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An Assessment of the Potential for Urban Rooftop Agriculture in West Oakland, California

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This Master's Project

An Assessment of the Potential for Urban Rooftop Agriculture in West Oakland, California

by

Nicole Reese

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University of San Francisco - MSEM Master's Project

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Abstract

Throughout the world, all forms of urban agriculture are growing in popularity with the desire to grow and eat locally sourced food. Barriers such as access to vacant land and contaminated soil make it difficult to implement urban agriculture projects on the ground (i.e. at grade). Rooftop farming is a feasible solution to such barriers of forms of urban agriculture at grade.

The small Business Mix Zone in West Oakland, California has over one million square feet of untapped rooftop space available for urban rooftop farming. Revenue of up to $4 million can be earned from the sale of produce grown on this space at local farmers markets, at produce stands, and to grocery stores, businesses, and restaurants. The produce grown on these rooftops will assist the City of Oakland meet its 30% locally sourced food goal and will provide the food desert of West Oakland with fresh fruits and vegetables currently unavailable to this area.

Acknowledgements

This research could not have been completed without the support from my family and friends, my coworkers and clients, my peers, instructors and professors in the MSEM program, and the guidance from my advisor, Dr. Maggie Winslow. I would also like to thank Mr. Darin Ranelletti, a Planner at the City of Oakland's Department of Planning, Building, and Neighborhood Preservation, for directing me to the tools necessary to complete this research.

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1.0 Introduction

Industrialization has allowed and encouraged the food system to become a global one. Instead of consuming food produced locally and sustainably, on average food in the United States travels 1,500 miles before it reaches our mouths (Green, 2007). This distance is called "food miles". The globalized food system requires an immense amount of energy resulting in emitted greenhouse gases to the atmosphere which can accelerate climate change. As a result, there is a growing movement to grow and eat local, sustainable food.

Urban Agriculture, defined simply, is the growth of food and raising of animals within the city limits. The various forms of urban agriculture include urban farms, community gardens, rooftop gardens, rooftop beehives, and backyard chicken coops. Many cities around the world have been evaluating the possibility and feasibility of implementing various forms of urban agriculture within the city limits. Oakland, California is currently evaluating and developing policies and rules to promote the growth and production of local food. As an interim measure, in March of 2011, the City of Oakland updated its zoning laws to allow the production of food and the raising of animals in all commercial and residential zones throughout the city after obtaining a conditional use permit (City of Oakland, n.d.-b). Additionally, the Oakland Food Policy Council was established to create a sustainable food system where at least 30% of the city's food requirements will come from within the city or its adjacent environment (Green, 2007). Urban agriculture in all forms will be paramount to reducing food miles and creating a resilient city.

Although urban agriculture is becoming a very popular food production practice, it is hardly a new one by any means. Urban agriculture has existed since before the Common Era (i.e., Before Christ). The Classic Mayan civilization and the Byzantine Empire utilized urban agriculture for long term food security and resilience during times of crisis, such as invasion. Other historical examples of urban agriculture that were utilized to enhance food security and resilience during times of crisis include the Victory Gardens planted in various countries throughout World War I and II, and the urban farming in Cuba following the United States blockade and collapse of the Soviet Union (Barthel & Isendahl, 2013).

Urban agriculture has numerous benefits for a city, residents, and communities. The most obvious benefit is food production. It increases food security because it reduces the reliance on rural areas for food (Whittinghill & Rowe, 2011). All forms of urban agriculture can help a city be resilient in times of crisis such as food shortages, price spikes, and invasion. It also reduces the distance of food travelled from farm to fork. Urban agriculture can connect people back to the food system, which has become a global one, and provide educational, occupational, and economic opportunities for a community.

Urban agriculture is a key component to a sustainable community food system and can remove the diet related diseases associated with food deserts because healthy foods are not available at affordable prices (Cano, 2011).

Another known benefit of urban agriculture is reduced stormwater runoff because gardens and farms absorb rainwater whereas pervious surfaces do not.

Urban agriculture provides ecological habitats (Cosier, 2011). Other land uses such as commercial or residential development destroy ecological habitats.

Additional benefits include improving the quality of life for the poor, providing aesthetic benefits to a city and increased property values for owners. Lower crime rates exist in cities with urban agriculture because urban gardens create a greater sense of community within a city (Heckler, 2012). When the city of Philadelphia converted 4,400 out of 54,000 vacant lots to urban farms the number of shootings surrounding the newly greened areas were reduced (Kotlowitz, 2012)

Air quality improvements are observed in cities with urban agriculture because particulates are removed from the air. Urban agriculture reduces the urban heat island effect which is the elevated temperatures of urban areas compared to surrounding areas due to the non-reflective surfaces storing incoming solar radiation (Unger & Wooten, 2006).

Urban agriculture reduces greenhouse gas emissions which accelerate climate change. By selecting the right crops that yield the highest amount of food in local conditions, a significant amount of greenhouse gas emissions can be saved (Kulak, Graves, & Chatterton, 2013). Urban farms can reduce greenhouse gas emissions at a faster rate than carbon sequestration from city parks and forests. In the United Kingdom, a life cycle analysis showed that the conversion of 26 hectares of vacant land to community farming designed with certain specifications could reduce greenhouse gas emissions into the atmosphere by 881 tons of carbon dioxide equivalent per acre (Kulak et al., 2013).

Conventional systems for producing fruits and vegetables are extremely energy intensive due to the use of heated greenhouses and the need to transport the produce to smaller markets by heavy good vehicles, ships, and planes (Kulak et al., 2013). Urban agriculture can reduce these negative effects because the food is grown and sold locally.

Despite the numerous benefits described above, there are also some barriers to urban agriculture. In most dense cities, access to affordable or vacant land is a barrier to urban agriculture. Even if land is available, it is likely that other competitive land uses such as commercial or residential development will be chosen because they are more advantageous and profitable to the land owner. Food crops require adequate sunlight, water, and fertile growth media (i.e., soil) and it can be difficult to find spaces that meet these criteria in urban settings. There are also perceived health risks associated with the growth of food in urban areas such as plant uptake of heavy metals or other toxins from contaminated soil and/or water. Additionally, the general population of urban areas typically lack the skill set needed to grow and harvest food as well as manage resource use, oversee a labor force, sell the products, and arrange transportation (Lovell, 2010).

A solution that has the potential to address many of the aforementioned barriers to urban agriculture is rooftop food production. Rooftop food gardens have many of the benefits, if not more, that other forms of urban agriculture that occur on the ground have including carbon dioxide abatement, less expired roofing material being sent to the landfill, stormwater retention, and noise reduction (Rowe, 2011). Some advantages of rooftop gardening over growing food on the ground are that contamination can be controlled, soil composition can be managed, and the growth of nuisance weeds are less likely (Urban Design Lab, 2012).

Rooftop food gardens can be very beneficial to the residents of Oakland, California. Such gardens can assist the city in reaching the Oakland Food Policy Council's mission of producing 30% of the food needed for the city's residents from within or adjacent to the city. The neighborhood of West Oakland specifically would realize significant benefits from urban agriculture in the form of rooftop food gardens. West Oakland is a poverty-ridden, semi-industrial neighborhood and has been identified as a "food desert" (Hagey, 2012). The United States Department of Agriculture defines "food deserts" as "urban neighborhoods and rural towns without ready access to fresh, healthy, and affordable food" (US Department of Agriculture, 2014). Urban agriculture in any form in West Oakland will help bring fresh fruits and vegetables to the residents and help the neighborhood be resilient against shortages of food due to reasons such as peak oil, natural disasters, and climate change.

Available land for urban agriculture is scarce in West Oakland as well as in the rest of the city. Due to historical operations such as iron works and canning, there is extensive soil contamination in the industrial area of West Oakland. Therefore, rooftop food production would eliminate the need to remediate soils prior to using land for other forms of urban agriculture (e.g., community garden). Using the untapped space on industrial/commercial rooftops for agriculture may solve the limited land issue and help to bring healthy and whole foods to this "food desert".

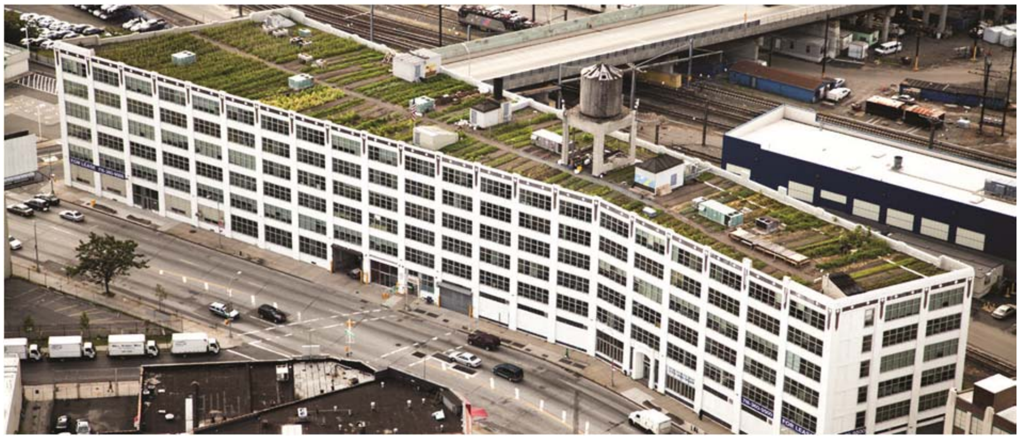
The goal of this research effort is to determine the hypothetical food production and revenue potential from farming on the suitable rooftops of buildings in the industrial/commercial zoned area (Business Mix Zone) of West Oakland (i.e., mainly adjacent to and to the East of Interstate 880 and the Port of Oakland). The growth and harvesting of fresh fruit, vegetables, beans, and more on suitable, underutilized, industrial/commercial rooftops in West Oakland can bring fresh food to the residents of this Oakland neighborhood.

This research paper will describe the barriers to at grade forms of urban agriculture. Green roofs will be defined and the benefits will be explained. Types and requirements of green roofs for food production will be introduced and described in detail. It will provide a history of West Oakland, which explains how the neighborhood has developed into a “food desert”. The establishment of the Oakland Food Policy Council’s goal of a sustainable urban food system will also be discussed. The methodology as to how the food production potential on rooftops in the Business Mix Zone of West Oakland was calculated will be explained and the results will be discussed. Limitations of this research and future research needs prior to the implementation of rooftop agriculture in the Business Mix Zone of West Oakland will discussed. Barriers and challenges to rooftop agriculture will be presented and policy recommendations will be offered on how to encourage rooftop agriculture in Oakland as well as in cities around the world.

2.0 Urban Agriculture

As noted in the introduction, SPUR (2012) defines urban agriculture as “growing of food through intensive plant cultivation and animal husbandry in and around cities”. Urban agriculture includes community gardens, urban farms, greenhouses, rooftop beehives, school gardens, and backyard chicken coops. Figure 1 shows an aerial view of the Brooklyn Grange rooftop farm - a one acre urban farm on top of a six story industrial building in Long Island City, a neighborhood in the borough of Queens in New York City (Brooklyn Grange, 2014). The existing forms of urban agriculture prevalent throughout Oakland include more than 100 school gardens, 10 community gardens that are managed by Oakland’s Office of Parks and Recreation, dozens of community gardens managed by non-profit organizations, and more. The extent of residential urban agriculture in Oakland is unknown (N McClintock, Cooper, & Khandeshi, 2013).

Figure 1 – Aerial View of Brooklyn Grange Rooftop Urban Farm (Brooklyn Grange, 2014)



2.1 Barriers to Non Rooftop Urban Agriculture

Implementing urban agriculture in the neighborhood of West Oakland, California has some significant barriers that need to be overcome.

2.1.1 Available Land

Cities are usually densely populated areas with little to no vacant land available for urban agriculture. Many cities, including Oakland, have changed their zoning rules to allow urban agriculture to occur in every zoning designation. The little land available for urban agriculture in cities are in high demand and are vulnerable to future residential or commercial development (Kortright, 2011). Additionally, unless urban farmers own the land they use or plan to use for urban agriculture, long term leases of three to five years or title are necessary to prevent the farmer from losing investments when the land is no longer available to them (Urban Agriculture Committee of the Community Food Security Coalition, 2002). These land availability issues can be discouraging to potential urban farmers.

To address this barrier, California enacted a law in late 2013 to "allow municipalities to lower taxes on vacant property if an owner agrees to dedicate the land to small-scale crop production for at least five years" (Selna, 2013). To date, Oakland has yet to approve the ordinance (Selna, 2013).

2.1.2 Soil Contamination & Remediation

Soil contamination and proper remediation of soils is another obstacle that must be recognized and overcome prior to starting a community garden or other ground form of urban agriculture. Historical uses of land such as heavy industry likely have resulted in heavy metal (i.e., lead) and synthetic organic contamination in urban soils. Industrial lead contamination usually results from atmospheric deposition downwind from smelting operations. Lead contamination can also occur along freeways from vehicular exhaust (Mcclintock, 2012). In residential areas, lead contamination results from lead containing painted surfaces. Although lead has been banned many years ago (circa 1970), large amounts of lead paint still remain both inside and outside older homes. Much of the exterior lead containing paint is contained in the home's surrounding soils. 52% of homes built prior to 1978 have lead concentrations in their front, back, and side yard soils that are greater than 400 milligrams per kilogram, the United States Environmental Protection Agency's contamination screening level (Mcclintock, 2012).

Urban farming can result in lead exposure by either contact with lead contaminated soil, lead containing painted surfaces, or by the consumption of food grown in lead-contaminated soil. Edible plants can uptake these heavy metals into their roots and can ultimately cause cognitive disruptions, nervous, cardiovascular, kidney, bone, and liver diseases, and cancer (Whittinghill & Rowe, 2011). Adults absorb 5% and children absorb 50% of the lead that is ingested or inhaled (Mcclintock, 2012).

The East Bay Urban Agriculture Alliance recommends soil testing or growing crops in raised beds. Soil should be tested for lead and then compared to the state and national health standards (East Bay Urban Agriculture Alliance, n.d.). The San Francisco Department of Public Health has guidelines for farmers to conduct lead hazard risk assessments and to mitigate identified hazards (San Francisco Urban Agriculture Alliance, 2011). Lead mitigation or remediation should occur where lead concentrations are greater than 80 parts per million (SF Environment, 2014).

As a precautionary measure, comprehensive soil investigations and possibly costly soil remediation will need to occur on all available vacant land prior to initiating an urban agriculture project.

2.1.2.1 Lead Contamination in West Oakland, California

There has been expressed concern over contaminated land that has the potential to be used for urban agriculture in the Oakland Flatlands, which includes West Oakland. Nathan McClintock, associated with the Department of Geography at the University of California, Berkeley, received funding from the University of California Division of Agriculture, the Natural Resources Analytical Laboratory, and the Natural Science Foundation to conduct a soils investigation and to determine larger scale spatial trends of lead contamination in the City of Oakland (Mcclintock, 2012).

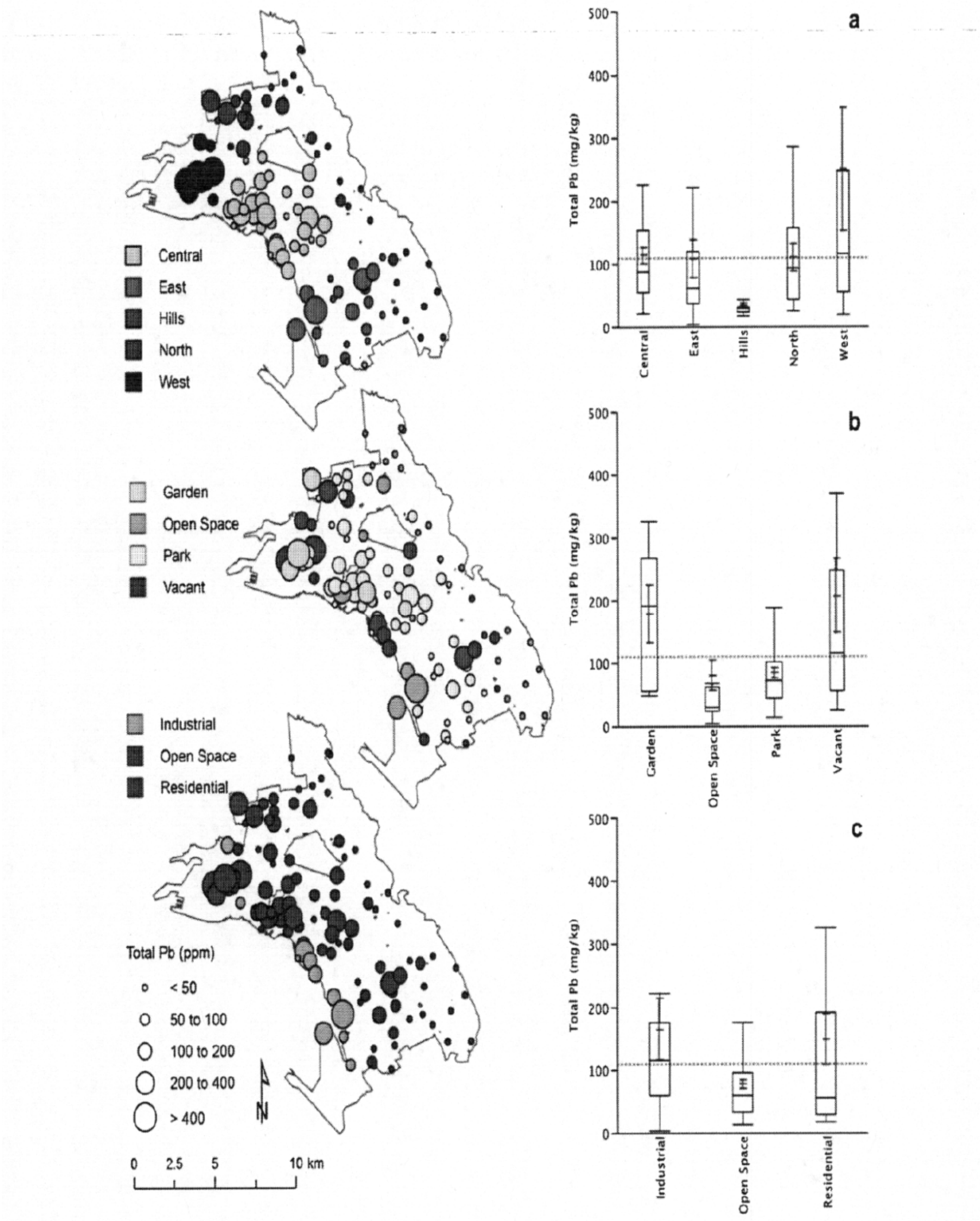
During the investigation, composite samples were collected at various potential urban agricultural sites in Oakland, California at depths ranging from 5 to 10 centimeters, dependent on penetrability. On the city-scale, most sites had lead concentrations of less than 100 milligrams per kilogram. However, a hotspot analysis showed clusters of elevated lead concentrations in the southern portion of West Oakland and around the San Leandro Bay and the Oakland Airport. Generally, lead concentrations throughout the City of Oakland were lower than the 400 milligrams per kilogram United States Environmental Protection Agency contamination screening level, but greater than the California Human Health Screening Level of 80 milligrams per kilogram (Mcclintock, 2012).

The study had concluded that the elevated lead concentrations were not naturally occurring and instead were due to atmospheric deposition from anthropogenic sources. Higher median lead concentrations were observed in West Oakland compared to the rest of the city and can be attributed to the age of the built environment as West Oakland is the oldest part of the city. Figure 2 (Mcclintock, 2012), shows the distribution of lead concentrations by a) geography, b) land use, and c) zoning classification.

Lead contamination in West Oakland is caused by a variety of anthropogenic sources including historical smelting and other polluting operations, vehicle exhaust from traffic on Interstates 580, 880, and 980, and old lead painted homes. There is some clustering of lead hotspots in the southwest corner of West Oakland, which is adjacent to the former Phoenix Iron Works which operated from the early 1900s through early 1990s. Lead is a byproduct emitted to the atmosphere during iron smelting (Mcclintock, 2012).

This lead contamination soil study for Oakland reinforces that a thorough site investigation must be conducted prior to starting a community garden or other at grade form of agriculture within an urban area. Costs to investigate and remediate any discovered contamination may deter the growth of urban agriculture on the ground. Alternatively, underutilized rooftops can provide uncontaminated space for food production.

<u>Figure 2 – Lead Distributions in Oakland, California</u> (Mcclintock, 2012)



2.2 Summary of Previous Urban Agriculture Studies Conducted in Oakland

In recent years, a few studies have been conducted in the City of Oakland to evaluate the potential for urban agriculture on both publicly and privately owned land. The next two sub-sections will provide summaries of these investigations.

2.2.1 Potential for Urban Agriculture on Public Land

The study, *Cultivating the Commons: An Assessment of the Potential for Urban Agriculture on Oakland's Public Land* (Mcclintock & Cooper, 2009), created an inventory of municipal, county, regional, state, and federal vacant lands that could potentially be used for urban agriculture within the city limits of Oakland, California. Vacant land included lawns or any other vacant land that is part of a park or located adjacent to a government building. Utilized lands such as playing fields were not included in the inventory. The authors included some vacant parking lots in the inventory as they could be used to stage agricultural equipment. Food could also be grown in raise beds in the vacant parking lots ((Mcclintock & Cooper, 2009) .

Initially, over 10,000 acres on 2,600 publicly owned parcels of land were identified through the City of Oakland's Geographic Information Systems database. Then satellite imagery was used to determine parcels that had open space potentially suitable for urban agriculture. Fully developed parcels, parcels that had less than 500 square feet of open space, and densely vegetated parcels were excluded from the inventory. About 10% of the identified sites were confirmed with a site visit. The total remaining areas of open space were then added together to determine the total area of public vacant land available for urban agriculture (Mcclintock & Cooper, 2009).

The results of this study concluded that there are 1,201 acres of open space distributed relatively evenly across the City of Oakland. Majority of the potential sites are located in East Oakland and a large number of sites are found in West Oakland. Approximately a third of the sites are suitable for community gardens (i.e., < .25 acres); a third should be used for community gardens or small market gardens run by urban agriculture organizations (i.e., .25 to 1 acre); and a third could be developed as large market gardens (i.e., 1 to 5 acres). Additionally, 45 sites are greater than 5 acres in size and could be leased to commercial farmers for development as a large-scale urban farm. A back of the envelope calculation concluded that Oakland's public lands that are suited for urban agriculture could potentially grow 5% of the city's vegetable needs and could double under intense production and managed by professional urban farmers (Mcclintock & Cooper, 2009) .

2.2.2 Potential of Urban Agriculture on Private Land

Two studies were conducted to evaluate the availability and suitability of vacant private land in Oakland. The studies came up with slightly different results.

The first study, *Evaluating the Feasibility of Urban Agriculture on Oakland's Private Land* (Baker, 2012), identified 2,961 parcels of privately owned land comprising of 1,076 acres of land. Geographic Information Systems data was obtained from the City of Oakland and was filtered by land use. Publicly owned land and residential land use were not included. Vacancy was confirmed through satellite imagery and parcels that were densely covered with trees were eliminated from the inventory. Once this initial inventory was complete, a suitability analysis was conducted to determine ground cover (i.e., grassy or hard surface), slope, aspect, and water access. Parcels with good opportunities for urban agriculture include south facing; grassy surfaces with less than 10% slope, and located within 10 feet of water access. Of the 2,961 parcels, 40% (430 acres) had grass or dirt surfaces. Slopes generally ranged from 0 – 30% with the majority of the flatter land in the flatlands. 27% of the parcels faced either south, southeast, or southwest and it appears most of the parcels in Oakland are within 10 feet of water access (Baker, 2012).

The second study, *Assessing the Potential Contribution of Vacant Land to Urban Vegetable Production and Consumption in Oakland, California* (N McClintock et al., 2013), initially identified 3,008 privately owned parcels of land comprising of 864 acres of land. The majority of the privately owned parcels are less than 0.25 acres in size, not suitable for urban agriculture, and total 289 acres. There are 15 parcels that are greater than 5 acres in size. The authors eliminated land that was greater than 30% slope, which left 337 acres of privately owned land potentially available for urban agriculture. A conservative estimate of 3,370 tons of vegetables could be grown via conventional farming methods on the suitable privately owned, vacant land in Oakland which could supply Oakland with 2.1% of its current vegetable consumption and 9.8% of the recommended consumption (N McClintock et al., 2013).

Although these studies indicate there are vast amounts of public and private land in Oakland available for urban agriculture, intensive soil investigations and costly remediation of lead contaminated soil will likely be necessary before any urban agriculture project on the ground commences. Additionally, long term leases to the available land will need to be issued. Long term leases may not be popular with landowners because possible future residential or commercial development would be more profitable for them. These barriers can be eliminated by using the untapped rooftops as a platform for food production.

3.0 Green Roofs

3.1 Definition of Green Roofs

A simple definition of a green roof is any planted space with clear segregation from the earth's surface by a building or other structure (Kortright, 2011). Green roofs can also be called living roofs, vegetated roofs, planted roofs, or eco roofs and are designed to improve building performance (SPUR, 2013) and even grow food. Green roofs can provide access to more space for urban agriculture (Whittinghill & Rowe, 2011). Green roofs could be a feasible solution to the barriers to urban agriculture discussed in the previous section because, besides photovoltaic solar installations, there is no other competitor for the use of rooftops (Berger, 2013). Flat rooftops ranging from 10,000 to 100,000 square feet are ideal for green roofs because they can support larger, commercial rooftop farms (Kortright, 2011).

3.2 Benefits of Green Roofs

In general, green roofs preserved for food production have many of the same benefits, and more, as forms of urban agriculture that are on the ground. Some of the more beneficial aspects of green roofs are described herein.

Biological carbon sequestration is a prominent aspect of green roofs that results in the planted rooftop being a carbon sink (Rowe, 2011). Additionally, green roofs provide insulation for a building and reduce the overall energy demand and consumption of a building regarding heating and cooling. Reduced energy use directly reduces greenhouse gas emissions and building operation costs (Kortright, 2011).

Green roofs, including rooftop agriculture, can reduce the urban heat island effect. The urban heat island effect is the elevated temperature (~ 2 to 4 degrees Celsius) within cities or other urban areas compared with surrounding rural areas caused by non-reflective surfaces that store incoming infrared radiation, ultimately storing heat. Increased vegetation on rooftops cools the surface more cost effectively than the installation of light roofs which increase albedo (i.e., reflectivity). In New York City, green roofs are projected to cool temperatures by 1.4 degrees Fahrenheit (Urban Design Lab, 2012). On average, green roofs have had temperatures 3 to 4 degrees Celsius cooler than surrounding traditional roofs (Foss, Quesnel, & Danielsson, 2011). Because climate models project global temperatures to continue to increase, green roofs are sustainable infrastructure features that should be implemented throughout urban areas to mitigate some of the increased heat (Berger, 2013).

A vegetated roof provides habitats for birds and insects which increases biodiversity within an urban area. "Then can provide food, habitat, shelter, nesting opportunities, and a safe resting place for spiders, beetles, butterflies, birds, and other invertebrates" (Foss et al., 2011).

Another benefit of a green roof in lieu of a traditional rooftop is that less expired roofing material will be sent to landfills. The lifetime of a traditional roof is 20 years and once it is expired and sent to a landfill, it can leach pollutants into the soil and groundwater. With a green roof, the bituminous membrane is covered with soils and plants which protect it from ultraviolet damage and variations in temperature throughout the day, making the green roof last approximately 45 years, double the lifetime of a traditional roofing system (Rowe, 2011). The vegetation on a green roof also protects the bituminous membrane from punctures (Kortright, 2011) and reduces noise experienced by the building. Soil and plants absorb sound waves better than traditional roofs and can greatly reduce noise pollution from airports, industrial areas, and urban areas (Rowe, 2011)

Vegetated roofs are a good tool for stormwater management. A green roof with 10 centimeters of growing media can absorb approximately two thirds of the rainfall (Foss et al., 2011). Stormwater reduction can range from 50 to 100%, depending on the installed green roofing system and specific parameters and conditions. The increased absorption decreases the occurrences of combined sewage overflows because the absorbed water transpires into the atmosphere and runoff is delayed. Additionally, green roofs can have a positive impact on water quality as stormwater managed on green roofs will not collect pollutants such as oil, metals, salts, pesticides, and animal wastes (Rowe, 2011).

Finally, the most pertinent benefit of green roofs regarding this research effort is food production. A few studies have determined that growing food on rooftops is not too much different than farming practices occurring at grade (Kortright, 2011; Whittinghill, Rowe, & Cregg, 2013). The sale of the produce grown on green roofs can be profitable. $3.59 per square foot per year is an attainable revenue (Brooklyn Grange, n.d.). A few land gardeners in San Francisco earned revenues of more than $1 million in 2007 (Mcclintock & Cooper, 2009). All the benefits of urban agriculture described in the introduction section of this report also apply to rooftop agriculture.

3.3 Types of Green Roofs and Requirements

3.3.1 Types of Green Roofs

There are three main types of green roofs that may be utilized for rooftop agriculture. These types include extensive, intensive, and hydroponic gardens.

Descriptions and characteristics of these three types of green rooftop gardens are described in the following subsections. Each type of green roof for agriculture is beneficial in its own way. However, since the goal of this research is to determine the food production potential of rooftops in the Business Mix Zone of West Oakland, a more detailed description of the vegetable crop growing, intensive green roof is included below.

3.3.1.1 Extensive Green Roofs

Like the name implies, an extensive green roof is usually installed on the entirety of the rooftop. Extensive green roofs are not typically installed for recreational purposes or in efforts to grow food crops. They are designed with the goals of improving building performance and can be installed on rooftops with slopes of up to 45 degrees. Growing medium (e.g., soil) usually ranges from 2 to 5 inches deep and plant heights usually range from 2 to 6 inches high. When saturated, weights typically ranged from 10 to 50 pounds per square foot. Plants that are suitable for extensive green roofs include succulents, grasses, and mosses (Bay Localize, n.d.). If utilized for growing food, an extensive green roof is best suited for growing herbs and low root vegetables such as leafy greens (Foss et al., 2011).

3.3.1.2 Intensive Green Roofs

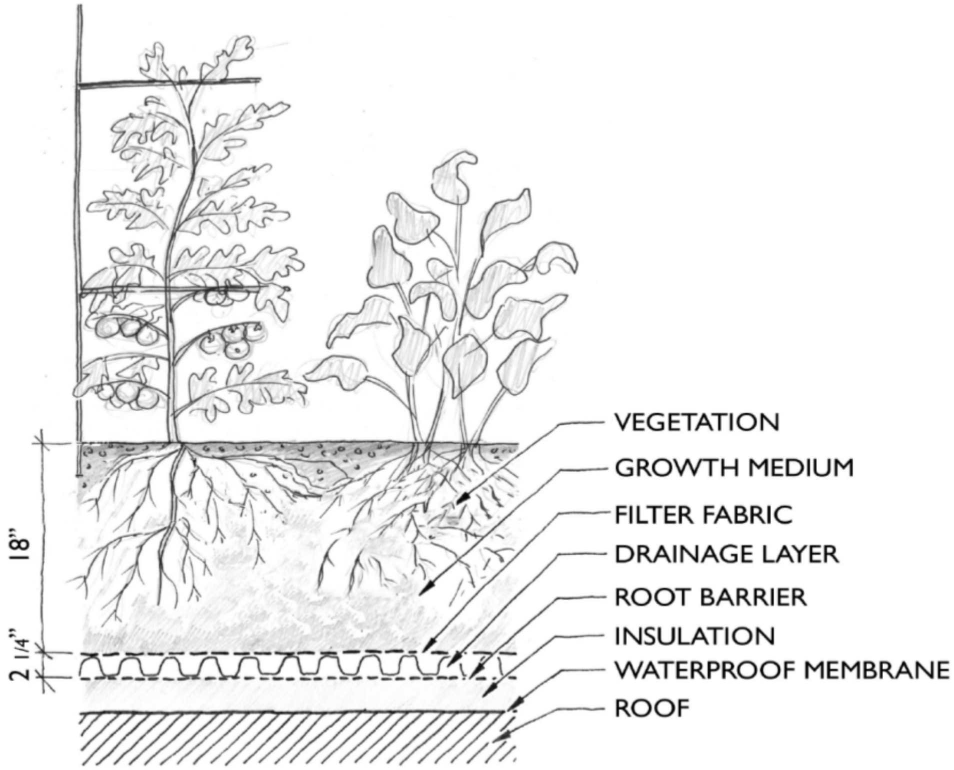
Compared to the extensive green roof, the intensive green roof type has deeper growing substrates and can grow a wide variety of vegetable crops (Foss et al., 2011). This type of green roof is installed on larger, flat rooftops. Soil depths usually range from 8 to 12 inches deep and can be as deep as 18 inches. Soil depths depend on the structural capacity of the building. When saturated, weights of this type of green roof range from 80 to 120 pounds per square foot (Bay Localize, n.d.).

3.3.1.2.1 Example Intensive Green Roof Prototype

Bay Localize, a non-profit, Oakland based organization with the vision of shifting from a globalized, fossil fuel based economy to a more local and sustainable one and a planning consulting company, Holmes Culley performed a neighborhood assessment on the

Eastlake District in Oakland to determine the rooftop potential of existing buildings. The assessment is called *Tapping the Potential of Urban Rooftops – Rooftop Resources Neighborhood Assessment* (Bay Localize, 2007). This study developed an intensive green roof prototype for typical, existing buildings in the San Francisco Bay Area. The authors note that this prototype is only an example and should not be installed without professional advice on design loads and roof loading capacity (Bay Localize, 2007). The prototype they advise is described herein and shown on Figure 3.

<u>Figure 3 – Cross-Section of Intensive Green Roof – Vegetable Prototype</u> (Bay Localize, 2007)



The prototype calls for at least 18 inches of growing substrate which is suitable for year-round growth of a wide range of edible, vegetable crops. The assembly on top of the existing roof, building upwards, includes a waterproof membrane, insulation, a root barrier, a 2 ¼ inch drainage layer overlain with a filter fabric, 18 inches of growing medium, and the vegetable crops. Because conventional growing mediums such as topsoil are too heavy for most rooftops, it is recommended to use a 1:1 ratio of organic mulch and mineral material as a substrate. It is recommended that the drainage layer be made of recycled polystyrene, filled with lava or similar material. The live load of this prototype is approximately 108 pounds per square foot. However, it is not intended to be installed over the entirety of the rooftop. Instead, it is estimated that 60% of the rooftop will be available for growing due to fixed features and paths needed to access the crops as well as space to store farming equipment (Bay Localize, 2007).

Crops that are suitable to be grown in this example of an intensive green roof include spinach, mustard, carrots, beets, tomatoes, cucumbers, winter squash, leaf lettuce, broccoli, celery, chard, collards, eggplant, kale, mustard, green onions, and peppers. This prototype can provide an annual yield of approximately 1.86 pounds of vegetables per square foot. Maintenance requirements would include frequent irrigation either by hand or an irrigation system along with pruning the vegetables, weeding, fertilizing, and pest control. Regular inspection and possible repair of the roof membrane are additional maintenance needs (Bay Localize, 2007).

3.3.1.3 Hydroponic Rooftop Garden

A hydroponic rooftop garden is one that involves growing vegetables without soils. Instead, crops are grown in water with controlled nutrient minerals in solution. This form of rooftop agriculture is the lightest of all rooftop gardens and can be installed on top of buildings that have structural limitations. Hydroponic systems can produce similar amounts of food as soil gardens in approximately 1/5 of the space. Additionally, this form of rooftop gardening can use up to 90% less water than traditional gardening (Foss et al., 2011).

The disadvantages of this rooftop agricultural system include costly equipment, huge energy inputs, and the need for technical expertise. Additionally, hydroponic rooftop gardens don’t manage stormwater or mitigate the urban heat island effect like other forms of rooftop agriculture (Foss et al., 2011). Growing food is only one of the benefits of urban rooftop agriculture. The aforementioned disadvantages negate many of the other advantages of green roofs. Therefore, rooftop agriculture in the form of hydroponics is not considered for implementation in the Business Mix Zone of West Oakland.

3.3.2 Building Code and Other Requirements

Because rooftop gardens are typically designed for public access, the alteration of a rooftop with the goal of growing anything must be in compliance with various codes and requirements including the California Building Code and city building, zoning, and fire codes (Bay Localize, n.d.). A summary of the requirements are provided below and it should be noted that interpretation of the California Building Code will vary by municipality.

3.3.2.1 California Building Code – Chapter 10: Occupancy Loads and Egress

The California Building Code includes occupancy load and egress requirements for rooftop installations. Rooftop gardens will require ways to access and depart them. Means of egress will be determined based on the occupancy load (i.e., number of occupants on the rooftop at one time) determined by the city's Building Department. One exit is suitable for occupancy loads up to 10 people. Most rooftops only have one egress and providing a second could be difficult and costly. Assuming "that gardening has similar intensity of use to manufacturing or a commercial kitchen", up to 2,000 square feet of a rooftop can be designated for rooftop agriculture and not exceed the occupant load of 10, which would require one means of egress. However, it should be noted that more advanced and intensive rooftop agriculture operations could be deemed a gathering space, thus requiring two exits from the roof (Bay Localize, n.d.).

3.3.2.2 California Building Code – Chapter 5: Guardrail

Guardrails, or other protective barriers of at least 42 inches in height are required to be installed to keep people from falling off the roof (Bay Localize, n.d.).

3.3.2.3 California Building Code – Chapter 11 and the Americans with Disabilities Act: Accessibility

Accessibility to rooftops for people with mobility disabilities is governed through the Americans with Disabilities Act and the California Building Code, Chapter 11. These regulations require accessibility features such as elevators and ramps to provide universal accessibility to public rooftop gardens. There are some instances where elevators are not required and include buildings with fewer than three stories and buildings with less than 3,000 square feet per floor. Buildings not exempt from elevator requirements are shopping centers, health care provider offices, public transit stations, and airport passenger terminals. Chapter 11 of the California Building Code includes residential buildings in its scope. Accessibility features may be waived if the cost to install these features is greater than 20% of the entire planned alteration if under $120,000. These financial figures usually hold true for rooftop gardens (Bay Localize, n.d.). However, this decision is up to the municipality.

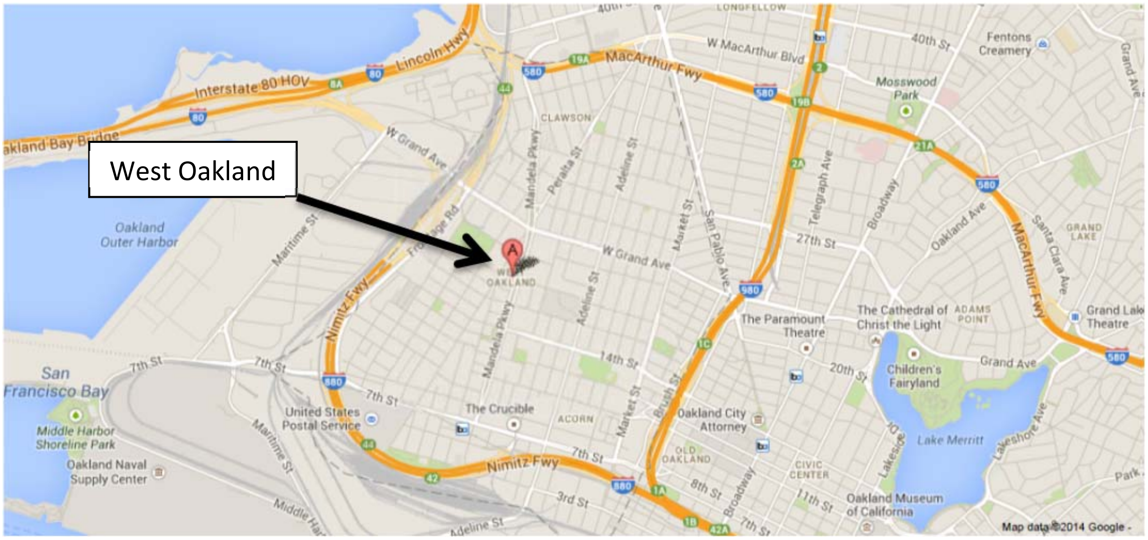
The inconvenience and associated costs of complying with the applicable building requirements for installing a rooftop garden may be outweighed by the countless benefits the rooftop garden will provide. The next section will provide background information regarding West Oakland and how rooftop agriculture can be paramount in providing fresh fruit and vegetables to the area.

4.0 West Oakland Food Desert & Oakland Specific Food Goals

4.1 West Oakland – Site Location & Population

The neighborhood of West Oakland is 6.5 square miles and is bordered by Interstate 880 to the West and South, Interstate 580 to the North, and Interstate 980 to the East. A site location map is provided in Figure 4. This Oakland neighborhood population is currently 32,272 and the population density is 4,967 persons per square mile. A third of the population (33%) is below the poverty line (City-data.com, n.d.). Persons living below the poverty line have not improved much compared to 1989.

Figure 4 – Site Location Map (Google, 2014)



4.2 History of West Oakland's Industry and Population

When first developed, West Oakland was a suburb to the City of San Francisco. In 1869, the transcontinental railroad was completed and extended as far west as West Oakland. West Oakland was the terminus of the railroad. The blue collar nature of the neighborhood was a result of the many employment opportunities the railroad had provided (Douglas, 1994).

West Oakland was not negatively affected by the 1906 earthquake and many businesses from San Francisco relocated to West Oakland. As a result, there was a high demand for labor for these industries that had moved into West Oakland including grain milling, canning, lumber planing, iron works, and miscellaneous light manufacturing. Most of these businesses settled near the railroad yards and along the waterfront. The labor demand for these new businesses caused a demographic shift throughout West Oakland (Douglas, 1994).

The "Golden Age" lasted from 1911 through the end of the 1920's and was a result of the World War I industries. At this point in time, West Oakland was an established neighborhood and had a community of mixed ethnicities, both working and middle class. Similar to the rest of the United States, the great depression had a negative effect on West

Oakland and its employment and economy. Consumer goods industries such as canning and other food processers were not affected too much. Homeless camps emerged in West Oakland because of its operation as the western terminus of the Southern Pacific Railroad (Douglas, 1994).

By the end of the 1930s, the infrastructure in West Oakland had been neglected and the neighborhood was undergoing degradation. Homes in the areas that were deemed as "slums" were bulldozed and public housing projects replaced them. These housing projects were built for World War II industry workers. The Second World War brought wartime industries, including shipbuilding, back into West Oakland. The Oakland Army Base and the Naval Supply Center were built along the waterfront on the filled tidelands. Although, these wartime jobs helped boost the economy of West Oakland, they didn't increase commerce on the Seventh Street business strip. After the war, the economically successful residents of West Oakland took their families to live in the suburbs (Douglas, 1994).

With the transportation makeover in America, the Southern Pacific Railroad Oakland yards become obsolete and the work force was cut to a skeleton crew. The Cypress Freeway, which was later destroyed during the Loma Prieta earthquake in 1989 was completed in 1957 and resulted in the demolishment of buildings located on Blocks 1 through 11. The freeway physically divided West Oakland from the rest of the city. Later, urban planners built a huge post office and ran the new BART station up Seventh Street in efforts to re-integrate this neighborhood back into Oakland (Douglas, 1994).

In 1989, unemployment in West Oakland averaged 21.5% and more than 35% of the residents lived below the poverty line. The ethnic mix was as follows: 77.3% African Americans, 11% Euro Americans, 5.7% Hispanics, 3.5% Asian and Pacific Islanders, and 0.3% Native Americans (Douglas, 1994).

4.3 The Food Desert in West Oakland

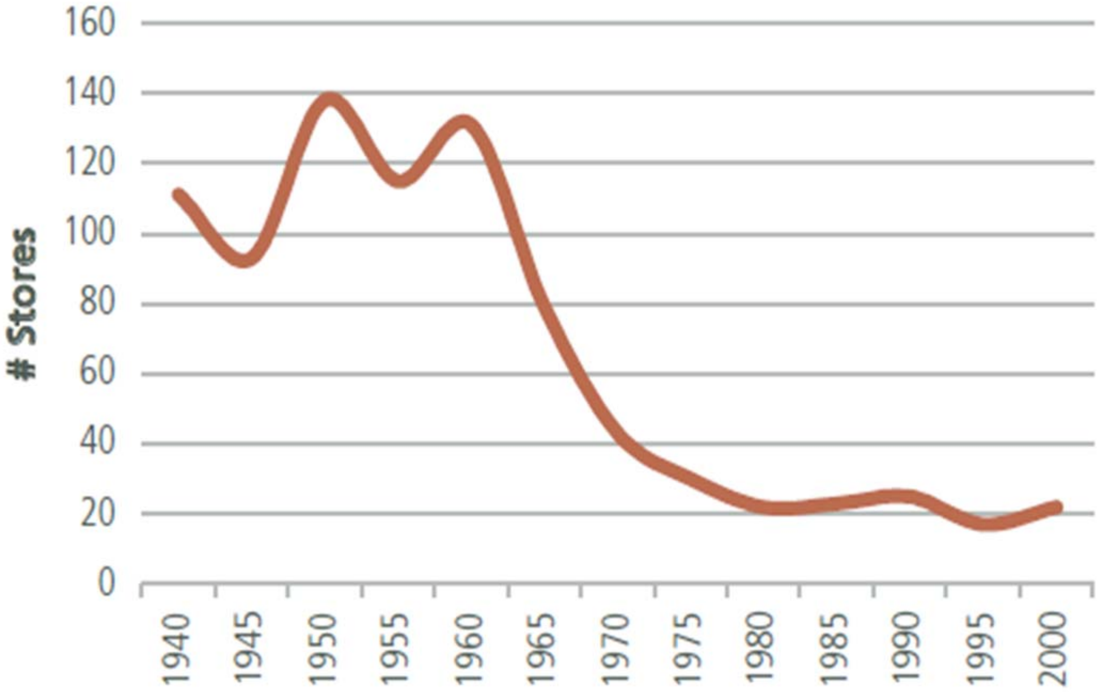
Food deserts are areas that lack access to healthy, affordable foods such as fruits, vegetables, and whole grains, and generally exist in lower income communities (Bonanno, 2012). Instead of having access to such healthy foods, there is an overabundance of unhealthy foods including packaged and processed foods at convenient stores and fast food restaurants (Ver Ploeg, 2010). Chronic food related diseases such as obesity and diabetes are very prevalent throughout food desserts (Kornberg, 2010). The West Oakland neighborhood of Oakland, California has been identified as a food desert (Hagey, 2012).

Compared to the Oakland Hills, an affluent neighborhood in Oakland, where there is one supermarket for every 8,175 people, there is only one supermarket for every 42,350 people in the Oakland Flatlands (Oakland Food Policy Council, 2010). West Oakland is a part of the Oakland Flatlands.

The declining trend of open food stores in West Oakland is depicted on Figure 5 (Oakland Food Policy Council, 2010). Between 1940 and 1960, the number of food stores in West Oakland ranged from 90 to 140. After 1960, the number of food stores steadily declined through 1980 and then remained steady with approximately 20 open food stores through 2000. The last remaining large (>10,000 square feet) supermarket closed its doors in 2007 (Oakland Food Policy Council, 2010).

Most “mom and pop” grocery stores and larger supermarkets have left the neighborhood of West Oakland because majority of the businesses and industries that thrived in the early to mid-20th century are no longer there. The remaining corner stores only provide processed foods, alcohol, and cigarettes to their customers. Healthy food and fresh produce are not readily available to the residents of West Oakland (People’s Grocery, 2014). These statistics define West Oakland as a “food desert”, where liquor stores serve as food retailers (Nathan McClintock, 2008).

Figure 5 – Number of Food Stores in West Oakland (The Alameda County Public Health Department, 2008)



4.4 City of Oakland's Local Food Goal

The Oakland Food Policy Council was created in 2006 as a result of a unanimous vote of the Oakland City Council to allocate $50,000 towards its creation. The primary goal of the Oakland Food Policy council is to develop a sustainable food system where at least 30% of Oakland's food needs will be grown or bought from within the city or it's fringe (Green, 2007). The objective of this local sourcing goal is to "ensure food security, promote economic development, maximize urban agricultural and food waste recovery, support regional agricultural preservation, and increase community 'food literacy'" (Oakland Food Policy Council, 2010).

Jerry Brown, the Mayor of Oakland at this time, initiated a food systems assessment which determined that 14,601 acres of land or space is needed to reach the 30% local food sourcing goal (Hagey, 2012). Amongst the various recommended first steps in transforming the Oakland Food System is to protect and expand urban agriculture (Oakland Food Policy Council, 2010). Various studies have been implemented to determine the amount of land or space accessible for urban agriculture. These studies were discussed in detail in Section 2.2 of this report. The Oakland Food Policy Council recognized that there are various and difficult obstacles to overcome regarding accessing land for urban agriculture. The underutilized rooftops in the Business Mix Zone of West Oakland have the potential to help the City of Oakland reach their goal of sourcing 30% of the city's food needs from within or adjacent to the city. The next section will discuss the methods and results of the research.

5.0 Methodology and Analysis

This section will describe the methods used to determine the available area of untapped, suitable rooftops for the use of urban agriculture as well as the potential annual yield of produce and associated revenue from these underutilized spaces.

5.1 Existing Methodology

A sound approach to determining the availability of rooftops for food production is provided in the Master's thesis of Danielle Berger: *A GIS Suitability Analysis of the Potential for Rooftop Agriculture in New York City* (Berger, 2013). The author's research was conducted in two phases.

The author obtained the 2009 New York City Department of City Planning PLUTO building footprint shape file, which includes all five boroughs of the city. She then selected areas within the boroughs that were zoned either commercial or manufacturing. All residential use buildings were eliminated from the dataset (Berger, 2013).

She then eliminated any buildings that were taller than 10 stories high because rooftop conditions at heights beyond 10 stories are not advantageous for growing plants and are logistically difficult to move supplies, people, and produce. The next step was to determine the area of the rooftops of the buildings remaining in the dataset. The building footprint shapefile included the footprint area of each building. The author assumed that the footprint area is the same as the rooftop area and identified the buildings with areas greater than 10,000 square feet. These areas are conservative as they do not account for permanent rooftop features or other obstructions. The author notes that although there is no mandated size for a farm to be profitable, it is generally assumed the bigger the space, the more profitable the farm (Berger, 2013).

Buildings that were listed as having noxious or utility use on the building footprint shape file were also eliminated from the dataset. Such uses include heavy manufacturing; garage and gas stations; bridges, tunnels, and highways; electric utilities; telephone utilities; communication facilities (non telephone); and revocable consents (Berger, 2013).

Finally, buildings built post 1968 were then eliminated from the dataset. This was done because after 1968, the building codes were revised to require a lower minimum live load of 30 pounds per square foot. Previous New York City Building Codes dated 1916 and 1938 required minimum live loads of 40 pounds per square foot. Phase I resulted in identifying 5,701 buildings with rooftop agriculture potential throughout Manhattan, Brooklyn, Queens, Bronx, and Staten Island (Berger, 2013).

During the second phase of the research, the study area was narrowed to include only the North Brooklyn Industrial Business Zone. This was done in effort to assist the Newtown Creek Alliance promote the implementation of green infrastructure projects, not exclusively for food production, in the Newtown Creek Watershed, located in this Industrial Business Zone. Three building categorization criteria described in Phase I was implemented in Phase II as well. These included areas zoned as commercial and manufacturing, excluding residential use buildings, buildings less than 10 stories tall, and not having noxious or utility uses (Berger, 2013).

During this phase, the author determined that buildings should not be eliminated from the dataset based on size. Instead, the remaining buildings were categorized by the potential size of the rooftop gardening operation. The categories are defined as follows:

- Small Scale: < 5,000 square feet
- Medium Scale: Between 5,000 and 40,000 square feet
- Large Scale: > 40,000 square feet

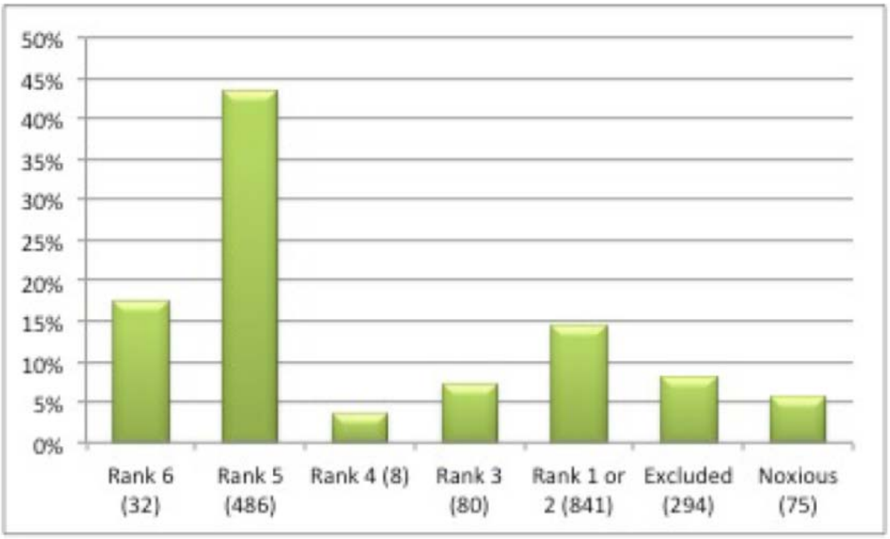
The author consulted Bing maps to visually determine if the roofs of the buildings were visually flat and that they did not have obvious protrusions and/or obstructions. The New York City Solar Map was then used to determine the usable roof area for food production. The assumption was made that roof space suitable for solar installation is also suitable for food production and buildings with less than 50% of the rooftop area suitable were removed from the dataset (Berger, 2013).

A ranking system was created to determine rooftop food production suitability with "1" being the least suitable and "6" being the most suitable. Buildings excluded from the dataset up to this point of Phase II were not ranked. Additionally, buildings with rooftops that had significant rooftop infrastructure, such as photovoltaic installations, large HVAC units, or greenhouses were also eliminated and not ranked. The ranking matrix is provided in Figure 6 and the number of buildings correlating to each ranking as a percentage of the entire building inventory of the North Brooklyn Industrial Business Zone is provided in Figure 7.

Figure 6 – Rooftop Agriculture Suitability Matrix (Berger, 2013)

Rooftop Agriculture Suitability Matrix	Intensive Green Roof (Built Prior to 1968)	Extensive Green Roof (Built After 1968)
Small Scale: **Area = < 5,000 square feet**	**2**	**1**
Medium Scale: **Area = 5,000 to 40,000 square feet**	**5**	**3**
Large Scale: **Area = > 40,000 square feet**	**6**	**4**

Figure 7 – Distribution of Green Roof Suitability in North Brooklyn Industrial Business Zone (Berger, 2013)

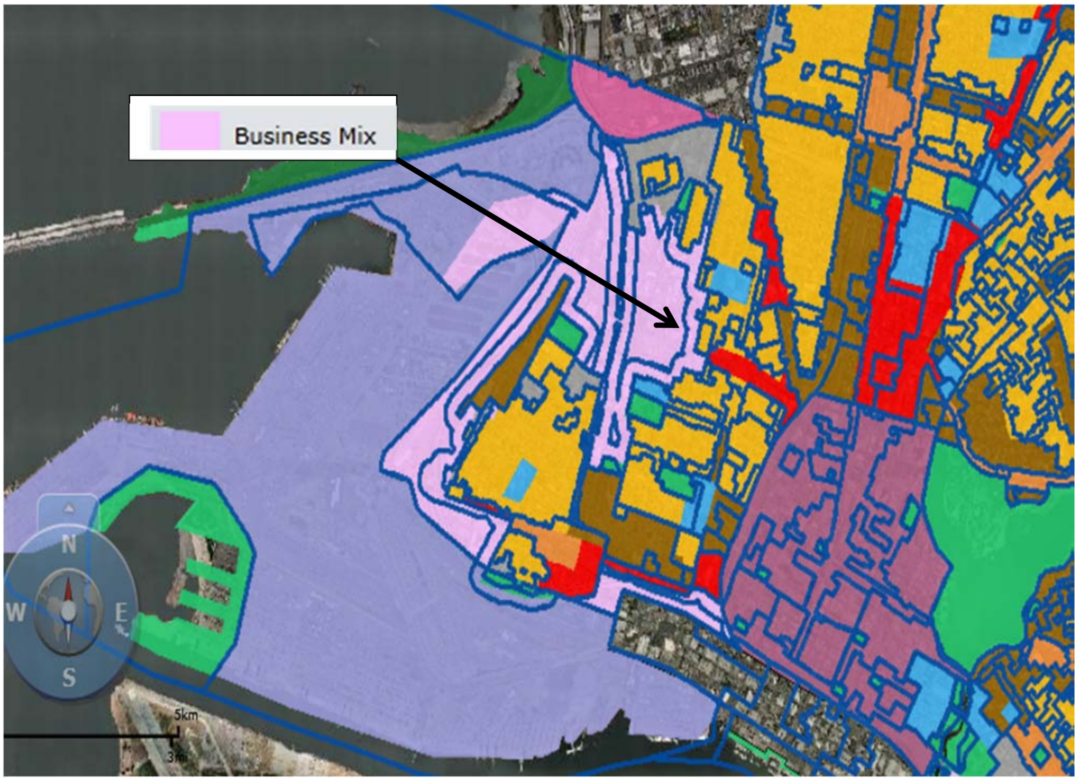


5.2 Methodology for Determining Rooftop Food Production Potential in the Business Mix Zone of West Oakland

The methodology used to determine the food production potential on the underutilized rooftops in the Business Mix Zone of West Oakland was similar to the methods described in the previous section with the main exception that Geographic Information Systems was not used.

An interactive planning and zoning map is available to the public and accessible through the City of Oakland's website. The map is a satellite view and can be overlain with various layers. The "zoning" layer was used to determine the parcels of land that were located within the Business Mix Zone (i.e., commercial and industrial) in the neighborhood of West Oakland. The Business Mix Zone is shown in light pink on Figure 8.

<u>Figure 8 – "Business Mix" Zone of West Oakland</u> (City of Oakland, n.d.-a)



Additional building information was available through the City of Oakland's Planning Department and the Alameda County Tax Assessor such as parcel address and parcel number.

For the most part, the methods described in Phase I and Phase II of *A GIS Suitability Analysis of the Potential for Rooftop Agriculture in New York City* (Berger, 2013) were followed. Each building within each parcel of land located within the Business Mix Zone (Figure 8) was assessed to determine its suitability for a rooftop food garden. Visually obvious noxious or utility use buildings were eliminated from the inventory. It was then determined if the building was under 10 stories tall. No buildings in the study area had more than 10 stories. Then the rooftop was assessed for visual flatness as observed on Oakland's planning and zoning map and cross-referenced with Google maps (satellite view). If the building's rooftop was not visibly flat, then it was eliminated from the inventory. Buildings with major infrastructure on top of the roof such as large HVAC units or photovoltaic installations were also removed from the inventory.

Unlike buildings in New York City, building live loads cannot be estimated from construction dates. Buildings in the study area fall into the Mixed Use, Warehouse, Big Box, Repair Shop, and Office building types described in *Tapping the Potential of Urban Rooftops – Rooftop Resources Neighborhood Assessment* (Bay Localize, 2007) and can have live loads ranging from 5 to 17 pounds per square foot. This is a generalization and buildings in the Business Mix Zone of West Oakland could have been designed with greater live loads (Bay Localize, 2007). Due to the lack of specific information regarding live loads for a particular building within the study area, it is assumed that all buildings identified in the inventory could support intensive rooftop farms after a structural analysis and possible retrofits.

If a building in the Business Mix Zone of West Oakland met the aforementioned criteria, then the area of the rooftop was measured with the "measure tool" on the interactive planning and zoning map. The measured area of the rooftop was reduced by 40% to account for fixed features and paths needed to access the crops as well as space to store farming equipment (Bay Localize, 2007). Based on the previous study conducted in New York City (Berger, 2013), the area of the rooftop was used to determine if it could support a small (<5,000 square feet), medium (5,000 to 40,000 square feet), or large (>40,000 square feet) scale farm operation. The ranking system identified in the New York City study was not used in this analysis because it does not provide any additional information or value to this data.

5.3 West Oakland Rooftop Suitability Results & Food Production Potential

5.3.1 Rooftop Suitability

The methods described above identified 84 parcels of land that contained at least one building with a rooftop that is potentially suitable for an intensive rooftop agricultural farm. Attachment 1 provides a detailed inventory of each identified parcel and the potentially suitable buildings located within them. As shown on Table 1, a total of 108 buildings consisting of 1,151,495 square feet were identified for this sustainable building use.

Table 1 – Potential Rooftop Farm Inventory Summary

Size of Farm	**# of Rooftops**	**Total Area (ft^2)**
Small	64	143,220
Medium	37	577,491
Large	7	430,783
Total	*108*	*1,151,495*

Over half of the rooftops in the building inventory (64 buildings) consisting of 143,220 square feet may be able to support a small scale farm (<5,000 square feet); 37 building rooftops consisting of 577,491 square feet may be able to support a medium scale farm (5,000 to 40,000 square feet); and 7 building rooftops consisting of 430,783 square feet may be able to support a large scale farm (>40,000 square feet). Figures 9 and 10 graphically display these results.

Figure 9 – Number of Buildings by Potential Intensive Rooftop Farm Size

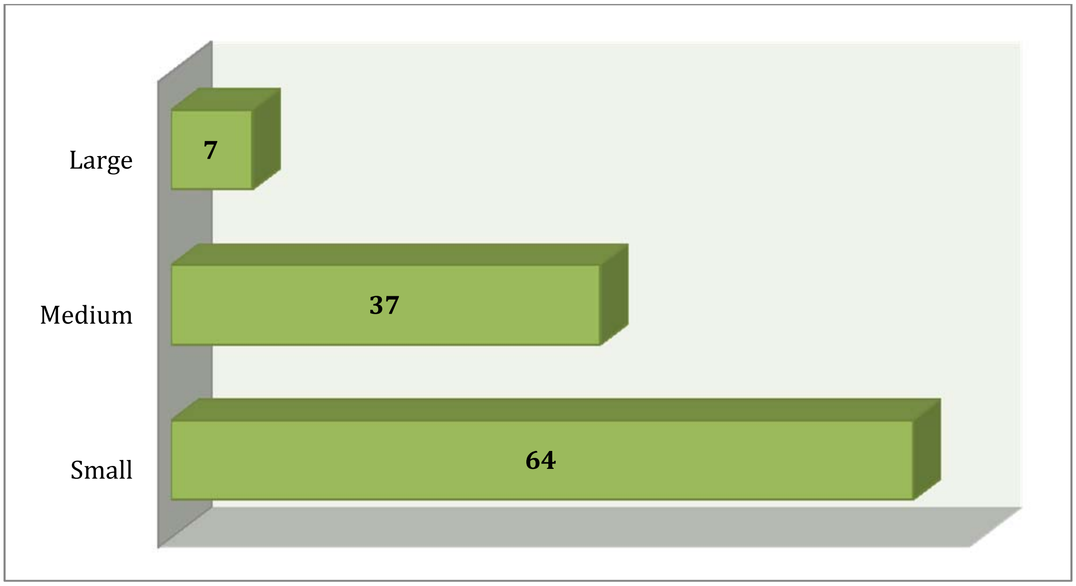
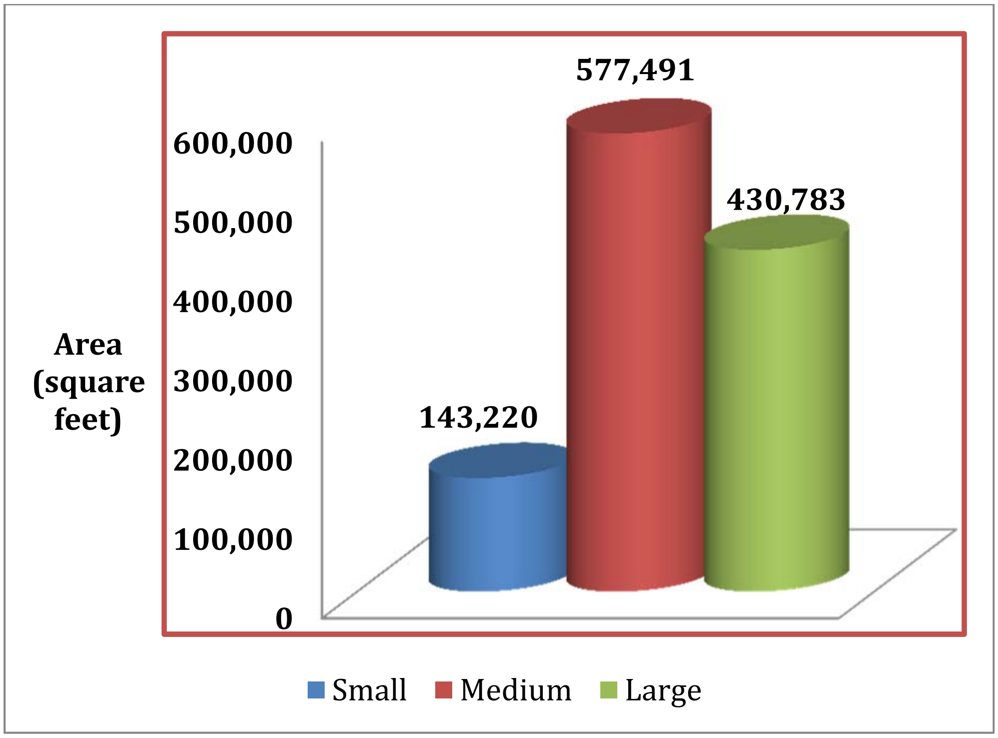


Figure 10 – Available Rooftop Area for Intensive Rooftop Farming



5.3.2 Food Production Potential

Studies have concluded that rooftop growing conditions are not terribly different from those on the ground (Kortright, 2011; Whittinghill et al., 2013). One study determined there was no difference in the production of produce between an intensive green roof, a green roof platform, or in ground growing conditions (Whittinghill et al., 2013). Conservative annual produce yields of urban agriculture is 10 tons per acre which equates to .46 pounds per square foot (Mcclintock & Cooper, 2009; Urban Design Lab, 2012). City Slickers farm located in West Oakland produced over 9,600 pounds of produce on 21,569 square feet (Hagey, 2012) which is a produce yield of .45 pounds per square foot.

Table 2 summarizes the produce yields from rooftops in the Business Mix Zone of West Oakland. Assuming the conservative annual produce yield of .46 pounds per square foot, the total potential yield of produce from the rooftops potentially suitable for intensive rooftop farming is 529,688 pounds per year. The annual yield of the vegetable prototype intensive green roof described in Section 3.3.1.2.1 is 1.86 pounds per square foot. Assuming that all the buildings identified for intensive green roof development can support or be retrofitted to accommodate this vegetable crop prototype, the annual produce yield is 2,141,781 pounds. Converted to tons, the vacant and potentially suitable rooftops in the Business Mix Zone of West Oakland have the potential to produce 265 to 1,071 tons of fresh fruit and vegetables. For comparison, the entire population of Oakland should eat about 93,000 tons of vegetables per year (Mcclintock & Cooper, 2009). Rooftop agriculture in a just this small portion of West Oakland can provide .28% to 1.15% of the vegetable needs of the entire city.

Table 2 – Produce Yields from Rooftops in Business Mix Zone of West Oakland

	Annual Produce Yield (lbs/ft^2)	Rooftop Area Available in Business Mix Zone of West Oakland (ft^2)	Annual Produce Yield from Business Mix Zone of West Oakland (lbs)	Annual Produce Yield from Business Mix Zone of West Oakland (tons)
Conservative Yield	0.46	1,151,495	529,688	265
Prototype Yield	1.86	1,151,495	2,141,781	1,071

These potential agricultural yields can support more of the consumption needs for the neighborhood of West Oakland. Gender and age specific population data for West Oakland is not available. It was assumed that 40% of the population of the neighborhood is both male and females over the age of 10 and the remaining 20% are children under 10 years old. The United Stated Department of Agriculture recommends the following servings of vegetables per day:

- **Males over 10 years old**: 2.5 – 3.5 cups per day (456 – 639 pounds per year)
- **Females over 10 years old**: 2.0 – 2.5 cups per day (365 – 456 pounds per year)
- **Children under 10 years old:** 1.0 – 1.5 cups per day (182 – 274 pounds per year)(Mcclintock & Cooper, 2009)

Using the highest recommended servings of vegetables for each age/sex group and the population data for West Oakland provided in Section 4.1, West Oaklanders should consume 15,903,751 pounds or 7,951 tons of vegetables per year. The produce yields from potential rooftop farming in the Business Mix Zone of West Oakland could potentially provide 3.3 to 13.5% of the vegetable needs of this neighborhood. See Table 3 for calculations.

Table 3 – West Oakland Vegetable Needs

Demographic	Assumed % of Population[1]	# of Persons	Highest Recommended Servings of Vegetables per Year	Vegetable Needs Per Year (lbs)	Vegetable Needs Per Year (tons)
Males over 10 years old	40	12,909	639	8,248,851	4,124
Females over 10 years old	40	12,909	456	5,886,504	2,943
Children under 10 years old	20	6,454	274	1,768,396	884
Total	--	--	--	**15,903,751**	**7,951**
1 - Total population = 32,272					

5.3.3 Revenue Potential

As mentioned in Section 3.2 of this report, urban rooftop farming can have revenue of up to $3.59 per square foot (Brooklyn Grange, n.d.). With 1,151,495 square feet of rooftop space available for farming in the Business Mix Zone of West Oakland, $4,133,867 in revenue from the sale of produce can be earned by operators of rooftop farms. The produce can be sold at local farmers markets, at produce stands, and to grocery stores, businesses, and restaurants.

5.3.4 Limitations and Additional Research Needs

All observations were made using satellite imagery. No ground truthing of these observations or measurements were performed. Measurements of rooftops may include human error. Additional investigation of the study area is needed. A detailed field survey of the buildings identified in the inventory should be conducted. The survey should include verification that the rooftop is flat and in good condition and actual measurements of the rooftop should be collected. Additionally, the field survey should collect the address of the building, the owner, and contact information.

A professional engineer should be consulted and a structural assessment of the building and roof should be performed prior to developing any type of green roof.

A pilot study should be implemented on a few rooftops identified in the inventory to determine if the produce yield and revenue estimates described in Sections 5.3.2 and 5.3.3 are accurate.

6.0 Barriers and Challenges of Rooftop Agriculture Implementation

Section 3.2 presented the numerous benefits of green roofs. Those benefits, including carbon sequestration, reduced overall building energy use, reduced urban heat island effect, improved biodiversity, reduced materials to landfill, and management of stormwater all extend to green roofs designated for rooftop agriculture. Despite all these benefits, green roofs for rooftop agriculture have not been implemented expansively due to many barriers and challenges.

One significant barrier is that there is lack of confidence and insufficient experiences and research on the successes and productivity of agricultural rooftops (Kortright, 2011). Rooftop agriculture is not an established practice (Urban Design Lab, 2012). It appears that before cities, startup companies, or individuals will invest in and implement rooftop agriculture, there needs to be more published research demonstrating successful farms with significant food production.

Another major barrier to rooftop agriculture implementation is one that has been discussed in the previous section(s) at depth. Demanding agricultural crops need more intensive roofs and deeper soils (Kortright, 2011). Additionally, one square foot of saturated soil weighs upwards of 50 pounds (Urban Design Lab, 2012). Buildings are designed and constructed to support a specific live load on the roof, usually according to the building code in effect at time of construction. Few rooftops have the loading and structural capacities to support intensive rooftops for food production. Expensive retrofits will likely be required before installing an intensive rooftop agricultural system on rooftops in West Oakland, as well as the rest of the world. Straight compost is an alternative growing media to soil as it weighs much less and contains much more nutrients (Kortright, 2011).

There are some environmental barriers to rooftop agriculture. These include high winds and almost constant sun exposure compared to agriculture on the ground. Additionally, edibles can become contaminated with airborne pollutants as a result of atmospheric deposition from point sources. However, this is only a concern when the food production is located near industrial point sources or transportation highways (Kortright, 2011). This is also true for other forms of urban agriculture.

Gaining affordable access to rooftops can be a barrier to those wanting to create a rooftop farm. Due to the lack of published research on urban rooftop farming, long-term viability of the practice is unknown and buildings owners do not want to be left with a farm on their roof with no one to tend to it (Urban Design Lab, 2012). Additionally, building owners may be hesitant and not want to deal with liability concerns or maintenance of the roof (Urban Design Lab, 2012). Insurance is difficult to obtain and/or is expensive. This is because of the associated risk for having people on the roof to maintain the farm. Owners of buildings may be unwilling to pay the additional liability of having people on top of their roof (Region of Waterloo Public Health, 2005).

Some logistical barriers include access to water and ease of transporting equipment and materials to the rooftop for farming purposes (Kortright, 2011). Buildings with elevators or ramps are ideal for the logistics of moving materials and will also satisfy the requirements of the American Disabilities Act and other accessibility requirements for public spaces. If ramps or elevators are not available, cranes will likely be needed to move equipment and materials from the ground to the rooftop. Water utility water meters are usually at every building, but getting water to the roof may be difficult. Stormwater can be collected in containers on the roof and then used for agricultural purposes. This solution would not apply during drought conditions or less severe, dry winters. Alternatively, a sophisticated irrigation system which delivers water to the roots of the plants is an efficient alternative to manual watering.

There is a major economic barrier related to the cost of installation of a green roof for food production. The upfront capital costs of installation of a green roof are 2 to 6 times more expensive when compared to conventional roofing systems (Whittinghill & Rowe, 2011). Assuming the rooftop is complaint with structural and architectural requirements of buildings codes, installation costs would range from $30 to $45 per square foot; $20 - $40 per linear foot of guardrails; and $2-4 per square foot for irrigation (Bay Localize, 2007). As mentioned earlier, additional costly expenditures will be required to retrofit buildings to support the live load of an intensive rooftop farm if it cannot already.

Currently there are no regulations to install green roofs (Kortright, 2011). Also, there is no public or governmental access to capital (Whittinghill & Rowe, 2011) to install a green roof for food production. The Brooklyn Grange rooftop farm in New York City encountered capital startup costs of $5 per square foot or $200,000 (Brooklyn Grange, n.d.). This urban rooftop farm broke even in its first year of operation and aimed for profitability in its second year (Urban Design Lab, 2012). Additionally, a few land farmers in San Francisco earned revenues of more than $1 million in 2007 (Mcclintock & Cooper, 2009). Although the capital cost of installing a green roof for farming exceeds the cost of installation of a traditional roofing system, the green roof has economic benefits associated with the sale of produce.

The willingness and competence of residents to farm the rooftops may also be a barrier to this form of urban agriculture. The typical urban dweller lacks the skillset to operate and run a farm. The residents will need to be educated on the benefits of urban rooftop farming as well as how to operate a farm.

Some of the aforementioned barriers to rooftop farming may be very difficult to overcome and may not be cost effective or feasible to be installed on some rooftops. However, there is a multitude of benefits to rooftop farming and cities can promote the growth of this form of urban agriculture by implementing policies as described in the following section.

7.0 Summary and Policy Recommendations

7.1 Summary

Urban agriculture is difficult to compete with other uses of the land, such as residential and commercial development. Rooftop farming is an alternative to urban agriculture forms that take place at grade because it has many of the same and more benefits and eliminates some barriers and challenges such as land availability and contaminated land. In order to promote urban farming, the City of Oakland has revised its zoning laws to allow urban agriculture in all zones.

The Oakland Food System Assessment (Unger & Wooten, 2006) included an acreage scenario needed to support 30% of the population's diet. The scenario included 30 rooftop gardens, each comprising of 600 square feet for a total of 18,000 square feet. This study determined that there is potentially 1,151,495 square feet of rooftop area suitable for farming in the Business Mix Zone of West Oakland, a small part of the entire city of Oakland.

The Oakland Food System Assessment determined that a total of 14,601 acres of land or space is needed to reach the 30% local food sourcing goal (Hagey, 2012). The small Business Mix Zone of West Oakland alone can potentially contribute 26 acres of space to meet this goal.

The over 1 million square feet of untapped rooftops available for urban farming can provide the residents of West Oakland with 3.3 – 13.5% of their vegetable needs each year. Additionally, over $4 billion of revenue can be earned with the sale of produce at farmers markets, produce stands, restaurants, grocery stores and other businesses.

Even if additional investigation of this small study area concludes that the rooftop agriculture potential is less than as reported in this study, rooftop farming in West Oakland has great potential in assisting the City of Oakland reach it's 30% local food sourcing goal and bringing fresh fruits and vegetables to the residents and help the neighborhood of

West Oakland be resilient. The City of Oakland needs to enact specific polices to ensure rooftop agriculture is implemented.

7.2 Policy Recommendations

Because of the barriers to other forms of urban agriculture, rooftop inventories like the one created as part of this research should be conducted throughout the City of Oakland. This research determined that 108 buildings suitable for intensive rooftop agriculture in the Business Mix Zone of West Oakland have the potential to produce annual yields ranging from 500,000 to 2,100,000 pounds of produce. Despite the food production benefit as well as stormwater management, urban heat island effect mitigation, increased green space, and other benefits, green roofs have significant barriers as described in the previous section that need to be overcome. The City of Oakland should enact some of the policy recommendations that follow to promote rooftop agriculture.

7.2.1 Technology Standards

In January, 2010, the City of Toronto required the installation of green roofs on all new commercial, institutional, and multifamily residential developments throughout the city. In 2012, this requirement was expanded to include new industrial developments as well. In Fall of 2011, Green Roofs for Healthy Cities reported that the aforementioned requirement had yielded 1.2 million square feet of green space on top of buildings throughout Toronto (Benfield, 2012).

Oakland can enact a similar policy or revise its building code to require all new construction of commercial and residential buildings, as well as retrofits to existing buildings, if suitable, to include green roofs suitable for farming. The policy should require 60% of the rooftop area of new buildings and 30% of the rooftop area of planned retrofit buildings to include intensive rooftop gardens. The policy should include the specifications of an intensive green roof for vegetables, similar to the prototype described in Section 3.3.1.2.1. This policy would be enforced by the city's building department when the developer submits the building plan to obtain the building permit. There might be great opportunity for policy implementation with the upcoming West Oakland Specific Plan and the West Oakland Redevelopment Project.

This recommended policy could be implemented with little to no cost to the City of Oakland and all costs would be at the expense of the developer. This regulatory policy would provide the highest level of confidence that urban rooftop farms are installed on suitable buildings in Oakland.

7.2.2 Direct Financial Incentives

Instead of developing a regulatory policy as described in Section 7.2.1, the City of Oakland can provide economic incentives in the form of subsidies which can nudge developers to install green roofs (Taylor, 2007). Subsidies or other direct financing can encourage developers of green roofs to overcome the barrier of adapting to a "new" technology. The City of Chicago distributed $100,000 to twenty different green roof projects, including an 800 square foot vegetable garden (Carter & Fowler, 2008).

Oakland should obtain a grant and have developers submit applications for intensive green roof projects for food production. The city should select the most productive farms and provide them with startup funding from the grant money. To ensure compliance, half of the funding should be provided prior to installation and the rest should be provided once the food has been harvested.

Another direct financial incentive that Oakland can provide is to create a subsidy in a dollar per square foot amount. This type of subsidy should cover 10 to 50% of the initial installation costs (Carter & Fowler, 2008). The city would have to include money in the annual budget to fund this subsidy program. Similar to the grant funding, to ensure compliance, half of the funding should be provided prior to installation and the rest should be provided once the food has been harvested.

Other financial incentives that should be considered include:

- Provide a tax incentive for building owners of inadequate structural integrity and/or live roof loads who retrofit the building to ensure buildings and rooftops can support an intensive rooftop farm;
- Provide seeds, soil, and other farming equipment to voluntary building owners or farm operators who implement an urban rooftop farm; and
- Provide the cost of additional insurance to building owners to have people on top of the roof to maintain the urban farm.

7.2.3 Other Policy Tools

Competitions and positive media coverage can promote growth of green roofs. These instruments can make sure green roof efforts are seen and appreciated. The competitions are voluntary compared to regulatory burdens on the owner/developer. It is important in increase the public awareness of green roofs through media coverage because these roofs are not visible or accessible to the public (Ngan, 2004). Oakland can organize an urban rooftop farm competition with a monetary prize.

Some other policy instruments include:

- Once a building owner installs the rooftop farm on the roof, require a percentage of the sales from the produce go back to the owner, if the operator of the farm is not the owner.
- Creation of a Floor to Area Ratio incentive to encourage rooftop farming on new residential developments. If a developer installs a farm on the roof, the developer could build more residences/units. The incentive for the developer is if they invest the money for the urban rooftop farm at the time of development, they can make additional money on the sale of the additional units down the road (Taylor, 2007).
- Provide expedited processing for urban green rooftop permit application review and waive the permit application fees.
- Offer classes, free of charge, to educate the community members or startup companies interested in starting and operating a rooftop urban farm.

- Allow operators of urban rooftop farms to sell their produce at local Bay Area farmers markets for the first year at no charge.
- Provide additional law enforcement presence in areas with urban rooftop farms to prevent crime, theft, and unlawful access.

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Attachment 1
Intensive Rooftop Farm Inventory

Parcel ID #	Parcel Address	Area of Rooftop (ft^2) [1]	Adjusted Area (ft^2)[2]	Small, Medium, Large Scale Farm Potential[3]
006 000100106	1675 7th Street	115,500	69,300	Large
		23,750	14,250	Medium
006 000100105	Wood Street	85,500	51,300	Large
006 004902501	1819 10th Street	17,850	10,710	Medium
006 002900302	1820 10th Street	42,090	25,254	Medium
006 003101400	1776 11th Street	3,408	2,045	Small
006 003100200	1791 12th Street	2,800	1,680	Small
004 005902501	1340 Mandela Parkway	79,616	47,770	Large
004 005902002	1312 Kirkham Street	11,748	7,049	Medium
		4,968	2,981	Small
005 037600901	1266 14th Street	33,654	20,192	Medium
005 048200100	1315 16th Street	9,600	5,760	Medium

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Intensive Rooftop Farm Inventory

Parcel ID #	Parcel Address	Area of Rooftop (ft^2) [1]	Adjusted Area (ft^2)[2]	Small, Medium, Large Scale Farm Potential[3]
005 048200300	1315 16th Street	45,000	27,000	Medium
005 048200200	1385 16th Street	34,146	20,488	Medium
005 039200301	1601 Poplar Street	45,792	27,475	Medium
005 039200301 & 005 039201301	1601 Poplar Street & 1620 Kirkham	38,528	23,117	Medium
005 039401701	1617 Kirkham Street	8,080	4,848	Small
005 039302301	1701 Kirkham Street	20,670	12,402	Medium
Not Listed	Not Listed	2,397	1,438	Small
005 039800801	1800 Peralta Street	26,344	15,806	Medium
007 056900500	1620 18th Street	7,905	4,743	Small
		7,938	4,763	Small
007 056900101	1933 Peralta Street	18,080	10,848	Medium
007 057200102	1700 20th Street	44,051	26,431	Medium
		29,078	17,447	Medium

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Intensive Rooftop Farm Inventory

Parcel ID #	**Parcel Address**	**Area of Rooftop (ft^2) [1]**	**Adjusted Area (ft^2)[2]**	**Small, Medium, Large Scale Farm Potential[3]**
007 057100301	1699 W Grand Ave	6,732	4,039	Small
007 057000200	2001 Peralta Street	24,420	14,652	Medium
005 040300200	1911 Union Street	5,890	3,534	Small
005 040300100	1255 21st Street	32,193	19,316	Medium
005 040603900	1115 21st Street	7,314	4,388	Small
005 040506400	1940 Union Street	29,452	17,671	Medium
005 040300100	1255 21st Street	34,540	20,724	Medium
005 041400204	2139 Linden Street	6,188	3,713	Small
005 042700101	2340 Adeline Street	9,546	5,728	Medium
005 042601501	2211 Adeline Street	2,752	1,651	Small
005 042601302	2217 Adeline Street	2,376	1,426	Small
005 042601201	2311 Adeline Street	1,960	1,176	Small
		2,510	1,506	Small
		5,265	3,159	Small
005 042502800	2323 Magnolia St	9,898	5,939	Medium

Attachment 1
Intensive Rooftop Farm Inventory

Parcel ID #	**Parcel Address**	**Area of Rooftop (ft^2)** [1]	**Adjusted Area (ft^2)**[2]	**Small, Medium, Large Scale Farm Potential**[3]
005 042502000	2321 Magnolia St	1,656	994	Small
005 042300101	2201 Poplar Street	115,010	69,006	Large
005 042200203	2300 Peralta St	137,280	82,368	Large
007 057700302	2311 Peralta Street	5,214	3,128	Small
007 057700110	1624 W Grand Ave	3,465	2,079	Small
007 057600115	2225 Campbell Street	9,688	5,813	Medium
007 057600114	1696 W Grand Ave	16,112	9,667	Medium
		2,070	1,242	Small
007 057600111	1685 24th Street	7,668	4,601	Small
007 057500303	2217 Willow Street	2,640	1,584	Small
007 057500205	2200 Wood Street	3,000	1,800	Small
007 057500400	2240 Wood Street	3,358	2,015	Small
		2,601	1,561	Small
		3,450	2,070	Small
007 057500100	1735 24th Street	27,495	16,497	Medium

Attachment 1

Intensive Rooftop Farm Inventory

Parcel ID #	Parcel Address	Area of Rooftop (ft^2) [1]	Adjusted Area (ft^2)[2]	Small, Medium, Large Scale Farm Potential[3]
007 058000301	2403 Willow Street	51,405	30,843	Medium
		4,558	2,735	Small
007 058000500	2510 Wood Street	6,786	4,072	Small
007 058000101	2526 Wood Street	4,680	2,808	Small
		714	428	Small
007 057900202	2415 Campbell Street	5,610	3,366	Small
007 057900302	2534 Mandela Parkway	1,540	924	Small
007 057800105	2450 Mandela Parkway	14,734	8,840	Medium
007 057800103	2500 Campbell Street	23,310	13,986	Medium
007 057800107	2533 Peralta Street	25,032	15,019	Medium
007 057800106	2431 Peralta Street	56,000	33,600	Medium
005 043900801	2430 Poplar Street	5,405	3,243	Small
		1,600	960	Small
005 043901201	2500 Poplar Street	2,553	1,532	Small
		4,446	2,668	Small

Attachment 1
Intensive Rooftop Farm Inventory

Parcel ID #	Parcel Address	Area of Rooftop (ft^2) [1]	Adjusted Area (ft^2)[2]	Small, Medium, Large Scale Farm Potential[3]
005 043800400	1200 24th Street	1,746	1,048	Small
005 043800202	2423 Magnolia Street	7,400	4,440	Small
		3,290	1,974	Small
005 043701100	2401 Adeline Street	1,225	735	Small
		1,064	638	Small
		638	383	Small
005 043701404	2506 Magnolia Street	846	508	Small
		800	480	Small
		800	480	Small
		800	480	Small
		800	480	Small
		800	480	Small
		1,880	1,128	Small
005 043701700	1165 26th Street	4,801	2,881	Small
005 043601102	2400 Adeline St	5,460	3,276	Small

Attachment 1
Intensive Rooftop Farm Inventory

Parcel ID #	Parcel Address	Area of Rooftop (ft^2) [1]	Adjusted Area (ft^2)[2]	Small, Medium, Large Scale Farm Potential[3]
005 043601207	2434 Adeline St	2,120	1,272	Small
005 043601208	2440 Adeline Street	3,913	2,348	Small
005 044600501	2601 Adeline Street	7,110	4,266	Small
		3,528	2,117	Small
005 044600700	2650 Magnolia Street	15,534	9,320	Medium
005 044600301	2713 Adeline Street	1,517	910	Small
005 045703400	2923A Adeline Street	13,454	8,072	Medium
		12,322	7,393	Medium
005 044500601	2619 Magnolia Street	86,920	52,152	Large
005 044500300	2725 Magnolia Street	12,100	7,260	Medium
005 045902702	2850 Poplar Street	13,230	7,938	Medium
005 046000602	2800 Peralta St	7,137	4,282	Small
007 058801200	1618 28th Street	1,269	761	Small
		3,000	1,800	Small
007 058801100	2857 Hannah Street	2,720	1,632	Small

Attachment 1
Intensive Rooftop Farm Inventory

Parcel ID #	Parcel Address	Area of Rooftop (ft^2) [1]	Adjusted Area (ft^2)[2]	Small, Medium, Large Scale Farm Potential[3]
007 058600106	2717 Peralta Street	39,790	23,874	Medium
007 058500202	2606 Mandela Parkway	7,638	4,583	Small
007 058500104	2792 Mandela Parkway	15,513	9,308	Medium
007 058500301	2607 Mandela Pkwy	7,876	4,726	Small
007 058400102	2801 Mandela Pkwy	98,146	58,888	Large
007 060000110	3211 Wood Street	1,525	915	Small
007 059900103	3300 Wood Street	5,500	3,300	Small
007 060500122	3401 Mandela Pkwy	36,337	21,802	Medium

Notes:

1 - Dimensions were measured using the "measure tool" on the City of Oakland's Planning and Zoning map.

2 - Calculated Area is reduced by 40% to account for fixed features and paths needed to access the crops as well as space to store farming equipment.

3 - Small = 5,000 ft^2; Medium = 5,000 ft^2 to 40,000 ft^2; Large = >40,000 ft^2