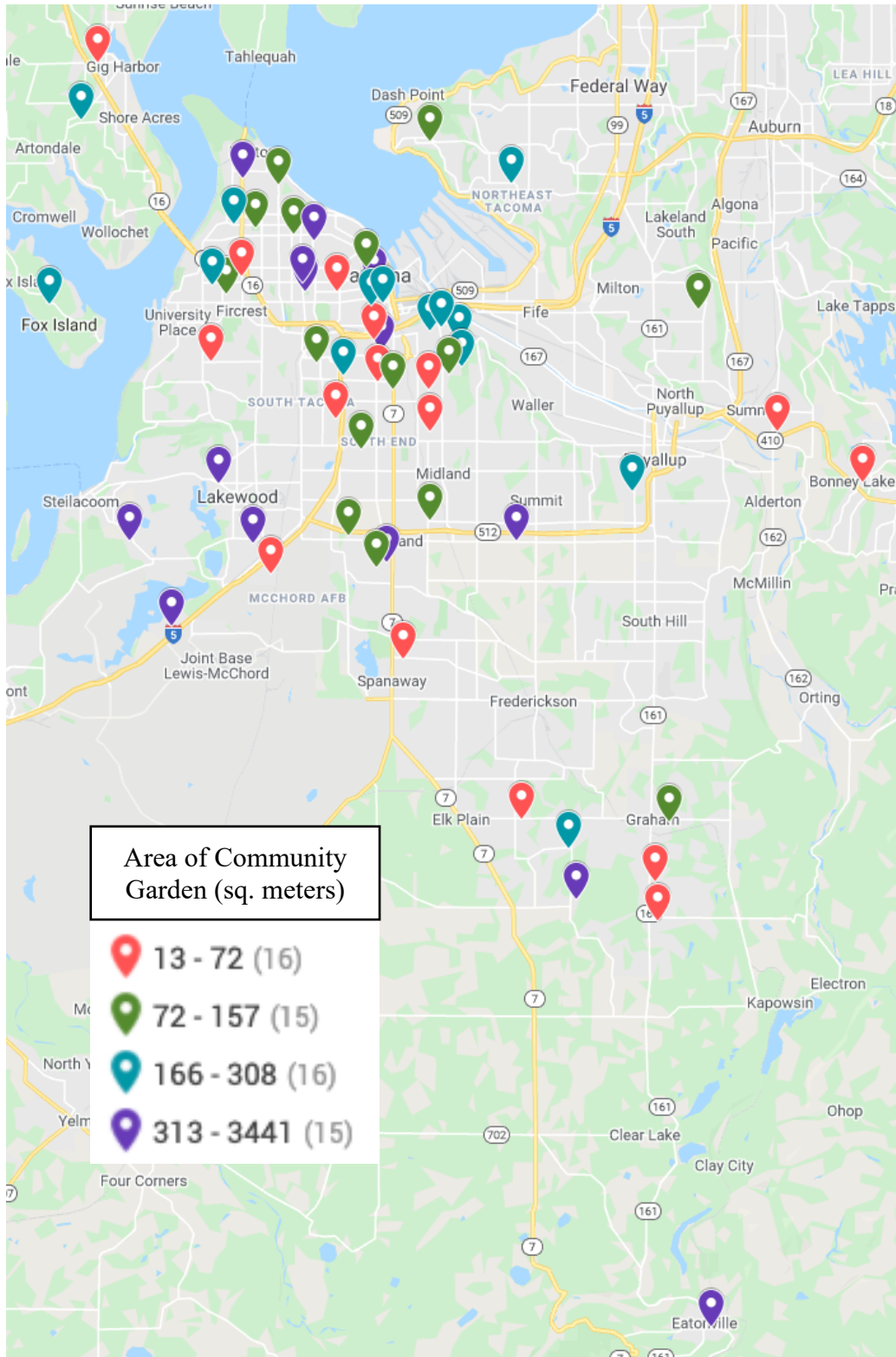


Excluding the 11 largest gardens from the analysis, the mean size of the gardens was 146 m² (standard deviation of 107 m²) with an average plot size of 8 m² and a mean of 27 plots per garden average with a standard deviation of 16.8 plots. Most community gardens in the program are well distributed below 500 m² (Figure 2). Although the total number of plots is not strongly correlated with the size of the garden, the correlational relationship is weakly positive. This is intuitive as gardens with larger area will have more space to create individual plots. In general, the larger the garden the more plots that a garden is broken into. With a strong positive correlation (0.677), the larger the garden, the larger the size of the plots in the gardens. This may reflect a tendency to maximize the size of plots with constraints by total garden size. Although larger gardens tend to be used more, the trend is not significant (F-value = 3.084, p-value = 0.0842). Of any of the variables examined, the area of the garden is the most significant predictor for intensity of use.

We also looked at external factors to see if size of garden varied based on income (F-value=0.491, p-value=0.486), neighborhood (F-value=1.077, p-value=0.304), median home value (F-value= 0.116, p-value=0.735), or percent white (F-value=0.07, p-value=0.793) and found no relationship between any of these variables and garden size. The nine largest gardens were in different neighborhoods and census tracts, and the smallest garden (Graham Lutheran Community Garden) was in another. There is no pattern in distribution of size according to neighborhood grouping by Harvest Pierce County or population density. This suggests that there is no pattern in garden size distribution and that the gardens are consistent in size across geographic and social variables included in this analysis. Figure 3 shows the distribution of gardens by the size of the garden.

The total area available for gardens is relevant as a tool to estimate yield potential for the program. With a better sense of the average use intensity for this total area more accurate food yields and other benefits can be accounted for.

Figure 4: Distribution of Community Garden Area
 A map of community gardens color coded by the total area of the garden to show the distribution of garden size in square meters.



What is the total number of plots across gardens?

The total number of plots within each garden varied from as small as 2 (Mountain View – Eatonville Garden) to 81 (University Place Garden). Although there were outliers, the number of plots was relatively consistent across gardens. The median number of plots was 25 and the average community garden had about 32 plots (with a standard deviation of 20.2). Outside of one standard deviation, 12 gardens have fewer than 15 plots while 11 gardens have more than 55 plots. The distribution in the number of plots per garden is shown in Figure 5. The total number of plots tended in the program was 1,960.

The number of plots in a garden is not significantly correlated with the total area in the garden, however a weak positive correlation of 0.445 confirms a trend of more plots in larger gardens. A correlation close to zero, -0.016, of the number of plots with size of plots indicates that plot size is independent of the number of plots (Figure 6). University Place has 81 plots with an average plot size of 6.42 m² while Shepherd's Field has 73 plots with an average plot size of 47.13 m². The total number of plots reflects how many individuals have allotments in the garden and the individual interest in the garden could drive the delineation of plots rather than a standardization of a size of plot. It is also possible that in gardens with a large number of smaller plots, a single individual or family could maintain multiple plots. Casual conversations with gardeners during the survey suggested that this is sometimes the case.

The total number of plots in a garden does not predict how well used the plots are but the variability in use is greater when there are fewer plots. Gardens with more plots had a tendency towards a higher use intensity but this was not significant at $p < 0.05$. Level of use within a garden was also more consistent for the larger gardens. The 12 gardens with the fewest plots, outside of one standard deviation, have an average use intensity of 2.29 with a standard deviation of 0.79. The 11 gardens with the most plots, one standard deviation above the mean number of plots, have an average use of 2.37 with a standard deviation of 0.47. The six most highly used gardens range in the number of plots from five to 66 (Table 4). Similarly, the six least used gardens range in the number of plots from 2 to 49 (Table 4).

Figure 5: Distribution of Number of Plots
Gardens differ in how the total area is divided into plots, at the higher end there is a 40-fold difference in the number of plots compared to the garden with fewest plots.

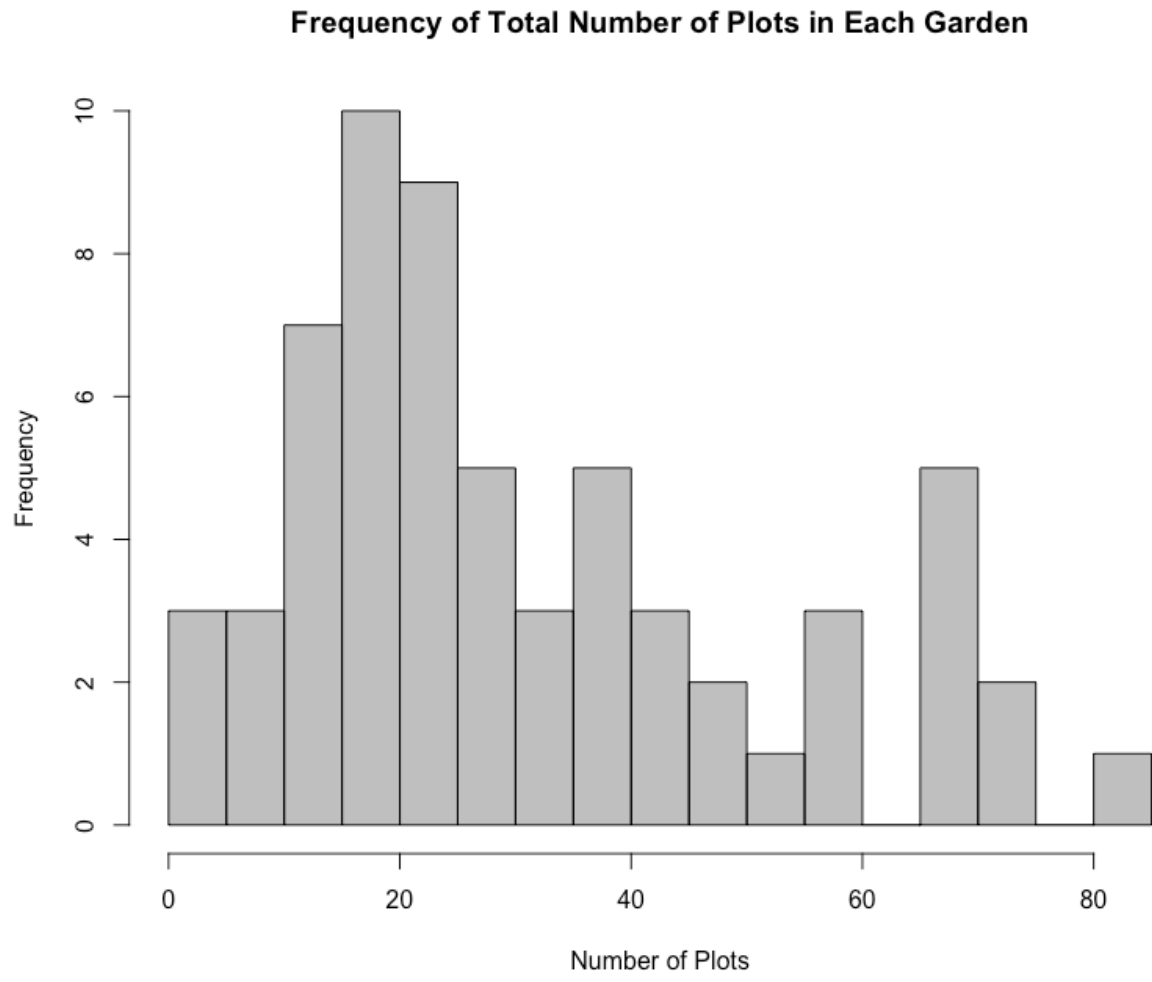
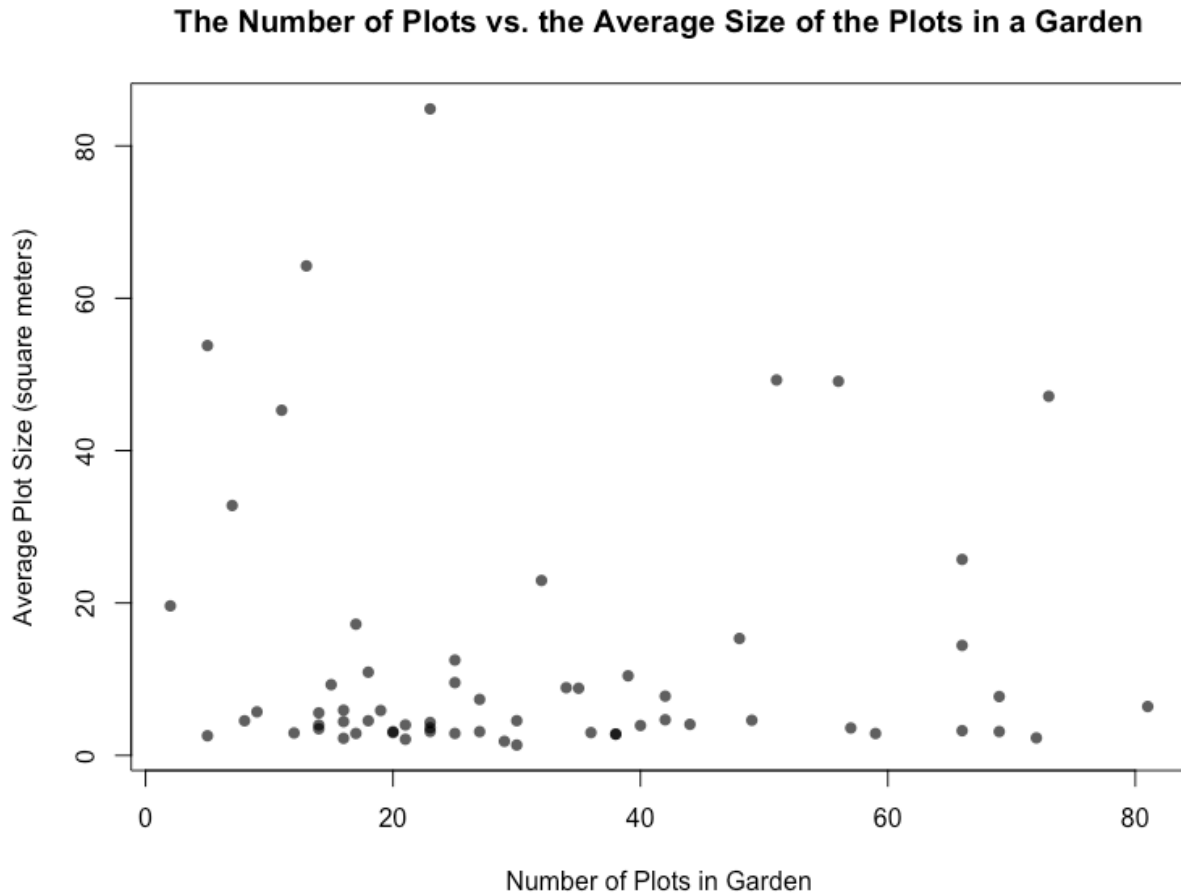


Figure 6: Comparing the Plot Size to the Number of Plots in a Garden

Each point represents a single garden with the number of plots in a garden plotted on the X-axis and the average plot size in the garden on the Y-axis. This plot shows a general relationship between how large plots are and the number of plots in a garden, which tends to be non-linear.

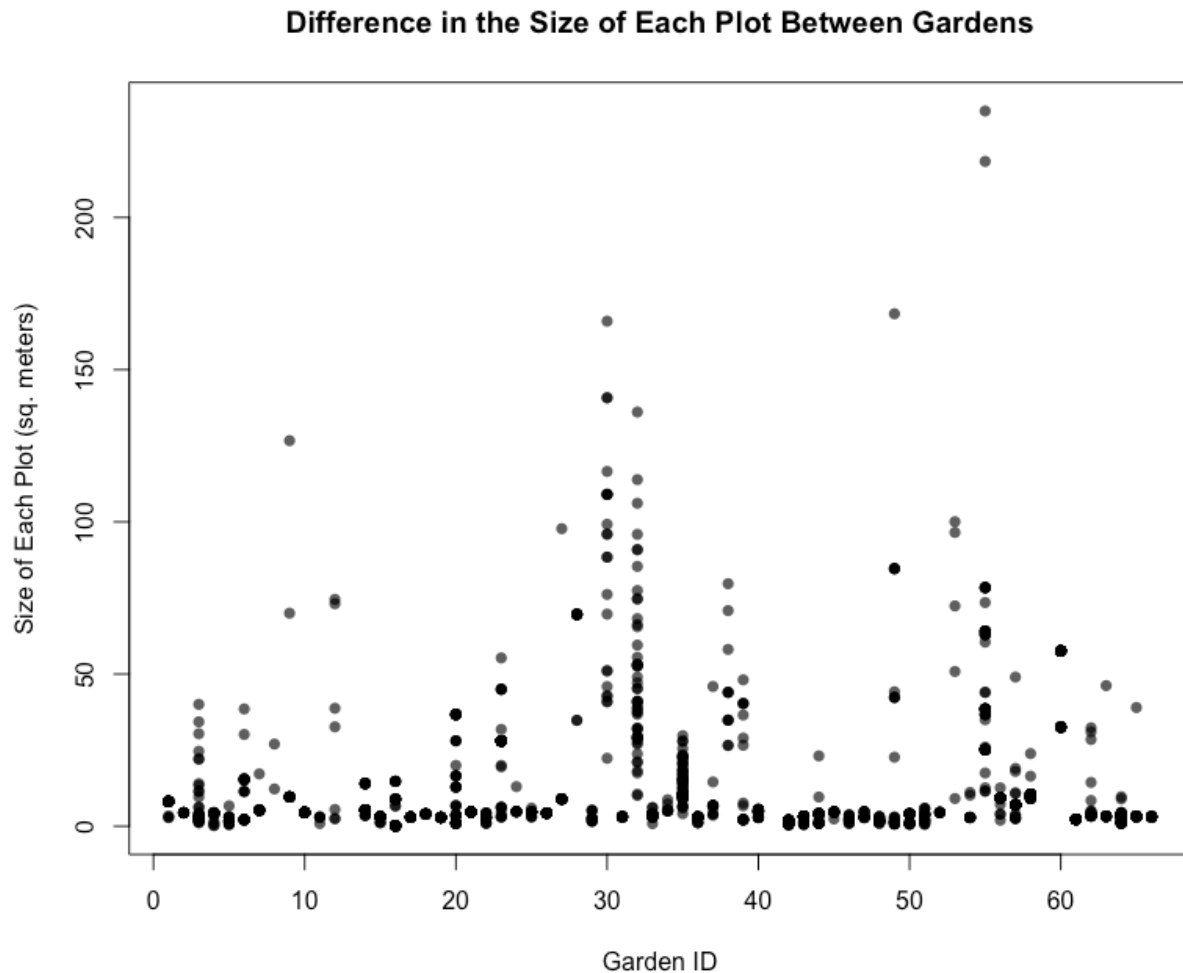


What are the plot sizes and the average plot size across gardens?

To describe the difference in the size of garden plots within gardens, each plot was measured individually, and the size of these plots were averaged to a garden level. The average plot size across all gardens is 12.3 m² (standard deviation of 17.3). The smallest plot size was 1.36 m² in Abundance Gardens. Every plot in this garden was highly used and rated a 3. The largest plot average was 84.85 m² in Tacoma Community College Community Garden, with 87% of the plots highly used and the remaining plots rated at use intensity 2, for a high overall garden use of 2.87. There were significant differences (F-value=13.32, p<0.0003) in plot size by garden. Different gardens divided the arable area into different size plots.

Figure 7: Distribution of Plot Sizes In and Between Gardens

The stacked columns represent the variability of plot sizes in a garden. Each garden has a column with the smaller plots in a garden stacked below larger plots. The plot size distribution varies between gardens with some gardens having plots of consistent sizes and other gardens with a widespread of plot sizes. Each point on the X axis corresponds to a garden. The corresponding points on the y axis show the range of sizes of individual plots within the particular garden



However, the average size of plots in a garden does not predict how well used the plots are on average in a garden (F-value= 5.672, p-value=0.204). A mixed effects liner model comparing the plot size and use intensity between gardens finds that there is a significant relationship between the size of plot and how well used it is but that this relationship between use and plot size varies based on the garden the plot is in (p-value= 2.6×10^{-12}). Some gardens have larger plots that are used more intensively than smaller plots such as Abundance Gardens,

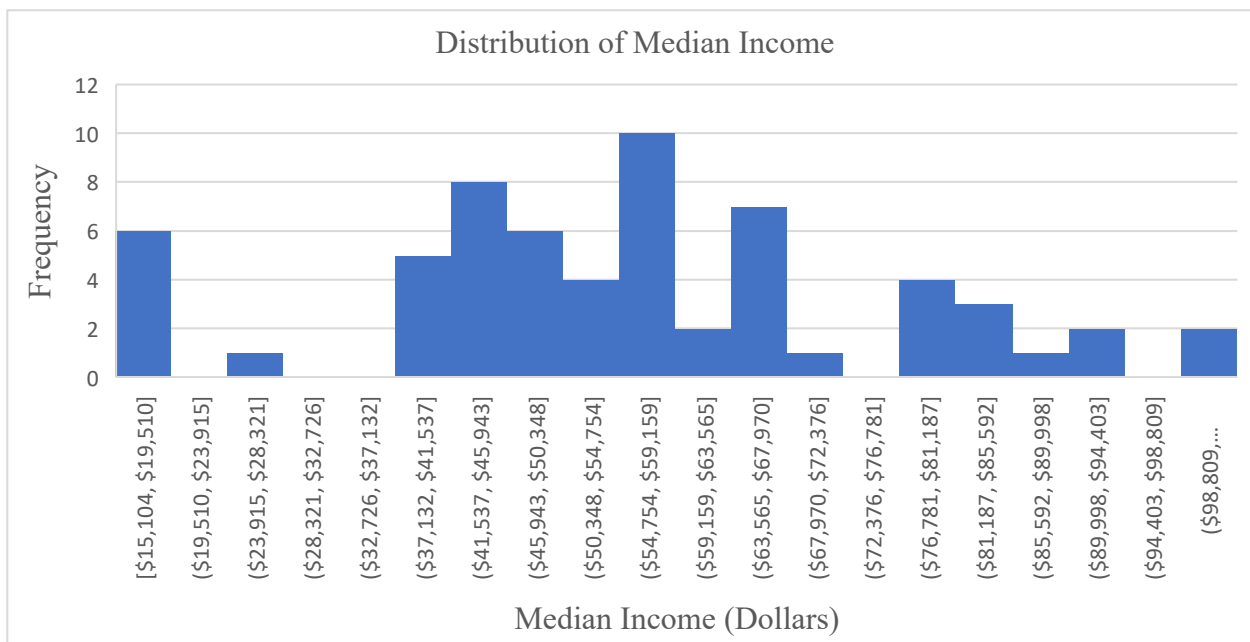
Bethel, St. John Bosco. Other gardens such as Boze Neighbors Community Garden, Evergreen Presbyterian Church of Graham, Green Thumb Community Garden have the reverse trend. These gardens have smaller plots that are more highly used than the large plots even in the same garden.

The pattern between use and plot size is not significantly predicted by other internal or external variables. Plots are not predictably larger in more affluent (p-value=0.899), whiter (p-value=0.69), or gardens with more plots (p-value=0.89).

In addition to number of plots, the size of the plots is a factor that has a direct impact on yield potential across the program and can describe the potential yield of food per participating individual. The size of plot that an individual uses dictates the amount of food that can be grown and could influence not only the type of food grown but the techniques used to tend the garden. Some gardens, such as the Viet Huong Community Garden are used to grow traditional Vietnamese produce to supplement apartment dwelling residents' groceries. The plots at this garden are generally well used, the average use is 2.83, and the plots are about 15 m².

What is the distribution of the median income of residents across gardens?

*Figure 8: The Distribution of Median Household Incomes
The range of household incomes across census tracts with gardens according to 2016 US Census Data.*



Gardens in the Harvest Pierce County Program are distributed across Pierce County and located in neighborhoods that have a range of reported household income levels. For this analysis I assumed that the median household income for the census tract where each garden is

located was representative of the income of the gardeners for each garden. The median income of the census tracts with community gardens, and therefore the median income of gardeners in different gardens ranged from \$15,000 to \$100,000 (\$15,104 and \$103,214). Across all gardens, the median income per garden was \$55,597 (with standard deviation of \$20,850). Gardens differed significantly based on the wealth of surrounding residents (F-value=346.2; p-value=<2e-16). The gardens in the census tract with the lowest median income, \$15,104, were Salishan Community Garden (2.19) and Swan Creek Park Community Garden (2.38). Both gardens serve a large number of individuals, with 72 and 56 plots respectively. Swan Creek Park Community Garden had 2,750 m² of growing area and Salishan covered only 166 m² of area. One of the least used gardens, 8th and 1st Neighbor’s Park (1.41), was located in an equally low-income neighborhood as was one of the mostly highly used gardens, Viet Huong (2.83). Both gardens, along with Gallucci Learning Garden (2.67) and Hilltop House Community Garden (2.71), are located in a census tract with a median income of \$17,105.

The three gardens closest to the mean income are Hosmer Tropical Park and Community Garden (2.36), 48th and Yakima (2.43), and Boze Neighbor’s Community Garden (1.07). Hosmer Tropical Park and Community Garden is the smallest of the three gardens with 14 plots that cover 49 m². The other two gardens are similar in the number of plots and the total area they cover with 48th and Yakima Community Garden covering 72 m² split into 23 plots and Boze Neighbor’s Community Garden 84 m² split into 27 plots.

The four gardens located in the highest income census tracts were Garden of Peace Community Garden, Junett, Bethany Presbyterian Church, and Fox Island Community Garden. These gardens were all located in census tracts where the median income was over \$90,000. The highest median income was recorded around the Garden of Peace Community Garden that has 25 plots over 238 m² with an average plot use intensity of 2.12. Junett Community Garden contains 196 m² of cultivated area with 42 plots of an average use of 2.78. Bethany Presbyterian Church only had 9 plots with a total area of 52 m² and the average plot use was 2.33. The Fox Island Community Garden covers 302 m² with 34 plots that on averaged were used at the level of 2.14.

A general non-linear trend shows that gardens are the least well-used around the middle of the income distribution, with increased use intensity at both the lower income and higher income neighborhoods. Table 9 illustrates the non-significant trend.

<i>Table 9: Summary of Garden Use Grouped by Median Income</i>					
<i>The average use calculated for groups of gardens divided by standard deviations above and below the mean income.</i>					
Median income range	Distribution	Use	Standard deviation	Number of gardens	Number of Plots
\$15,104 – \$24,581	-2 SD	2.46	0.536	7	293
\$38,711- \$55,037	-1 SD	2.14	0.592	25	755
\$55,597	Mean	2.26	0.556	63	1,960
\$55,294 – \$71,536	+1 SD	2.24	0.641	18	549
\$78,720 – \$103,214	+2 SD	2.43	0.254	12	363

What is the distribution of median values of houses across garden neighborhoods?

In addition to income, I looked at median home values to gauge whether garden distribution is skewed to a higher or lower income range. The average median home value around gardens was just over \$300,000 (\$311,711). The range of home values for houses near each garden ranged from \$189,000 to \$576,000 (\$189,893 and \$576,635, with a standard deviation of \$8,647). The lowest median home value for houses in proximity to a garden was almost three times less than the median home value for homes close to the highest end garden. This difference was statistically significant with an ANOVA comparison between gardens (F-value=14.42; p-value=0.000343). The range of median home values around gardens is reflective of the general home values in Tacoma, which have increased in recent years. The median sale price ranged from \$273,600 to \$466,600 dollars in different neighborhoods and has been increasing in lower income neighborhoods while remaining stable or decreasing in higher income neighborhoods (Long, 2020). The median home value recorded was strongly correlated with median income (0.710) and strongly negatively correlated with diversity (-0.764), neighborhoods with more valuable homes are populated with more affluent and whiter individuals.

The median home value was not significantly predictive of use intensity (p-value = 0.899). However, gardens in areas with a median home value above \$400,000 were always rated at least moderately well-used (Figure 9). Springbrook Park was in the area with the lowest median home value but all plots in the garden were highly used at level 3. Likewise, Junett Community Garden is highly used with an average plot use of 2.73 and it is in a neighborhood with the second highest property value, \$519,524 for a median home value. Median home value has been shown in literature to increase in areas around community garden (Voicu & Been, 2008). With garden use well distributed across the range of incomes, any potential benefits brought to residents through increased property value are well-distributed across Pierce County. Property values are increasing throughout Tacoma and Pierce County (Figure 10).

Figure 9: Relationship Between Garden Use and Median Home Value
The median value of houses in the area surrounding gardens is plotted on the Y-axis with the average use of the garden plotted on the X-axis. The relationship between the variables is non-significant but there is an area represented in the Figure where areas higher property values have gardens that are at least moderately-well used.

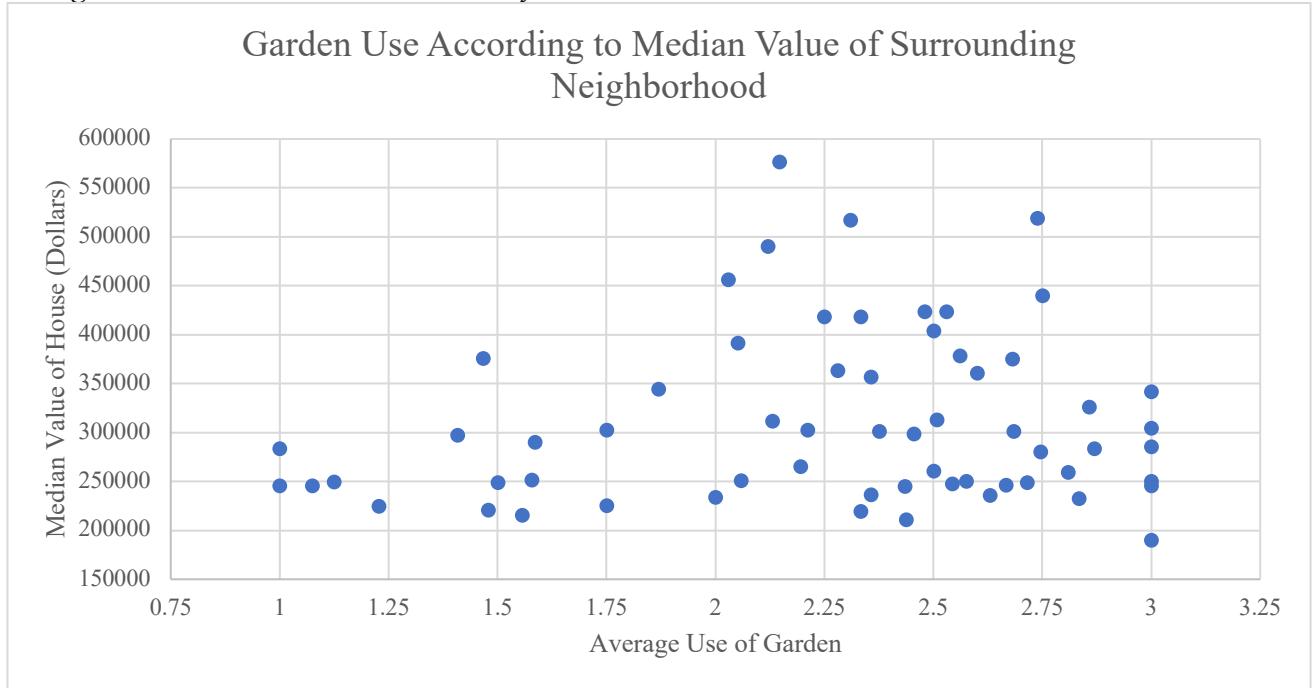
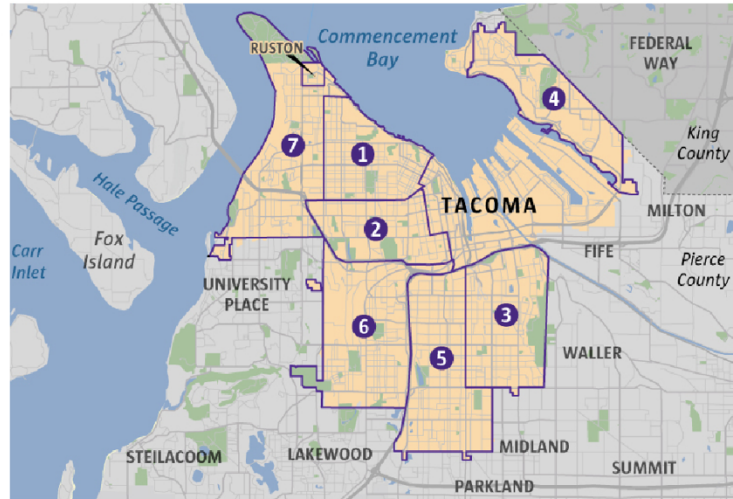


Figure 10 : Tacoma Home Prices
Tacoma home prices have increased in recent years, particularly in historically diverse neighborhoods (Long, 2020).

Where home prices boom

Home prices have risen slowest over the past five years in Tacoma's highest-priced neighborhoods. In historically diverse, low-income neighborhoods, homes are selling for more than twice as much as they were five years ago.



Median sale price for single-family homes by Tacoma neighborhoods (as of November 2019)

NEIGHBORHOOD	MEDIAN SALE PRICE	FIVE-YEAR INCREASE
1 North End	\$466,600	62%
2 Central Tacoma	\$323,100	115%
3 Eastside-ENACT	\$288,600	97%
4 Northeast Tacoma	\$456,400	71%
5 South End	\$281,500	100%
6 South Tacoma	\$273,600	116%
7 West End	\$380,500	63%

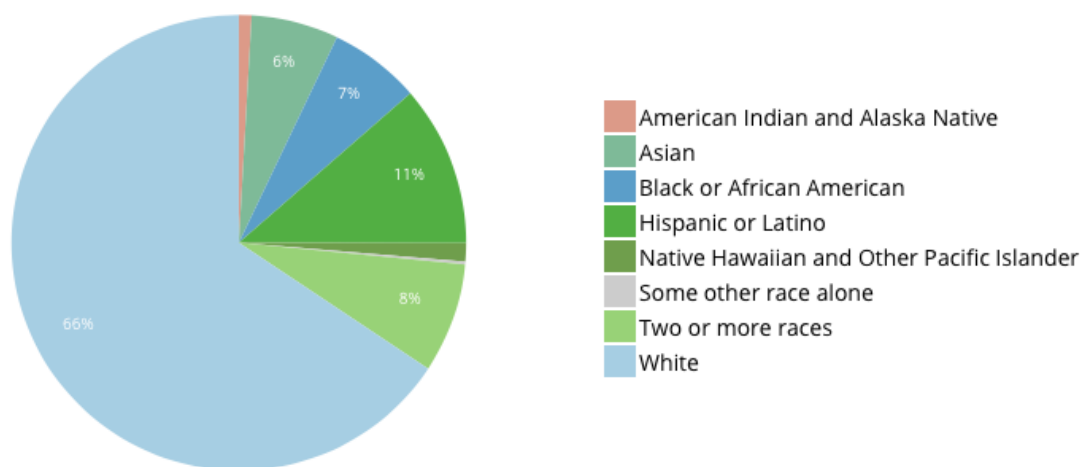
Source: Zillow

Reporting by KATHERINE K. LONG, Graphic by MARK NOWLIN / THE SEATTLE TIMES

What is the distribution of percentage of white residents across gardens?

Pierce County is largely (66%) white with Asian, Black or African American, Hispanic or Latino, American Indian and Alaska Native, and Native Hawaiian or Other Pacific Islander accounting for the other third of the population racial demographics (*Race/Ethnicity Diversity of the Pierce County Workforce, 2019*).

*Figure 11 : Division of Pierce County Residents into Reported Race Groups
The distribution of reported ethnicities in Pierce County according to US Census Data.*



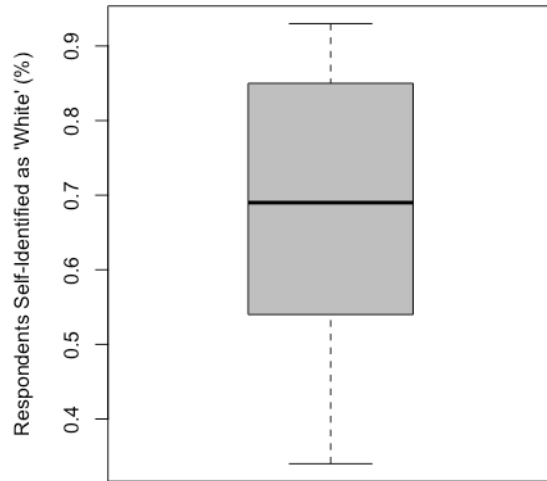
The census tracts surveyed have a similar distribution to the whole of Pierce County (Figure 11). The average percentage of white respondents in the census tract around a garden was 69% with a median of 68.4% and a standard deviation of 16.7%. Most of the gardens are located in census tracts with six or more racial groups identified. Thirty-one gardens were in census tracts with seven racial groups present according to census self-identification and 15 gardens were in census tracts with six racial groups. Some gardens are in census tracts with almost 100% white respondents (93%). Other gardens are in very diverse census tracts where only 34% of respondents are white.

The least diverse garden according to census data was the Lincoln High School Community Garden which had only two racial groups identified and a population of 93% white respondents. Puyallup Community Garden (Brown Property) only had three racial groups respond and a 93% white population. The gardens located in the most diverse census tracts were the Gallucci Learning Garden (34% white respondents), the UWT Giving Garden (34%),

Salishan (42% white respondents), Stewart Middle School (42% white respondents), Hilltop House (44% white respondents), Viet Huong (45% white respondents), Dometop (45% white respondents), Evergreen Presbyterian Church (48% white respondents), and Neighbor’s Park (48% white respondents). Including the gardens listed above, 28 gardens were in census tracts that were less white than the average racial demographics of Pierce County.

Racial distribution (based on neighborhood census data) is not equal across all gardens. Some gardens are in more racially diverse tracts while others are in primarily white census tracts (F-value=314.5; p-value= <2e-16). The most diverse gardens are significantly more diverse than the least diverse of gardens (Figure 13). However, despite the difference in diversity between census tracts, there was not a significant difference in the use between diverse gardens.

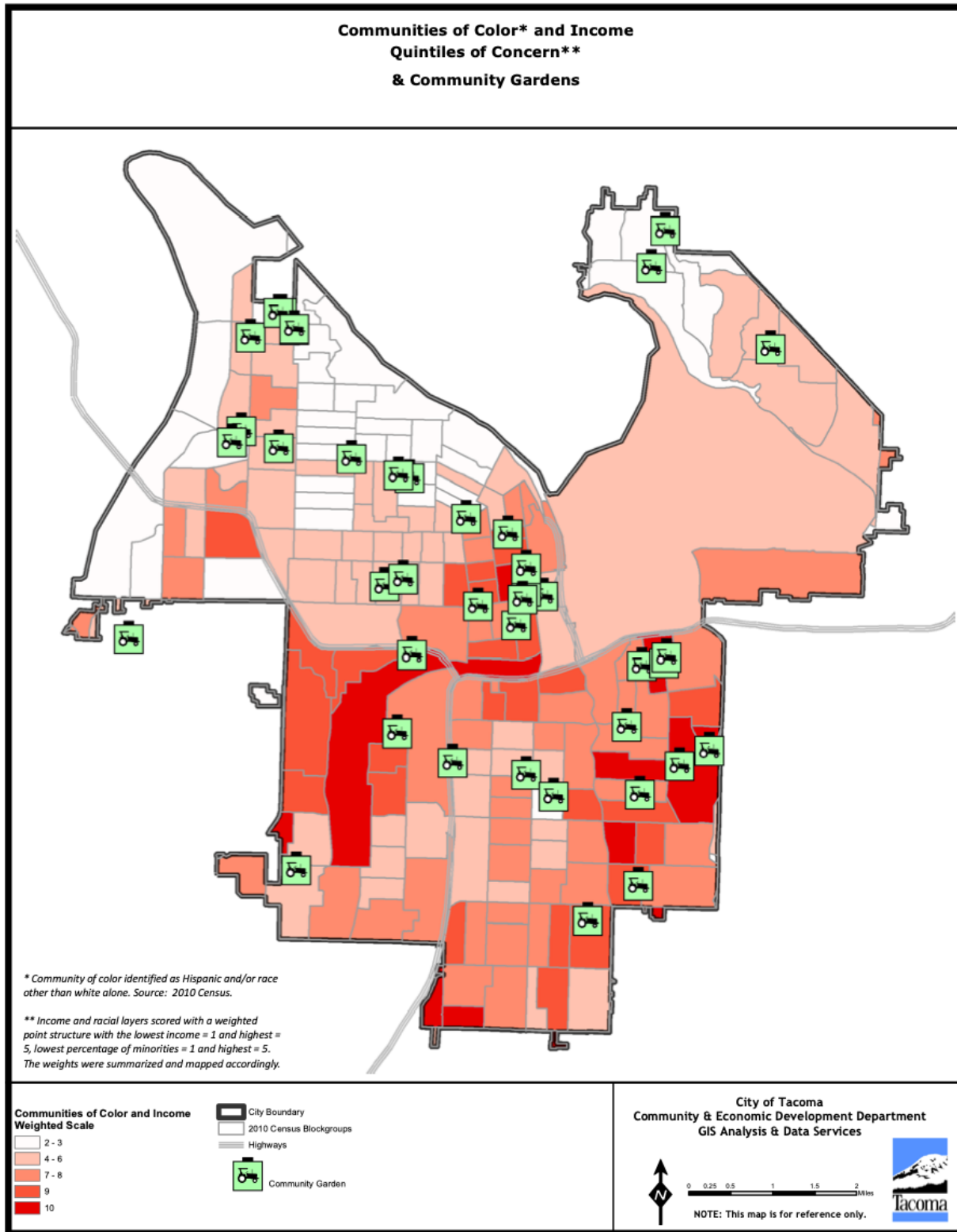
Racial Diversity in Garden Census Tracts



*Figure 12: Percentage of Census Participants Reported ‘White’ by Census Tract
A box plot of the relative diversity of census tracts with gardens as simplified to the percentage of white respondents.*

<i>Table 10: Distribution of Average Use Grouped by Diversity of Census Tract</i>					
<i>The average use calculated for groups of gardens divided by standard deviations around the percentage of white residents.</i>					
Percentage of white respondents	distribution	Use	Standard deviation	Number of gardens	Number of Plots
34% - 48%	-2 SD	2.06	0.587	9	322
52% - 67%	-1 SD	2.26	0.583	21	790
68%	Mean	2.26	0.556	63	1,960
69% - 85%	+1 SD	2.32	0.572	17	361
86% - 93%	+2 SD	2.29	0.506	15	487

Figure 13: Location of Community Gardens with Communities of Color
 Gardens within the City of Tacoma are located across racially diverse census tracts.

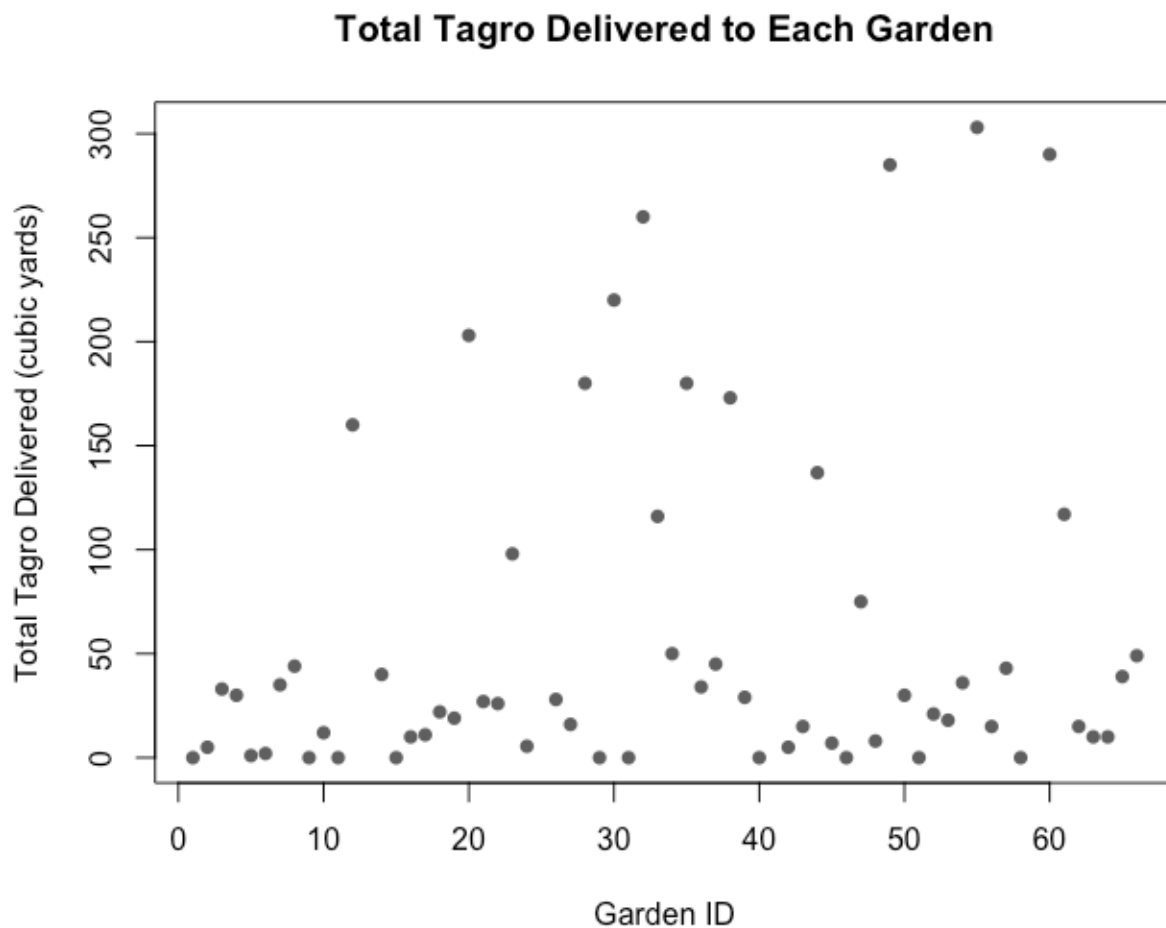


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How much total TAGRO was delivered across gardens?

I looked at total tonnage TAGRO deliveries as a variable that may influence garden usage or that may vary with garden usage. Although TAGRO is a free resource, some gardens or gardeners opt out of regularly applying or using TAGRO at all. The quality of TAGRO as a soil amendment reduces the barrier of knowledge and effort required to garden successfully. TAGRO increases the available nutrients in the soil, the bulk density, water infiltration, and water holding capacity of the soil (McIvor et al., 2012; McIvor & Brown, 2016). Crop yield was significantly larger in TAGRO amended soil compared to control native soil (Beebe, unpublished). The increase in soil and plant health can lower the amount of time, energy, and resources required to achieve a high-level of use.

*Figure 14: Quantity of TAGRO Delivered to Each Garden
Each garden varies in the quantity of TAGRO requested and then delivered.*



Although there are some gardens that ordered more TAGRO over a three-year period than average, most gardens ordered less than 50 cubic yards of TAGRO. The larger the garden, the more TAGRO is ordered. The correlation of amount of TAGRO delivered with total growing area was correlated at 0.831 which is above the commonly used threshold of 0.8 to note a very

high correlation. Ten gardens did not receive any TAGRO from 2017 to 2019 and 15 gardens received over 50 cubic yards. The ten gardens that did not receive any TAGRO averaged use of 2.15 and an average arable area of 144 square meters while the 15 gardens that received over 50 cubic yards averages a use intensity of 2.46 and an average arable area of 1,062 square meters. The Shepherd's Field Community Garden used the most TAGRO at 303 yds³, Swan Creek Park Community Garden ordered 290 yds³, and Wapato Hills Community Garden used 285 yds³. If the fifteen largest deliveries were excluded as outliers, a typical delivery of TAGRO was 18 cubic yards.

*Image 5: Unused Beds of Limited Size
Gardens with highly structured raised beds of a small size may not provide gardeners space to grow enough food to make tending the beds worthwhile.*



Like the trend of total area, gardens that ordered more TAGRO were not necessarily more highly used than those that did not order large quantities of TAGRO (p-value = 0.206). Although non-significant, gardens that did not order any TAGRO did tend to have below average use (2.15 with a standard deviation of 0.529). Gardens that received between 1 and 50 cubic yards averaged a use of 2.21 (SD = 0.608). Gardens that received more than 50 cubic yards over the course of three years averaged a use of 2.46 (SD = 0.401). The trend is non-significant and the very high correlation of the amount of TAGRO delivered with the total area of each garden makes it difficult to

conclude anything about the trend. Without data on the number of deliveries

Gardens differed in how often they received deliveries of TAGRO. Some gardens received TAGRO in one year but not others while other gardens received TAGRO every year. Ten gardens did not receive any TAGRO. Ten gardens received TAGRO delivery in one of the three years. Sixteen gardens received deliveries in two of the three years and the remaining 26 gardens received TAGRO all three years. The frequency of deliveries does not significantly predict the level of use. Some gardens that received yearly deliveries, of different quantities, such as Tacoma Community College (2.87), Franklin Park Community Garden (2.75), Kandle Community Garden (3), and Viet Huong Community Garden (2.83) are all well used. Other gardens such as Wapato Hills Community Garden (1.75), McCarver Community Garden (1.57), and 40th Street Community Garden (1.56) also received yearly deliveries but were some of the least used gardens.

An additional consideration for the variable of TAGRO is that the amount and frequency of TAGRO delivered only assumes that the product is well distributed and used by garden participants. TAGRO is so popular that some TAGRO does not make it into the garden beds. Additionally, the bed structure can impact repeat TAGRO deliveries. Gardens with limited bed sizes are constrained with adding more TAGRO if the beds are already full (Image 5 and Image 6).

What qualitatively is experienced through surveys, administration, and observations?

Harvest Pierce County administrators have qualitative experience accumulated over years of supervising gardens and assisting different gardeners. In the past, limited surveys have found that the HPC tends to attract gardeners at an average age of 55-65 with around 2,000 active gardeners in the program. There are currently 83 gardens registered with and receiving support from Harvest Pierce County

Administrators have noted that gardens succeed when some form of leadership takes responsibility and ownership of a garden. Gardens that take time to establish management structures can last beyond a single gardener. Similarly, without the ability to remove a problem gardener a garden can fail.

In gardens with larger plots, smaller plots are not used as frequently. Plots that are large enough to grow a decent amount of food tend to be worth the while of gardeners during hot or rainy days. Plots that are too small to produce food end up abandoned if gardeners have to make a trek specifically to care for the plot. However smaller plots can be effective if they are co-located in the vicinity of another destination such as a church where members are already traveling to the location for other reasons.

It is important to have a community in the garden, this can either be residents that live close to the garden or a garden where gardeners have a shared common interest. The Viet Huong Community Garden is an example of both factors converging. The residents and community in the surrounding apartment blocks all garden together so the existing local community is utilizing the garden. The gardeners also are primarily first-generation Vietnamese immigrants. In the Gallucci Learning Garden, a community of Master Gardeners do not live near to the garden, but they have built a community in the garden as they have taught and developed classes centered in the garden (McIvor, 2021).

Highly structured raised plots made out of concrete blocks or other more permanent borders prevent the natural assimilation, expansion, or shifting of plots. Smaller plots tend to be made more rigidly so rigid structuring could confound the effect of smaller plots. Larger plots or semi-structured plots that touch so a gardener or family can manage multiple plots or share management of plots can lead to effective use.

Based on insight from HPC staff the management of a garden, both in terms of integration into a larger structure and in the day-to-day management of garden specific issues can impact the success of a garden. Different community garden program administrators have observed how lack of management with no accountability to larger processes or longer-term

Image 6: Large Monocultured Beds

Intensive crop production with monocultured beds can be a collaborative effort with families sharing produce. Large unstructured beds may maximize the space and allow organic groupings of areas.



thinking can reduce the success of a garden. In many cases a single individual serves as the corner stone of a garden. This person organizes people or materials, gardens by example, and facilitates garden processes. However, this informal singular-leadership means that if that individual leaves the garden the garden does not fare well. Gardens with dispersed responsibilities but minimal formal accountability or organization are similarly vulnerable to garden failure (K. McIvor, personal communication, February 17, 2020).

Chapter 5: Garden Highlights – Conclusion

Garden use was consistent across the internal variables that were measured. Regardless of the garden size or the size of the plot the measured use was consistent and on average the gardens were well-used. Qualitatively gardens with smaller, fewer, fixed plots did not fare as well as gardens with more plots that were larger and more flexible. However, this analysis did not measure variables associated with plot flexibility, infrastructure, and intentionality of garden plots. The next census could include these more qualitative factors to include as interactions in the analysis.

Gardens are also well-used across demographic and social variables according to associated census data. Overall gardens are in communities of color and income quintiles of concern and according to the results of this analysis these communities have access to garden resources with no correlation or significance of diversity measures and the total area, or average use of a garden. However, surveys of participants would provide direct measures of garden impacts and experiences.

The program impact of the HPC program is related to the number of users and the level of effort users invest in their gardens. The total program benefit for both residents and garden users may increase as the intensity of garden use increases. The more well-used a garden the larger the benefits to the individual and the community.

When an HPC garden is well used: Pierce County residents have access to locally grown fresh produce and may consume more fruit and vegetables (Alaimo et al., 2008; Barnidge et al., 2013; Morris & Zidenberg-Cherr, 2002; Ober Allen et al., 2008), gardeners of all ages exercise which may have health benefits (K. H. Brown & Jameton, 2000; Teig et al., 2009; Wakefield et al., 2007), and the beauty and greenspace provides mental health benefits for Pierce County residents (Hayashi et al., 2008; Litt et al., 2011). HPC provides opportunities for greater community cohesion through regular interactions in and around the garden, especially with immigrant communities. The community gardening program additionally improves soil health, rainwater infiltration, and other ecosystem services for the county (S. L. Brown et al., 2016; Costanza et al., 2014; Gómez-Baggethun & Barton, 2013; Herrmann et al., 2017; Iuliano et al., 2017). These benefits that have been outlined in previous literature are intuitively realized only if the gardens are well-used.

Based on the results of this analysis gardens on average are moderately well-used (2.26 out of 3) and HPC is successfully providing benefits for the Pierce County community. If I assume that two people are directly involved or receive benefit from each plot, then there are 3,920 gardeners who are receiving moderate amounts of fresh food, exercise, and the mental health benefits of participating in outdoor recreation. The number of people who receive the indirect moderate benefits is more difficult to estimate but based on the peer reviewed literature, these residents would experience a moderate decrease in crime (Beam et al., 2021; Egli et al., 2016), access to the thousands of pounds of donated produce with gardens such as Abundance and the St. John Bosco Food Bank. Even more difficult to quantify is the community opportunity that many gardeners expressed to survey teams or to HPC employees. Viet Huong Community Garden is one example of this community which enables Vietnamese immigrants a place to gather and grow traditional produce. The ecosystem services provided by moderately used gardens are the most indirect and global in nature and difficult to quantify. These include a moderate increase in rainwater infiltration which reduces stormwater runoff (Gittleman et al., 2017), potential for carbon sequestration through increasing soil health (Gómez-Baggethun &

Barton, 2013), and any emissions reductions that comes from consuming more local produce. A specific cost benefit analysis would be a recommended next step to enumerate some of these ecosystem services.

To gain more accurate information about how intensity of use is predicted by other social elements that this analysis failed to measure the next iteration of an analysis could consider intensity of use a behavioral variable and collect data to build a predictive behavioral model. Potential variables to measure and include in the model include: the presence and strength of social or cultural norms associated with gardening, the use of educational resources, intention for participation, as well as incentives, organizational commitments, expected benefits, and barriers (costs, fees, time, effort, administrative burdens).

Finally the measure of use used reduces the variation seen qualitatively. Future analyses may consider including a more indexed use variable which combines effort with yield potential and intention. An indexed measure that better reflects the qualitative differences could spread out the clustered distribution in use seen at the high end of the measure (Figure 7).

Works Cited

- Abundance Garden. (n.d.). Our Savior Lutheran Church. <https://oslc.com/garden.html>
- Ackerman, K., Conrad, M., Culligan, P., Plunz, R., Sutto, M.-P., & Whittinghill, L. (2014). Sustainable Food Systems for Future Cities: The Potential of Urban Agriculture. *THE ECONOMIC AND SOCIAL REVIEW*, 45(2), 129–206.
- Alaimo, K., Packnett, E., Miles, R. A., & Kruger, D. J. (2008). Fruit and Vegetable Intake among Urban Community Gardeners. *Journal of Nutrition Education and Behavior*, 40(2), 94–101. <https://doi.org/10.1016/j.jneb.2006.12.003>
- Aptekar, S. (2015). Visions of Public Space: Reproducing and Resisting Social Hierarchies in a Community Garden. *Sociological Forum*, 30(1), 209–227. <https://doi.org/10.1111/socf.12152>
- Armstrong, D. (2000). A survey of community gardens in upstate New York: Implications for health promotion and community development. *Health & Place*, 6(4), 319–327. [https://doi.org/10.1016/S1353-8292\(00\)00013-7](https://doi.org/10.1016/S1353-8292(00)00013-7)
- Barnidge, E. K., Hipp, P. R., Estlund, A., Duggan, K., Barnhart, K. J., & Brownson, R. C. (2013). Association between community garden participation and fruit and vegetable consumption in rural Missouri. *International Journal of Behavioral Nutrition and Physical Activity*, 10(1), 128. <https://doi.org/10.1186/1479-5868-10-128>
- Beam, D. R., Szabo, A., Olson, J., Hoffman, L., & Beyer, K. M. M. (2021). Vacant lot to community garden conversion and crime in Milwaukee: A difference-in-differences analysis. *Injury Prevention*, 27(5), 403–408. <https://doi.org/10.1136/injuryprev-2020-043767>
- Been, V., & Voicu, I. (2006). The Effect of Community Gardens on Neighboring Property Values. *New York University Lawanf Economics Working Papers*, 1–51.

- Birky, J. (n.d.). The Modern Community Garden Movement in the United States: Its Roots, its Current Condition and its Prospects for the Future. 140.
- Borrelli, D. A. (2008). Filling the Void: Applying a Place-Based Ethic to Community Gardens. *Vermont Journal of Environmental Law*, 9(2), 271.
<https://doi.org/10.2307/vermjenvilaw.9.2.271>
- Bos, E. (n.d.). Reconnections in the City: Exploring the Drivers of Community Garden Participation [Unpublished PhD Thesis]. Coventry University.
- Bos, E. (2017). Reconnections in the City: Exploring the Drivers of Community Garden Participation. Coventry University.
- Brown, K. H., & Jameton, A. L. (2000). Public Health Implications of Urban Agriculture. *Journal of Public Health Policy*, 21(1), 20. <https://doi.org/10.2307/3343472>
- Brown, S. (2018). Making Soils from Urban Wastes. In *Urban Soils* (pp. 215–228).
- Brown, S. L., Chaney, R. L., & Hettiarachchi, G. M. (2016). Lead in Urban Soils: A Real or Perceived Concern for Urban Agriculture? *Journal of Environmental Quality*, 45(1), 26–36. <https://doi.org/10.2134/jeq2015.07.0376>
- Brown, S., McIvor, K., & Hodges Snyder, E. (Eds.). (2016). *Sowing Seeds in the City*. Springer Netherlands. <https://doi.org/10.1007/978-94-017-7453-6>
- Caspersen, C. J., Bloemberg, B. P. M., Saris, W. H. M., Meritt, R. K., & Kromhout, D. (1991). The Prevalence of Selected Physical Activities and Their Relation with Coronary Heart Disease Risk Factors in Elderly Men: The Zutphen Study, 1985. *American Journal of Epidemiology*, 133(11), 1078–1092.
- Cooper, A. M., Felix, D., Alcantara, F., Zaslavsky, I., Work, A., Watson, P. L., Pezzoli, K., Yu, Q., Zhu, D., Scavo, A. J., Zarabi, Y., & Schroeder, J. I. (2020). Monitoring and

- mitigation of toxic heavy metals and arsenic accumulation in food crops: A case study of an urban community garden. *Plant Direct*, 4(1), e00198. <https://doi.org/10.1002/pld3.198>
- Costanza, R., de Groot, R., Sutton, P., van der Ploeg, S., Anderson, S. J., Kubiszewski, I., Farber, S., & Turner, R. K. (2014). Changes in the global value of ecosystem services. *Global Environmental Change*, 26, 152–158. <https://doi.org/10.1016/j.gloenvcha.2014.04.002>
- Daftary-Steel, S., Herrera, H., & Porter, C. (2015). The Unattainable Trifecta of Urban Agriculture. *Journal of Agriculture, Food Systems, and Community Development*, 19–32. <https://doi.org/10.5304/jafscd.2015.061.014>
- Deelstra, T., & Girardet, H. (n.d.). URBAN AGRICULTURE AND SUSTAINABLE CITIES. 23.
- Diaz, J. M., Webb, S. T., Warner, L. A., & Monaghan, P. (2018). Barriers to community garden success: Demonstrating framework for expert consensus to inform policy and practice. *Urban Forestry & Urban Greening*, 31, 197–203. <https://doi.org/10.1016/j.ufug.2018.02.014>
- Draper, C., & Freedman, D. (2010). Review and Analysis of the Benefits, Purposes, and Motivations Associated with Community Gardening in the United States. *Journal of Community Practice*, 18(4), 458–492. <https://doi.org/10.1080/10705422.2010.519682>
- Egerer, M., & Fairbairn, M. (2018). Gated gardens: Effects of urbanization on community formation and commons management in community gardens. *Geoforum*, 96, 61–69. <https://doi.org/10.1016/j.geoforum.2018.07.014>
- Egli, V., Oliver, M., & Tautolo, E.-S. (2016). The development of a model of community garden benefits to wellbeing. *Preventive Medicine Reports*, 3, 348–352. <https://doi.org/10.1016/j.pmedr.2016.04.005>

- Ferris, J., Norman, C., & Sempik, J. (2001). People, Land and Sustainability: Community Gardens and the Social Dimension of Sustainable Development. *Social Policy & Administration*, 35(5), 559–568. <https://doi.org/10.1111/1467-9515.t01-1-00253>
- Food Bank Garden. (n.d.). St. John Bosco Catholic Church. <https://stjbosco.org/food-bank-garden>
- Fox-Kämper, R., Wesener, A., Münderlein, D., Sondermann, M., McWilliam, W., & Kirk, N. (2018). Urban community gardens: An evaluation of governance approaches and related enablers and barriers at different development stages. *Landscape and Urban Planning*, 170, 59–68. <https://doi.org/10.1016/j.landurbplan.2017.06.023>
- George, D. R., Rovniak, L. S., Kraschnewski, J. L., Hanson, R., & Sciamanna, C. N. (2015). A growing opportunity: Community gardens affiliated with US hospitals and academic health centers. *Preventive Medicine Reports*, 2, 35–39. <https://doi.org/10.1016/j.pmedr.2014.12.003>
- Gittleman, M., Farmer, C. J. Q., Kremer, P., & McPhearson, T. (2017). Estimating stormwater runoff for community gardens in New York City. *Urban Ecosystems*, 20(1), 129–139. <https://doi.org/10.1007/s11252-016-0575-8>
- Gómez-Baggethun, E., & Barton, D. N. (2013). Classifying and valuing ecosystem services for urban planning. *Ecological Economics*, 86, 235–245. <https://doi.org/10.1016/j.ecolecon.2012.08.019>
- Guitart, D., Pickering, C., & Byrne, J. (2012). Past results and future directions in urban community gardens research. *Urban Forestry & Urban Greening*, 11(4), 364–373. <https://doi.org/10.1016/j.ufug.2012.06.007>

Hanna, A. K., & Oh, P. (2000). Rethinking Urban Poverty: A Look at Community Gardens. *Bulletin of Science, Technology & Society*, 20(3), 207–216.

<https://doi.org/10.1177/027046760002000308>

Hayashi, N., Wada, T., Hirai, H., Miyake, T., Matsuura, Y., Shimizu, N., Kurooka, H., & Horiuchi, S. (2008). The Effects of Horticultural Activity in a Community Garden on Mood Changes. *Environmental Control Biology*, 46(4), 233–240.

Heise, T. L., Romppel, M., Molnar, S., Buchberger, B., Berg, A. van den, Gartlehner, G., & Lhachimi, S. K. (2017). Community gardening, community farming and other local community-based gardening interventions to prevent overweight and obesity in high-income and middle-income countries: Protocol for a systematic review. *BMJ Open*, 7(6), e016237. <https://doi.org/10.1136/bmjopen-2017-016237>

Hemann, G. (n.d.). Feeding Tacoma, Harvesting Food Justice: Lincoln Students Grow Job, Life Skills at Abe's Golden Acres. *South Sound Talk*.

<http://www.southsoundtalk.com/2017/09/15/abes-golden-acres/>

Herrmann, D. L., Shuster, W. D., & Garmestani, A. S. (2017). Vacant urban lot soils and their potential to support ecosystem services. *Plant and Soil*, 413(1–2), 45–57.

<https://doi.org/10.1007/s11104-016-2874-5>

Iuliano, B., Markiewicz, A., & Glaum, P. (2017). Socio-economic Drivers of Community Garden Location and Quality in Urban Settings and Potential Effects on Native Pollinators. *Michigan Journal of Sustainability*, 5(1).

<https://doi.org/10.3998/mjs.12333712.0005.103>

- Kingsley, J., Foenander, E., & Bailey, A. (2019). “You feel like you’re part of something bigger”: Exploring motivations for community garden participation in Melbourne, Australia. *BMC Public Health*, 19(1), 745. <https://doi.org/10.1186/s12889-019-7108-3>
- Kondo, M. C., Oyekanmi, K. O., Gibson, A., South, E. C., Bocarro, J., & Hipp, J. A. (2020). Nature Prescriptions for Health: A Review of Evidence and Research Opportunities. *International Journal of Environmental Research and Public Health*, 17(12), 4213. <https://doi.org/10.3390/ijerph17124213>
- Laidlaw, M. A. S., Filippelli, G. M., Brown, S., Paz-Ferreiro, J., Reichman, S. M., Netherway, P., Truskewycz, A., Ball, A. S., & Mielke, H. W. (2017). Case studies and evidence-based approaches to addressing urban soil lead contamination. *Applied Geochemistry*, 83, 14–30. <https://doi.org/10.1016/j.apgeochem.2017.02.015>
- Lawson, L. J. (2005). *City bountiful: A century of community gardening in America*. University of California Press.
- Lee, J. H., & Matarrita-Cascante, D. (2019). Gardeners’ Past Gardening Experience and Its Moderating Effect on Community Garden Participation. *Sustainability*, 11(12), 3308. <https://doi.org/10.3390/su11123308>
- Litt, J. S., Soobader, M.-J., Turbin, M. S., Hale, J. W., Buchenau, M., & Marshall, J. A. (2011). The Influence of Social Involvement, Neighborhood Aesthetics, and Community Garden Participation on Fruit and Vegetable Consumption. *American Journal of Public Health*, 101(8), 1466–1473. <https://doi.org/10.2105/AJPH.2010.300111>
- Long, K. (2020, February 17). As Seattleites and their money flow south, Tacoma residents grapple with changing neighborhoods. *Seattle Times*.

<https://www.seattletimes.com/business/real-estate/as-seattleites-and-their-money-flood-south-tacoma-residents-say-the-edges-are-being-smoothed-off-grit-city/>

McCormack, L. A., Laska, M. N., Larson, N. I., & Story, M. (2010). Review of the Nutritional Implications of Farmers' Markets and Community Gardens: A Call for Evaluation and Research Efforts. *Journal of the American Dietetic Association*, 110(3), 399–408. <https://doi.org/10.1016/j.jada.2009.11.023>

McIvor, K. (2011). *Soil Quality and the Dynamics of Information Sharing in Community Gardens*. University of Washington.

McIvor, K. (2020, February 17). Discussion of Harvest Pierce County Program and Participation [Personal communication].

McIvor, K., & Brown, S. (2016). A Case Study: Integrating Urban Agriculture into the Municipal Infrastructure in Tacoma, WA. In *Sowing Seeds in the City* (pp. 385–400). Springer. https://www.researchgate.net/profile/Sally-Brown-8/publication/321544119_Sowing_Seeds_in_the_City_Human_Dimensions/links/5e4ea054a6fdccd965b41ff1/Sowing-Seeds-in-the-City-Human-Dimensions.pdf#page=382

McIvor, K., Cogger, C., & Brown, S. (2012). Effects of Biosolids Based Soil Products on Soil Physical and Chemical Properties in Urban Gardens. *Compost Science & Utilization*, 20(4), 199–206. <https://doi.org/10.1080/1065657X.2012.10737049>

Meadow, A. (2013). Alternative Food Systems at Ground Level: The Fairbanks Community Garden. *Journal of Ecological Anthropology*, 16(1). <https://doi.org/10.5038/2162-4593.16.1.6>

Milburn, L.-A. S., & Vail, B. A. (2010). Sowing the Seeds of Success: Cultivating a Future for Community Gardens. *Landscape Journal*, 29(1), 71–89. <https://doi.org/10.3368/lj.29.1.71>

- Milliron, B.-J., Vitolins, M. Z., Gamble, E., Jones, R., Chenault, M. C., & Tooze, J. A. (2017). Process Evaluation of a Community Garden at an Urban Outpatient Clinic. *Journal of Community Health, 42*(4), 639–648. <https://doi.org/10.1007/s10900-016-0299-y>
- Mitchell, R. G., Spliethoff, H. M., Ribaud, L. N., Lopp, D. M., Shayler, H. A., Marquez-Bravo, L. G., Lambert, V. T., Ferenz, G. S., Russell-Anelli, J. M., Stone, E. B., & McBride, M. B. (2014). Lead (Pb) and other metals in New York City community garden soils: Factors influencing contaminant distributions. *Environmental Pollution, 187*, 162–169. <https://doi.org/10.1016/j.envpol.2014.01.007>
- Morris, J. L., & Zidenberg-Cherr, S. (2002). Garden-enhanced nutrition curriculum improves fourth-grade school children’s knowledge of nutrition and preferences for some vegetables. *Journal of the American Dietetic Association, 102*(Number 1), 91–93.
- Mountain Community Garden—Home. (n.d.). <https://www.mountaincommunitygarden.org>
- Ober Allen, J., Alaimo, K., Elam, D., & Perry, E. (2008). Growing Vegetables and Values: Benefits of Neighborhood-Based Community Gardens for Youth Development and Nutrition. *Journal of Hunger & Environmental Nutrition, 3*(4), 418–439. <https://doi.org/10.1080/19320240802529169>
- Race/Ethnicity Diversity of the Pierce County Workforce. (2019). [Diversity Report]. County Government. <https://internal.open.piercecountywa.gov/stories/s/Tier-1-Race-Ethnicity-Diversity/bwdy-gvfi/>
- RStudio Team. (2020). RStudio: Integrated Development for R. PBC. <http://www.rstudio.com/>
- Saldivar-Tanaka, L., & Krasny, M. E. (2004). Culturing community development, neighborhood open space, and civic agriculture: The case of Latino community gardens in New York

- City. *Agriculture and Human Values*, 21(4), 399–412.
<https://doi.org/10.1023/B:AHUM.0000047207.57128.a5>
- Schukoske, J. E. (n.d.). COMMUNITY DEVELOPMENT THROUGH GARDENING: STATE AND LOCAL POLICIES TRANSFORMING URBAN OPEN SPACE. LEGISLATION AND PUBLIC POLICY, 3, 42.
- Springbrook Park Community Garden. (n.d.). City of Lakewood, WA.
<https://cityoflakewood.us/lakewood-community-gardens-2/>
- Teig, E., Amulya, J., Bardwell, L., Buchenau, M., Marshall, J. A., & Litt, J. S. (2009). Collective efficacy in Denver, Colorado: Strengthening neighborhoods and health through community gardens. *Health & Place*, 15(4), 1115–1122.
<https://doi.org/10.1016/j.healthplace.2009.06.003>
- Ushka, C. (2020). Update from District 4 Council Member Catherine Ushka. City of Tacoma.
https://cms.cityoftacoma.org/CityCouncil/CM_Ushka/2020.12.02_Ushka_Enewsletter.pdf
- Van Den Berg, A. E., & Custers, M. H. G. (2011). Gardening Promotes Neuroendocrine and Affective Restoration from Stress. *Journal of Health Psychology*, 16(1), 3–11.
<https://doi.org/10.1177/1359105310365577>
- Voicu, I., & Been, V. (2008). The Effect of Community Gardens on Neighboring Property Values. *Real Estate Economics*, 36(2), 241–283. <https://doi.org/10.1111/j.1540-6229.2008.00213.x>
- Wakefield, S., Yeudall, F., Taron, C., Reynolds, J., & Skinner, A. (2007). Growing urban health: Community gardening in South-East Toronto. *Health Promotion International*, 22(2), 92–101. <https://doi.org/10.1093/heapro/dam001>

Zick, C. D., Smith, K. R., Kowaleski-Jones, L., Uno, C., & Merrill, B. J. (2013). Harvesting More Than Vegetables: The Potential Weight Control Benefits of Community Gardening. *American Journal of Public Health*, 103(6), 1110–1115.
<https://doi.org/10.2105/AJPH.2012.301009>

Appendix 1: Correlation Table

A complete correlation table that combines measured structural variables and socioeconomic variables, comparing pairwise correlations of values. The first value in each cell is the correlation value between the variable in the column and row. The value in the parentheses is the p-value associated with the correlation.

	use	total area	total plot	plot size	median income	home value	total tagro	percent white	racial groups
use	1	0.20 (0.12)	0.02 (0.90)	0.29 (0.02)	0.06 (0.64)	0.13 (0.32)	0.16 (0.21)	0.11 (0.39)	0.04 (0.77)
total area		1	0.45 (0.0003)	0.72 (0.00)	-0.09 (0.49)	0.04 (0.73)	0.80 (0.00)	0.03 (0.79)	-0.05 (.69)
total plot			1	-0.02 (0.90)	-0.15 (0.24)	-0.001 (0.99)	0.31 (0.01)	-0.16 (0.22)	0.11 (0.41)
plot size				1	-0.07 (0.61)	-0.001 (0.97)	0.71 (0.00)	-0.16 (0.69)	-0.09 (0.50)
median income					1	0.72 (0.00)	-0.22 (0.09)	0.74 (0.00)	-0.65 (0.00)
home value						1	-0.15 (0.25)	0.69 (0.00)	-0.73 (0.00)
total tagro							1	-0.14 (0.27)	0.11 (0.41)
percent white								1	-0.62 (0.00)
racial groups									1

Appendix 2: Linear Models

Multiple linear models were constructed with a combination of structural and socioeconomic variables. Variables were transformed to minimize skew and kurtosis and if variables were highly or moderately correlated (>0.5) they were not included in the same model to avoid overestimation of the model's explanatory power. The structure of the dataset presented some challenges for statistical power and pseudo replication or weighting. The intensity of use was measured for each plot, but most of the other variables are measured for each garden. Additionally, the outcome variable is categorical by plot, but averaged into a single value for each garden which makes an average use by garden that is continuous but with no variation and degrees of freedom equal to one. If analyses were completed by plot, then the number of the plots in the garden unfairly weighted the gardens with more plots. To combat the range in number of plots I manually created a dataset that had an even number of plots in each garden. However, this involved pseudo replicating some plots and removing others. This manipulated dataset addresses the lack of statistical power but contrives variance.

To highlight this difference, here are two linear models that both describe the predictive abilities of the total area of a garden, the number of plots in the garden, and the socioeconomic demographics of the garden on the average plot use of the garden.

$$use = \alpha + \beta(\text{total garden area}) + \beta(\text{number of plots}) + \beta(\text{diversity}) + \epsilon$$

When using a data set that averages the use at the garden level, with one sample for each garden results are:

Coefficients:				
	Estimate	Std. Error	t value	Pr(> t)
(Intercept)	2.0356200	0.3399863	5.987	1.43e-07
Total Garden Area	0.0001849	0.0001181	1.566	0.123
Percent White by Census	0.3088895	0.4300430	0.718	0.475
Total Plots in Garden	-0.0019203	0.0040194	-0.478	0.635
Residual standard error: 0.5549 on 58 degrees of freedom				
Multiple R-squared: 0.05374				
Adjusted R-squared: 0.004794				

When using the manually adjusted dataset with equal number of plots to understand use at a plot level, with 25 adjusted data points per garden results are:

Coefficients:				
	Estimate	Std. Error	t value	Pr(> t)

(Intercept)	2.026e+00	1.234e-01	16.419	<2e-16
Total Garden Area	5.470e-05	2.346e-05	2.331	0.0199
Percent White by Census	3.340e-01	1.555e-01	2.147	0.0319
Total Plots in Garden	-7.169e-04	1.406e-03	-0.510	0.6102
Residual standard error: 1.011 on 1605 degrees of freedom Multiple R-squared: 0.007551 Adjusted R-squared: 0.005696				

Both models violated different assumptions of the models and neither explained very much of the variance. Both R^2 values were lower when adjusted and explained less than one percent of residual variance. Neither models are robust or provide results that I feel comfortable claiming are significant or accurate. More advanced statistical practitioners may be able to construct more complete ordinal and mixed models.