Situating Urban Agriculture: What, Where, and Why in New York City

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Abstract

Urban agriculture has the potential to address multiple concerns simultaneously in dense urban spaces. Where and how urban agricultural interventions are sited within cities are critical questions to ask as governments, municipalities, and urban planners address the need for healthy and resilient food systems as well as environmental resiliency. This thesis explores the potential for planners to utilize digital mapping methodologies and multi-criteria decision making analysis (MCDA) in a way in which socio-economically vulnerable neighborhoods and neighborhoods facing environmental vulnerability can be addressed simultaneously. This research demonstrates this process by utilizing a geospatial mapping model that incorporates multiple layers of information on the current state of food access, rates of health, economic need, and water and heat risk that New York City currently exhibits. The results of this model, run multiple times, are applied to each of the tax lots in New York City, thus identifying exactly where the greatest socio-economic need and environmental vulnerability exists.

The methodology used in this thesis includes the collection, classification, and rasterization of a series of decision layers that feed into five larger components of analysis. These components are combined to generate an overall map that displays socio-economic need and another that displays environmental vulnerability as the combination of water and heat vulnerability. When analyzed together different sets of core targeted areas are identified and evaluated for potential available and appropriate land and rooftop areas that can be conducive to three different types of urban agriculture — ground level farms, rooftop open-air farms and rooftop greenhouses.

This methodology builds on previous methodologies developed by the Urban Design Lab at Columbia University / The Earth Institute that evaluate the potential for urban agriculture in New York City (published in 2011 and 2013). This thesis advocates for the development of a comprehensive city-wide plan for the application of urban agriculture as a networked system of open spaces and productive greenhouses that have the potential to offer co-benefits through proximity, clustering, and strategic siting within the core targeted areas. This plan would ideally be supported by the development of open space zoning and ecological corridor zoning districts.

While the data used here supports lot-level and high resolution decision making, it ultimately identifies areas of opportunity which can be starting points for areas of participatory processes and a set of community engagement practices that may be able to address issues such as private owner development constraints in the potential siting of urban agriculture. Mapping and data collection is one part of the decision making process in planning but it is not the end goal. How findings of this type of mapping study are actualized on the ground or made actionable should be done with community involvement. In this regard, utilizing GIS and MCDA with public participation can be seen as a community empowerment strategy whereby (a) communities that can benefit from an intervention are first identified and incorporated into the overall process and (b) the maps generated can be used to advocate for specific types of development that will offer co-benefits. Regardless of the issue being analyzed, this thesis concludes that there are immense benefits to using digital mapping methodologies in making large city-wide decisions and in incorporating the public and non-expert voices into the conversation.
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INTRODUCTION

THE NEED FOR HEALTHY FOOD IN NEW YORK CITY AND THE RELEVANCE OF URBAN AGRICULTURE

There is a pressing need for more responsive and resilient food production and distribution systems in New York City which can address health disparities in communities that continually face low or no access to fresh produce. Utilizing open space for small scale agricultural production can counter the presence of food deserts while strengthening environmental resiliency in response to key challenges that the city faces. The benefits of urban agriculture are numerous. These can be highly productive and also offer important health benefits, future jobs, and a sense of ownership through resident engagement with them. Where and how these interventions are located within the dense urban fabric of New York City are critical questions to address as the city moves forward with its green infrastructure resiliency plans. Furthermore, those who are affected by them -- who benefits and who pays -- needs to be carefully examined. The potential for urban agriculture to address multiple concerns simultaneously is immense. There is not necessarily a clear path forward in terms of identifying the communities addressed and understanding the realities behind the power of the political and developmental systems that are typically needed to leverage and realize many of these interventions.

In 2013 the United Nations released a report titled, “Wake Up Before It’s Too Late,” that concluded that small-scale farming is the only way to achieve sustainable agriculture globally. With the growing presence of food deserts in dense urban spaces, limited supply of fossil fuels, and vast global environmental pressure, small scale farming is going to continue to grow in importance not only in rural spaces but also in urban spaces throughout the world. Having fresh fruits and vegetables grown locally can enable individuals and families who do not typically have the opportunity to purchase fresh food to eat these more frequently. Encouraging these types of habits improve human health while also enabling greater health for Earth’s ecosystems. In New York City alone, the demand for produce far outstrips the production capacity and ability of the surrounding bioregion (Ackerman, Dahlgren, and Xu, 2013). Currently, the New York City Department of Food Policy estimates that 16.4% of New York residents did not get enough food
in 2014, and are technically considered “food insecure” (nyc.gov - Department of Food Policy, 2016). Given a growing urban population and variety of environmental pressures, alternative urban food production systems need to be incorporated as key elements within the resiliency and development plans of the city (nyc.gov - Department of Food Policy, 2016). While the city does have the capacity to better provide for its own needs through urban agriculture it will, for the immediate future, be dependent on outside sources for a substantial amount of its produce needs.

Urban agriculture is becoming more popular and present within cities for a variety of reasons. It can be seen as being - “at the nexus of a variety of issues which are seen as critical to the ongoing sustainability and livability of our urban environments: public health, healthy food access, green space, air and water quality, economic development, and community engagement” (Ackerman, Plunz, Conard, Katz, Dahlgren, Culligan, 2011, p. 6). Urban agriculture enables city residents to be involved in the production of food and to reengage with the natural environment in a way that has been relatively abandoned in urban spaces for the better part of the past century. It also has the capacity to radically change how we envision the development of cities and the use of open land and rooftop space in dense urban situations. Urban agriculture, as a network of soft edge interventions and open space initiatives can be utilized on a variety of different scales and have high applicability to issues of production, provision of health, and environmental mitigation concerns.

This thesis asks two primary questions. The first is, where and how should urban agricultural interventions be sited in New York City such that they address critical flooding and heat resiliency challenges (as outlined in New York City’s 2015 Resiliency Strategy - OneNYC) while offering the most benefit to communities that continually face low or no access to fresh produce. The second question explores the role and potential for digital mapping methodologies as tools for multi-criteria decision support systems that planners, policy makers, and governmental groups can use regardless of the issue being analyzed. In this regard, the methodology used here is demonstrative towards that end. This thesis identifies neighborhoods within New York City that have the potential to benefit the most from urban agricultural interventions through a multi-criteria geospatial mapping model that illuminates a number of different suitable areas for urban
agriculture interventions. Additionally, it discusses the immense relevance that GIS when combined with MCDA and participatory processes have for urban planning as a discipline. The history and role of GIS supported MCDA and its applications within the field of planning are reviewed.

The first portion of this thesis includes a review of the green infrastructural proposals made in OneNYC that address flooding and heat challenges critical to the future resilience of New York City. These proposals are discussed in relation to the findings of the Urban Design Lab on resource consumption rates and production benefits of soil-based, rooftop, and controlled environment agriculture. The methodology of this thesis identifies potential areas for intervention of these three urban agriculture types through the utilization of a geospatial multi-criteria mapping model that includes critical decision layers on the current state of food access, rates of health, economic need, and water and heat risk in New York City. The results of this model, run multiple times, are applied to each of the tax lots in New York City, thus identifying exactly where the greatest socio-economic need and environmental vulnerability exists. Through the combined utilization of GIS and MCDA that focus on both socio-economic need and environmental vulnerability this methodology builds upon already existing methodologies for defining potential areas of urban agricultural opportunity as developed by the Urban Design Lab in their 2011 and 2013 publications.

This thesis posits that agricultural integration into urban spaces is necessary but that there are not necessarily single answers to the critical where, how, and who questions. Instead, there are multiple options that can address various challenges simultaneously. While there are many serious challenges to developing agriculture in urban spaces—especially New York City—if sited strategically, these interventions can offer numerous co-benefits to communities. Mapping is a tool that offers immense potential for a variety of disciplines and clearly offers an evidence base for large-scale city-wide decisions where planning is involved. This type of mapping analysis is not the end result of the planning process but acts as one key step that can identify neighborhoods and communities to begin community engagement and participatory processes in that can lead to further developed and clarified strategic urban agriculture developments.
LITERATURE REVIEW

WHAT IS URBAN AGRICULTURE AND WHERE CAN IT OCCUR?

Urban agriculture is defined as growing food within cities. These agricultural practices range in type, scale, vertical and horizontal spatial locations. Community gardens, outdoor ground level farms, rooftop farms, greenhouses and hydroponic systems all can be utilized as productive systems within New York City. In the city, it is estimated that there are over 1,000 community gardens and over 700 urban agricultural sites (Cohen, Reynolds, Sanghvi, 2012) including between 15-30 active farms that range across a variety of locations, scales, and types (Ackerman et al., 2013). These active farms are high functioning areas of production within the city supporting the growth of plants as well as cultivation of bees and fish. Most of New York City’s farms and community gardens are concentrated in areas where incomes are lower because many of them were established through Community Development Block Grants that can only be used in low-income areas (Ackerman et al., 2013).

Map 1: Existing Urban Agriculture Projects in New York City

Prior to the city becoming more developed and steadily densifying, agriculture was practiced in yards, community plots and parks throughout the city. City farming has been a means of relieving urban poverty in New York City and elsewhere; vacant-lot cultivation associations and relief gardens acted as a means of direct aid and social reform during the 19th and 20th centuries (Lawson, 2016). Specifically, large-scale urban farming in Manhattan squatter settlements and the “Victory Gardens” and WWI and to a lesser extent WWII played a defining role in the city. The prominence of agriculture in urban centers declined rapidly with the growth and development of refrigeration, trucking infrastructure, and air freight, all of which promoted the nationalization and globalization of food production and distribution, pushing agriculture, for the most part, out of the city. Currently, New York City has “very supportive urban agriculture related policies and programs” and a thriving network of varied growing spaces, most of which utilize public land (Cohen et al., 2012, p. 14).

Spatially, urban agriculture and areas of produce production can occur in a variety of different physical locations within the built environment. They can occur within buildings, on rooftops, on the ground within close proximity to buildings, on the sides of buildings, or in more peripheral areas within the city. Human Habitat, a design and urban agriculture advocacy group from the Netherlands, has categorized and generated a system of evaluation for each of these locations. Specifically they are looking at the applicability of hydroponics systems (hydroponics is the process of growing plants in sand, gravel, or liquid, with nutrients but without soil) and the relative utility of each of the locations that can be optimized for production within urban zones. Each location has benefits as well as drawbacks. In New York City, rooftops can be highly useful as the city is incredibly dense and land costs are some of the most expensive in the world. Building facades and spaces exterior to buildings, typically on the ground floor near buildings, all have good potential to be developed as spaces for cultivation. While there are many different spatial locations for urban agricultural interventions, Human Habitat concludes that each location can offer different benefits given the varied social and economic realities of those regularly engaging with them (Human Habitat, 2015).
THE BENEFITS OF URBAN AGRICULTURE

Research has been ongoing on the benefits of urban agriculture for different population groups including those who live in high density urban areas. The research of Five Borough Farm targets the population of New York City and evaluates benefits within the categories of health, social, economic, and ecological that constitute an overarching benefits framework (Cohen et al., 2012). The metrics that they use to evaluate the potential benefits of urban agriculture are cross-cutting. In fact, almost all of the activities that organizations like Five Borough Farm associate with urban agriculture feed into all of the four categories of benefits that can be accrued from different urban agricultural interventions. In New York City, it is critical to understand that while all of the four benefit categories — improved health, economics, social, and ecological conditions — are important from a food production point-of-view, that they also speak to a genuine need for more fair social conditions and accessibility to healthy food for all people. Food production is an essential avenue to addressing this broad range of issues. This thesis asserts the realization of these potential benefits as directly corresponding to a need for holistic mapping approaches that generate a better understanding of areas where the greatest potential co-benefits can be achieved due to current high environmental vulnerability and high socio-economic need.

1. Proximity, Production, and Current Demand for Produce

Total demand for produce in NYC requires an “estimated land area of between 162,000 and 232,000 acres” not including acreage needed for the 886 pounds of tropical or warm weather fruits consumed by New Yorkers annually (Ackerman et al., 2013, p. S-1). 58-89% of the total demand for produce in the NYC MSA for a population of approximately 18,897,019 (2013) could be provided for with all of the 368,884 acres of active farmland in the counties within the MSA (not including warm-weather produce). Land-use changes to the NYC MSA must be considered. Land for farming in the bioregion and in the NYC MSA is being regularly lost to development. These numbers suggest that New York City will always be dependent on areas outside of the MSA and bioregion for fresh produce. That being said, the city does have the capacity to produce some of what it needs, especially when greenhouses and controlled
environment agriculture (CEA\(^1\)) are taken into consideration (Urban Design Lab, 2013). Growing produce locally can enable some reduction in total energy and fossil fuel consumption from trucking and flying produce in from other parts of the country and world. Additionally, growing produce locally helps to minimize wear on infrastructural systems. The Urban Design Lab calls for measuring impact through the metric of embedded energy / unit of food delivered. “Anticipating reduced losses as well as food-miles traveled, applying such a metric would presumably reveal substantial benefits in favor of local farming with leaner distribution networks,” (Ackerman et al., 2013, p. 1-29).

Vertical or controlled environment agriculture has the capacity to produce 2-20 times as much produce as conventional soil based agricultural methods do (Ackerman et al., 2013). This number fluctuates due to differences in growing periods of crops and varied climatic growing conditions that range depending on geographic location. The Urban Design Lab at Columbia University / The Earth Institute has completed multiple spatial placement and resource use studies, the results of which address urban agriculture’s potential to provide fresh produce, mitigate heat and stormwater concerns, and reduce building energy use. They have found that hydroponic rooftop greenhouses, while typically the most energy consumptive, have the capacity to be the most productive when evaluating potential yearly yield compared to that of soil-based farming and open-air rooftop farming. These spaces have the potential to produce continuous, year round yields that are predictable and consistent. While the cost of constructing a rooftop greenhouse is approximately three times that of installing a green roof, if properly designed and managed, annual yields may be an order of magnitude higher than for an outdoor rooftop farm (Delor, 2011). On the other end of the spectrum, community gardens and smaller, more accessible farm plots that are at ground level have greater capacity to offer social benefits to the communities that use these spaces. Community gardens, soil-based outdoor farms, and rooftop outdoor farms (green roofs) are each susceptible to changing climate, weather conditions, and pests. Outdoor rooftop farms, to a lesser degree, have to combat pest issues due to their elevated

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\(^1\) **Controlled environment agriculture (CEA)** is a technology-based approach toward food production. The aim of CEA is to provide protection and maintain optimal growing conditions throughout the development of the crop. Production takes place within an enclosed growing structure such as a greenhouse or building.
nature and the fact that the growing medium on top of the roof can be more easily controlled than ground-level soil.

2. Ecological Health, Urban Heat Island, and Stormwater Mitigation

Urban agriculture has the potential to reduce total building energy consumption. Rooftop farms and green roofs are both excellent means of lowering total energy output. Greenhouses on roofs have the potential to utilize excess heat from the buildings that they are on top of, thus, lowering total anticipated energy needed (Delor, 2011). Green roofs and rooftop farms can contribute to lowering excessive heat in the city by absorbing excess heat. Rooftop greenhouses have the capacity to use excess building heat. Similarly, “rooftop greenhouses could also use potential excess heat due to solar gains in the greenhouse during cold but sunny days to heat the building below,” (Delor, 2011, p. 2). Both processes have the potential of reducing “urban heat island effect.” Urban heat island effect is the result of human activities in a city that causes the city or a portion of the area to become much warmer than its surroundings. This is typically exacerbated by low rates of vegetation and high presence of impermeable surfacing. While more research is needed, Delor (2011) concludes that the energy impacts of a rooftop greenhouse are similar to those of a green roof, but are especially beneficial to poorly insulated buildings — “It was found that a combined building + greenhouse structure requires less energy to heat than if they are stand-alones. With a poorly-insulated building it is estimated that the integrated system can reduce the total heat load by 41%.” (Delor, 2011, p. 5). The research of Rosenzweig, Solecki, Parshall, Gaffin, Lynn, Goldberg, Cox, and Hodges (Mitigating New York City's Heat Island with Urban Forestry, Living Roofs, and Light Surfaces, and Green Roofs in the New York Metropolitan Region - Research Report, 2006) additionally confirms that green roofs can offer substantial heat mitigation during peak heat times in the city. Overall, these techniques can result in lowered use of air conditioning, energy consumption, and greenhouse gas production.

Introducing ground-level community gardens and farms to traditionally hard surfaced spaces has the potential to both reduce urban heat island effect and mitigate flooding. Interventions on both the ground-plane and roof levels have the capacity to capture rainwater and enable stormwater
mitigation and filtration, thus protecting against combined sewer overflow (CSO). The report “Stormwater Retention for a Modular Green Roof Using Energy Balance Data” analyzed data from the modular green roof on the Con Edison Building and found that the roof retained around 30% of annual rainfall that fell on it (Culligan et al., 2011). Assuming New York City has approximately 1 billion square feet of roof surface area, this study suggests that 10–15 billion gallons of annual rainfall would be retained if all this area were covered with a 4-inch sedum-based green roof layer (Culligan et al., 2011). Soil improvement, increased biodiversity and habitat creation in urban areas are additional benefits that can be generated through these types of interventions (Cohen et al., 2012). While outside of the scope of this thesis, an interesting question relative to heat island involves future studies of the effects of green roof clustering strategies. Can certain clustering strategies offer increased benefits due to proximity or total amount of square footage covered within a designated area?

3. Human Health and Access to Fresh Produce

Foods produced through urban agriculture, whether at a hydroponic rooftop farm or on a ground-based community hub, have the capacity to respond to growing food deserts and New York City specific FRESH Zones that are becoming more and more prominent within the fabric of the city. FRESH Zones are spaces that have been designated as substantially lacking options for the purchase of fresh, healthy foods. Both tax incentives and zoning incentives are now being offered to building / land owners and developers to incorporate outlets for the distribution of fresh foods in these neighborhoods. The Design Trust for Public Space and Added Value, two local New York City organizations that support Five Borough Farm, emphasize that urban agriculture has the potential to help encourage food health literacy, healthy eating habits, and physical activity through working on an agricultural site and being outdoors (Cohen et al., 2012). These benefits are likely to be far more important than the actual food production benefits that urban agriculture can achieve.

If sited, designed, and maintained well, these types of interventions can be used to directly benefit populations that are facing higher rates of food related health issues. The Office of
Manhattan Borough President Scott M. Stringer (2009) clearly explains that there is a — “dearth of stores selling fresh fruits and vegetables in many of the city’s poor neighborhoods” — and that this disproportionately causes neighborhoods that are primarily Black and Latino to experience high rates of obesity, diabetes, heart disease, hypertension, depression, and other diseases that are associated with insufficient consumption of fresh produce and high consumption of fatty and sugary foods (Office of Manhattan Borough President Scott M. Stringer, 2009, p. 4). Stringer calls for a variety of initiatives, from lobbying for more federal funding for food programs to meeting with major distribution companies to determine how to distribute more locally grown food. Of major importance to this thesis is Stringer’s recommendations to:

“Identify land in the five boroughs and in the foodshed that can be used for agriculture, including suitable public properties (e.g. right of ways, easements, parks), private land (e.g. rooftops, backyard gardens), and underused land. Create policies to streamline the process for agricultural land use that benefits the public.

Promote local agriculture in neighborhoods with limited access to fresh foods through new farmers markets, food cooperatives, CSA’s and local building clubs (with universal EBT machine access and targeted advertising), as well as community gardens in parks, schools, NYCHA, and other city-owned land.

Promote urban food production in NYC.

Conduct a review of policy obstacles that discourage urban agriculture, such as brownfield identification, the beekeeping ban, and land use priorities.

Conduct comprehensive research on sustainable urban farming methods to identify which techniques, scale, and locations are most appropriate for the city’s urban conditions.

Encourage new development projects to include gardening in neighborhood development plans, using guidelines such as LEED © Neighborhood Developments (ND) as a reference. Consider creating incentives for edible landscaping, green roofs, and backyard gardening, particularly in new large-scale residential and mixed use development projects.”

- Office of the Manhattan Borough President Scott M. Stringer, 2009, p. 8
This recommendation calls for a more holistic, integrated site suitability approach that looks at not only socio-economic factors, siting low-income neighborhoods, and issues of access but that also analyzes areas of increased food-related diseases. These are the neighborhoods to target.

4. Socio-Economic Need

While food security is a huge and pressing need in New York City, a critical benefit that many urban communities are currently exploring is the capacity for urban agriculture to create jobs that facilitate both financial benefit and educational opportunities for those who may not typically have access to them. The New York City Housing Authority (NYCHA) has incorporated job training into the Red Hook Farms establishment, the largest urban farm — and currently only urban farm — that NYCHA operates. In New York City, Red Hook Farms is one of the most important case-studies apart from Brooklyn Grange to recognize. In this space, management and maintenance of the facilities as well as cultivation of the different produce, flowers, and trees that are grown on-site are primarily done by youth and residents of the NYCHA homes nearby who are interested in participating in this kind of work. A similar program for job creation is being used by Sky Vegetables at Arbor House who are able to offer different job opportunities to the residents who live in the affordable housing below the rooftop farm and to NYCHA residents living nearby.

The social and community-based benefits of those who are able to experience these spaces abound. It is clear that working and learning in outdoor spaces as well as simply enjoying the out-of-doors is both generative of greater levels of health and frequently greater levels of community coherence and appreciation. Offering neighbors the opportunity to enjoy an outdoor space and engage with one another in a way that transcends doors and walls can build community. “The potential to use urban agriculture sites as ‘celebratory space’ has been identified in [the] 2005 CPUL book, and is demonstrated in NYC, where rooftops are often used as venues for celebrations, such as weddings, anniversaries and birthday parties,” (Bohn and Viljoen, 2014, p. 124). These spaces have the potential to be spaces of production and distribution as well as spaces of celebration, joy, and education.
While there are limitations to urban agriculture in New York City — space, soil contaminants, management, maintenance and upkeep, cost-benefit financial gain, seasonal shifts, and development challenges for private owners — the benefits that these types of systems and spaces can offer urban inhabitants are plentiful. The City of New York sees and recognizes many of these benefits and has incorporated urban agriculture into its future resiliency plans and goals.

THE FUTURE OF NEW YORK CITY - OneNYC

OneNYC is New York City’s current “roadmap” of social and environmental intentions that the city hopes to achieve in the coming decades. It is organized in the categories of job growth and thriving business environments, just and equitable housing and health services, sustainability in environmental footprint and greenhouse gas emissions, and resiliency against storms and disruptive events. Each of these categories contains many sub-categories of goals and initiatives that aim to achieve them. While all four of the overarching categories — growth, equity, sustainability, and resiliency — are pertinent to this thesis the categories of equity, sustainability and resiliency are focused on as either support for the thesis in its entirety or as drivers for the development of the multi-criteria site suitability model and as justification for the final integration of specific decision layers. These categories directly incorporate both urban agriculture and green infrastructure into their recommendations and strategies.

Within the equity category, New York City hopes to “improve food access, affordability, and quality, and encourage a sustainable, resilient food system” (The City of New York, 2016, p. 132). The city intends to do this by (a) investing in the regional food system and encouraging an increase in the share of regional food that the New York City food system uses, (b) supporting and improving the quality of food offered in schools, (c) ensuring that underserved neighborhoods have access to multiple fresh food retail options, and (d) supporting community gardens and urban farms. The city believes that “urban agriculture plays a small but critical role in communities underserved by quality, affordable, fresh food” and has vouched to support the development of both smaller-scale community farms in neighborhoods that have the necessary infrastructure as well as larger-scale urban farming projects (The City of New York, 2016, p.
Additionally, they will research “emerging urban agricultural opportunities such as vertical farming projects, to activate underutilized light industrial space and offer related community programming” (The City of New York, 2016, p. 135).

Within the *sustainability* category, New York City hopes to “mitigate neighborhood flooding and offer high quality water services” through (a) protecting the city’s water supply, (b) installing and repairing water fountains, (c) expanding green infrastructure throughout critical neighborhoods, and (d) reducing pollution from stormwater runoff (The City of New York, 2016, p. 200). The third initiative, expanding green infrastructure that specifically addresses stormwater management, is followed by a supporting initiative — “alleviate flooding in Southeast Queens” — one of the city’s most impacted neighborhoods (The City of New York, 2016, p. 205). Urban agricultural interventions could be utilized as a means of addressing flooding and food production simultaneously. It should be noted that this thesis believes that while urban agriculture could be used to address both concerns simultaneously that it most likely would not be utilized on its own as a means of combating only flood concerns. This is discussed further in the findings section.

Within the *resiliency* category, New York City has four main target areas — neighborhoods, buildings, infrastructure, and coastal defense. The neighborhoods goal includes a heat mitigation intention that addresses vulnerable neighborhoods that are disproportionately affected by high heat during the summer months. Through using updated high resolution LiDAR data, including thermal radiation data and tree canopy, the city hopes to more accurately understand which neighborhoods are affected the most and will be working with the Nature Conservancy and the Board of Health to come up with new strategies that target these neighborhoods. The coastal defense goal includes continued investment in new infrastructure along the coasts of the boroughs in areas that were most heavily hit by hurricane Sandy. It should be noted that these areas are highly vulnerable but current plans don’t necessarily address all of the areas that are vulnerable to stormwater and flood inundation in the city.
MAPPING FOR POTENTIAL WHILE MAPPING FOR NEED

Mapping through GIS supported MCDA can identify areas where future interventions can offer the greatest co-benefits as outlined through the literature cited and address the city’s desire for more healthy and resilient food systems as well as effective green infrastructure that address both flooding and high heat concerns.

*Mapping For Potential Urban Agriculture in New York City - Existing Studies*

The Urban Design Lab has generated two substantial reports on the current state of urban agriculture in New York City. The first of these reports, *The Potential for Urban Agriculture in NYC: Growing capacity, food security and green infrastructure (2011)*, includes a methodology for identifying sites that are both available and appropriate for urban agriculture in the city. Their methodology begins by broadly outlining all available potential areas for intervention. They identify potentials based off of the criteria of being vacant, unused, and being open. They discuss the impact of soil remediation needs, fresh food availability and the presence of food deserts, CSO outfall areas, and high surface heat index. After they have displayed all of these potential layers of analysis they identify four case study neighborhoods to look into further. This thesis builds on their methodology by utilizing fully updated sets of data for 2016 where available. Additionally, the methodology used in this thesis (discussed in the following section) first identifies core targeted areas for intervention based on access to fresh produce, health factors, economic need, and environmental vulnerability (heat and water risk), the results of which are applied to the tax lot boundaries. This model is run multiple times and from here available and appropriate acreage that can be hypothetically developed within those areas is identified. Key changes within this methodology from those of the Urban Design Lab are found within the specificity of the decision making unit itself. This mapping model enables the combined use of many different data sets with varying resolutions through rasterization and combination of the decision layers. Within the rasterization process the unit of specificity can be chosen depending on the decision-maker’s intention. In this regard the method can have varying degrees of specificity.
Neither the use of GIS nor the use of multi-criteria decision analysis (MCDA) is new to the field of planning. “GIS-based MCDA can be thought of as a process that combines and transforms spatial and aspatial data (input) into a resultant decision (output). The MCDA procedures (or decision rules) define a relationship between the input maps and the output map. The procedures involve the utilization of geographical data, the decision-maker’s preferences and the manipulation of the data and preferences according to the specified decision rules ” (Malczewski, 2004, p. 33). Digital mapping methodologies as tools for multi-criteria decision support systems within the field of planning have their roots in the use of hand-drawn overlay techniques employed by American landscape architects in the late nineteenth and early 20th century in establishing land-use suitability analysis (Malczewski, 2004). “McHarg (1969) advanced the overlay techniques by proposing a procedure that involved mapping data on the natural and human-made attributes of the environment of a study area, and then presenting this information on individual, transparent maps using light to dark shading (high suitability to low suitability) and superimposing the individual transparent maps over each other to construct the overall suitability maps for each land use” (Malczewski, 2004, p.5). These overlay procedures have developed into what now are specialized land-use suitability methodologies including MCDA, artificial intelligence (AI) geocomputation methods, visualization methods, and Web-GIS (Malczewski, 2004).

When Jacek Malczewski published his monograph *GIS-based land-use suitability analysis: a critical overview* in 2004 the development of GIS-based methods for land-use suitability analysis had been developing into the more advanced methods mentioned above for around 30 years. During this time, a number of different types of planning projects had utilized GIS supported land-use analysis methodologies. These projects include among others a suitability analysis for greenways and other open-space features, land suitability modeling for transmission lines, management strategies for watersheds, web-GIS for nuclear waste disposal, and the use of GIS-MCDA as a land-use conflict management tool (Malczewski, 2004). Another example of the application of GIS-MCDA is Land-use Conflict Identification Strategy (LUCIS), a model
developed by ESRI (Environmental Systems Research Institute), that enables the spatial visualization of incremental decisions made with community input towards smart land-use. The LUCIS model, while good for smaller communities may not be as applicable to New York City.

GIS-MCDA has the potential to address two very different perspectives in land-use suitability planning—that of the “techno-positivist” and that of the “socio-political, participatory GIS perspective.” For GIS-MCDA to have the greatest beneficial impact, while opposing in nature both perspectives should be taken into consideration. GIS-MCDA advances the use of GIS for spatial decision support and as a tool for participatory planning. “The major advantage of incorporating MCDA techniques into GIS-based procedures is that the decision-makers can insert value judgements (their preferences with respect to evaluation criteria and/or alternatives) into GIS-based decision making procedures, and receive feedback on their implications for policy evaluation” (Makczewski, 2006, p.717). Maps generated through GIS-MCDA can act as the evidence base needed for many different policies and varied intervention systems and types within planning. “An integration of MCDA into GIS can support collaborative work by providing a tool for structuring group decision-making problems and organizing communication in a group setting” (Makczewski, 2006, p.717). This is an immense asset to GIS-MCDA—non-expert voices, voices of public-interest groups, individuals, developers, city organizations, etc. can all be included if desired. While the data and methodology used in this thesis identify clear areas of need (core targeted areas) that can benefit from core targeted areas, it recognizes that these areas would also be excellent starting points for community dialogue and participatory processes that could inform further iterations of the mapping model and its hypothetical use in the actual siting of different interventions.

Holistic Mapping Approaches

Multiple lines of analysis through mapping and community engagement must be completed to best site agricultural interventions in the city such that they have the potential to directly address environmental concerns and socio-economic factors. While open and available lot area can be mapped, it is useful to begin by first locating areas of need within the city and analyzing these
spaces for potentially developable area. The sources cited on issues of access, health, economics, water, and flood risk illuminate the need for a more holistic mapping approach that utilizes GIS supported MCDA in a way where the needs of people are not neglected for the sake of environmental concerns or, simply, development potential. With intensive and abundant focus on environmental concerns globally, the social aspect of planning has the potential to be forgotten—

“Concerned with environmental sustainability, we must be aware not just of the power - but of the limits - of traditional scientific approaches to thinking about environmental problems […] and of technical work divorced from theories of governance and deliberation. This limit is reflected in the saying that refers to the medical profession: ‘The operation was a success but the patient died.’ […] If we are to care about environmental quality and sustainability, we need not only technical success, but we must also be able to reconcile the perspectives, prospects, and health of not one but many patients, including ways to honor those who’ve come before, to respect those alive today, and to protect the life chances of those yet to come.”

- Forester, 2008, p. 20

The field of planning frequently contains contradictory intentions but most clear is the conflict behind “protecting the green city, promoting the economically growing city, and advocating for social justice” all factors that constitute what many have termed “sustainable development” (Campbell, 1996, p. 296). These conflicts “go to the historic core of planning, and are a leitmotif in the contemporary battles in both our cities and rural areas” (Campbell, 1996, p. 296). As planners, it becomes paramount to be aware of these conflicts and how we address them. GIS supported MCDA has the potential to bridge disciplines and call out “collective areas of need” but this thesis recognizes the limits of even the most holistic mapping approaches. In regards to food production and distribution, supply chains are not always clear. Locating a project in one area does not ensure that the food produced by that project will go to serve the residents living within an immediate range of it. Market forces and established distribution points, such as greenmarkets, grocery stores, and restaurants, all play a role in the eventual outcome of where the produce could be distributed. Both spatial and policy recommendations will be needed in order to ensure that communities of need are being addressed. This will be elaborated on in further detail in the discussion section of this thesis.
METHODOLOGY AND RELEVANT DATA

RESEARCH DESIGN

This research utilizes a geospatial site suitability model with various criteria to help evaluate different potential outcomes for where urban agricultural interventions should be sited in New York City given the current environmental and socio-economic need-based conditions that the city exhibits. It utilizes criteria that feed into the component categories of access to fresh produce, health rates, economic need, and water and heat risk. The results of this model, run multiple times, are applied to each of the tax lots in New York City, identifying exactly where the greatest need and vulnerability exists. It then looks at these core targeted areas and identifies the best types of urban agriculture given the available and appropriate spaces that currently exist within these areas. This geospatial mapping model can act as a tool for future policy makers, community boards, developers, and other organizations interested in enabling urban agriculture to offer co-benefits through strategic siting. In this regard, it is important to consider not just the potential environmental resiliency enhancement that these spaces can offer, nor simply their capacity to produce fresh produce or offer ecosystem services, but also who these sites are serving. Current goals and budgetary plans of New York City as well as the overarching intentions of the hundreds of not-for-profit organizations currently operating in the city are utilized to inform which criteria layers are included in the site suitability model thus helping to shape a better understanding of the utility behind this type of multi-criteria mapping analysis.

It should be noted that within GIS supported MCDA there is the possibility of confounding variables that display a similar spatial pattern and co-locate within the area being analyzed. For example, within this methodology the economic need variables co-locate because there is confounding information—these variables are indicators of poverty. While other researchers may want to add in several more indicators, this methodology only uses three in an effort to not accidentally generate a map of poverty once the indicators go into the weighted and ranked model. Having five different main components of analysis which the raw decision layers feed into ensures diversity in the model from which clear patterns can still result.
Figure 1: Research Design

- **ACCESS**
  - USDA Food Desert Census Tracts
  - FRESH Food Store Zoning Boundaries
  - Subway Stops and 1/4 Mile Walking Radius

- **HEALTH**
  - % of Population with Obesity
  - % of Population with Diabetes
  - % of Population Who Consumed Fruit or Vegetables in the Past Day
  - Grocery Store SQFT / 100 People

- **ECONOMIC**
  - % of Population Below Poverty Level
  - % of Households Receiving SNAP Benefits
  - Median Income

- **WATER**
  - Combined Sewer Outfall Drainage Areas
  - Surface Permeability (Soil Category)
  - Flood Zone (NYC FIRM, FEMA 2013)

- **HEAT**
  - Surface Temperature (LANDSAT Imagery)
  - Vegetation (LANDSAT Imagery)

- **ENVIRONMENTAL VULNERABILITY**
  - Vulnerability to Natural Disasters

- **SOCIO-ECONOMIC NEED**
  - % of Population Below Poverty Level
  - % of Households Receiving SNAP Benefits
  - Median Income

- **CORE TARGETED AREAS**
  - Rooftops - privately and publicly owned
  - Community gardens
  - Open space and outdoor recreational areas
  - Transportation and utility easements
  - Vacant lots - privately and publicly owned
  - Parking lots
  - NYCHA greenspace
  - Greenstreets
  - Subway Stops and 1/4 Mile Walking Radius

- **AVAILABLE AND APPROPRIATE AREAS FOR URBAN AGRICULTURE**
  - Ground-level farms
    - As both a means of production and a piece of green infrastructure
  - Rooftop open-air farms
  - Rooftop greenhouses
  - Rooftops - privately and publicly owned
1. Socio-Economic Need - Decision Layers

The first step of this inquiry identifies core targeted areas in the city that have the potential to benefit the most from urban agricultural interventions. Multiple layers of analysis referred to as "decision layers" have been utilized to help inform where the areas of greatest socio-economic need exist in the city. These different data sets are described in detail in Table 1. The decision layers included in the first step fall into one of the three categories of socio-economic need — access, health, or economic need. Socio-economic need is seen as being a correlation between physical proximity to fresh food retail, means of procurement, capacity to purchase, and potential impact of a healthier diet. These areas are spatially located using GIS and understood as areas of greatest socio-economic need for fresh produce within NYC.

**Table 1: Data Used for Socio-Economic Need Decision Layers**

<table>
<thead>
<tr>
<th>Data</th>
<th>How it is used</th>
<th>Year of Publication</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>USDA Food Desert Census Tracts</td>
<td>Used to identify food desert census tracts within the USDA 1/2 mile range</td>
<td>2015</td>
<td>USDA</td>
</tr>
<tr>
<td>FRESH Food Store Incentive Boundaries</td>
<td>Used to show location of areas where zoning and/or tax incentives are applicable to owners and developers</td>
<td>2016</td>
<td>NYC Department of City Planning</td>
</tr>
<tr>
<td>NYC Subway Locations</td>
<td>Subway stations and a 1/4 mile spatial buffer are used to show neighborhoods with low-access to public transportation</td>
<td>2012</td>
<td>NYC Department of Information Technology and Telecommunications</td>
</tr>
<tr>
<td>% of Population with Obesity</td>
<td>Used to identify community health districts with the greatest prevalence of obesity</td>
<td>2015</td>
<td>NYC Department of Health and Mental Hygiene GIS Center</td>
</tr>
<tr>
<td>% of Population with Diabetes</td>
<td>Used to identify community health districts with the greatest prevalence of diabetes</td>
<td>2015</td>
<td>NYC Department of Health and Mental Hygiene GIS Center</td>
</tr>
<tr>
<td>% of Population Who Consumed Fruit or Vegetables within the Past Day</td>
<td>Used to identify community health districts with the lowest reported values of fruit and vegetable consumption</td>
<td>2015</td>
<td>NYC Department of Health and Mental Hygiene GIS Center</td>
</tr>
<tr>
<td>Grocery Store Square Footage / 100 People</td>
<td>Used to identify community health districts with the lowest square footage of grocery store space / 100 people</td>
<td>2015</td>
<td>NYC Department of Health and Mental Hygiene GIS Center</td>
</tr>
<tr>
<td>% of Population Below Poverty Level</td>
<td>Used to identify census tract areas with the greatest percentage of poverty</td>
<td>2015</td>
<td>US Census - American Community Survey 2015</td>
</tr>
<tr>
<td>% of Households Receiving SNAP Benefits</td>
<td>Used to identify census tract areas where the greatest percentage of households are on food support</td>
<td>2015</td>
<td>US Census - American Community Survey 2015</td>
</tr>
<tr>
<td>Median Income</td>
<td>Used to identify census tracts with lowest median income</td>
<td>2015</td>
<td>US Census - American Community Survey 2015</td>
</tr>
</tbody>
</table>
2. Environmental Vulnerability - Decision Layers

The second step of this analysis focuses on identifying areas where urban agricultural interventions have the potential to mitigate environmental issues focused on water and heat risk. As identified in the research of the Urban Design Lab, urban agricultural interventions have the potential to mitigate stormwater as well as address excessive heating within the city. These environmental issues are key to city-wide green infrastructure initiatives among other climate change and resiliency plans. In order to identify spaces within the city where urban agriculture can have the most impact this study geovisualizes and compares water risk and heat risk related data sets. The environmental vulnerability decision layers utilize the data sets explained in the Table 2. Areas of greatest water and heat risk are understood as areas of greatest environmental need or areas where urban agricultural interventions have the opportunity to offer the greatest mitigation or resiliency enhancement in regard to future conditions of New York City.

Table 2: Data Used for Environmental Vulnerability Decision Layers

<table>
<thead>
<tr>
<th>Data</th>
<th>How it is used</th>
<th>Year of Publication</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Combined Sewer Overflow Drainage Areas</td>
<td>CSO drainage areas are used to identify areas where the stormwater drainage system and sewer drainage system are combined. When storm events occur and these areas experience high levels of stormwater runoff into the sewer system the likelihood of CSO overflow into the river outflow points is high.</td>
<td>2016</td>
<td>NYC Open Sewer Atlas</td>
</tr>
<tr>
<td>Surface Permeability as a Function of Soil Type</td>
<td>Used to identify areas in the city where the soil type is considered to be within the ‘urban’ category. This category includes multiple entries, all of which have a very low permeability score relative to other soil types.</td>
<td>2016 version, 2013 original</td>
<td>USDA Natural Resources Conservation Service - Web Soil Survey</td>
</tr>
<tr>
<td>Flood Zones (NYC FIRM)</td>
<td>Used to identify areas of water risk (mostly coastal) based off of anticipated flooding post-Hurricane Sandy</td>
<td>2013</td>
<td>US Federal Emergency Management Agency</td>
</tr>
<tr>
<td>Surface Temperature</td>
<td>Used to identify areas of greatest thermal risk in the city based off of thermal band 6 LANDSAT raster file</td>
<td>2010</td>
<td>Global Land Cover Facility (GLCF), NASA Landsat Program</td>
</tr>
<tr>
<td>Surface Vegetation</td>
<td>Used to identify areas of greatest thermal risk in the city based off of the surface vegetation LANDSAT raster file</td>
<td>2015</td>
<td>Global Land Cover Facility (GLCF), NASA Landsat Program</td>
</tr>
</tbody>
</table>
3. Classifying and Scoring the Decision Layers - Combined Metrics

Each of the decision layers used in the above tables was classified and given a score according to its appropriate classification. Scoring each of the classes within the decision layers was completed in order to enable combination of the decision layers into the more condensed categories of access, health, and economic need as well as water and heat risk thus generating a result that is a clearly scored map representative of the different input decision layers. Figure 2, below, demonstrates this process.

**Figure 2: Scored Raster Summation Diagram**

The data used in the decision layers for the health and economic components of the socio-economic need metric are classified in quantiles with 50% of the data shown falling below the median score and 50% falling above. The classes are scored according to their quantile classification with ‘0’ or ‘null values’ being given a score of 0 and all other data in the four classes being given a score of 1, 2, 3, or 4 depending on their value. The bell-curve diagram shown in Figure 3 displays this type of classification and corresponding scoring. Table 3 shows
the % of Households Receiving SNAP Benefits decision layer as an example of data distribution using quantile classification and corresponding scoring. Data used in the decision layers included in the access component are put into two classes depending on whether they fall within the boundary being mapped, such as a food desert or FRESH zone. These are given a score of either 0 or 4 depending on whether or not they are considered to be within one of these zones.

Figure 3: Quantile Classification Bell-Curve and Corresponding Scoring

** It should be noted that the 1 - 4 score shown here infers that data points with high values correlate to greater need. For some decision layers — % of Population with Diabetes for example — this scoring makes sense but for other decision layers such as Grocery Store Square Footage / 100 People a high value implies more grocery store space thereby correlating to a lower need score. The 1 - 4 scoring would be reversed for a decision layer such as this.
Table 3: % of Households Receiving SNAP Benefits - Scoring Example

<table>
<thead>
<tr>
<th>% of Households Receiving SNAP Benefits</th>
<th>Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>0%</td>
<td>0</td>
</tr>
<tr>
<td>0.01 - 7.80%</td>
<td>1</td>
</tr>
<tr>
<td>7.81 - 16.80%</td>
<td>2</td>
</tr>
<tr>
<td>16.81 - 30.00%</td>
<td>3</td>
</tr>
<tr>
<td>30.01 - 88.00%</td>
<td>4</td>
</tr>
</tbody>
</table>

After the individual decision layers that feed into the access, health, and economic components of the socio-economic need metric have been rasterized and scored they are added together. The cumulative score ranges for the access, health, and economic components are 0 - 12, 0 - 16, and 0 - 12, respectively. These three final summation rasters are then added together to create a final map of socio-economic need (Map 15 on page 43) that is a scored raster file with a score range of 0 - 40.

The decision layers that feed into the water and heat risk components of the environmental vulnerability metric are classified differently depending on the data set. Combined sewer outfall drainage areas and soil types are shown as “yes or no” areas — either the area is a combined sewer outfall drainage area or it is not. Data points within the combined sewer outfall areas decision layer and the soil types decision layer are given a score of 1 if the area is a combined sewer outfall area or an area of that contains an urban soil type with a lower degree of permeability. All soil types considered “urban soil types” in New York City have been identified and mapped by the USDA Natural Resources Conservation Service - Web Soil Survey. If an area is not considered a combined sewer outfall area or an urban soil type, it is given a score of 0.

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2 “Low permeability: Low permeability restricts movement of water through the soil, impeding the infiltration function. The interpretation evaluates the range (low to high) of permeability values for the least transmissive layer in the soil” (USDA Natural Resources Conservation Service - Web Soil Survey). No permeability is where no volume of water moves through the surfacing type. Low permeability is considered to be under 1.0 in/hr.

3 To find out more about soil permeability and to see the full list of soils considered to be urban soils reference USDA Natural Resources Conservation Service - Web Soil Survey: [https://websoilsurvey.nrcs.usda.gov/app/HomePage.htm?TARGET_APP=Web_Soil_Survey_application_zu4ktz2qkqaixi1rrhv4rgjcw](https://websoilsurvey.nrcs.usda.gov/app/HomePage.htm?TARGET_APP=Web_Soil_Survey_application_zu4ktz2qkqaixi1rrhv4rgjcw)
Flood zones are classified as either being a high-risk, mid-risk, or very low-risk area depending on the FEMA designation of 1-percent-annual-chance flood event, 0.2-percent-annual-chance flood event, and areas of minimal flood risk, respectively. The flood zone decision layer is scored according to level of risk. These scores are 2, 1, and 0 respectively.

After rasterization and scoring these three decision layers are combined to generate the water risk component that has a cumulative score range of 0 - 4. The square root of the score values of this cumulative layer is taken in order to convert these scores into a range of 0, 1 - 2. This is done in order to enable this layer to either emphasize areas of need or allow specific areas to fall away, when multiplied with the socio-economic need metric. This will be described in greater detail in the results section of the thesis.

The decision layers, surface temperature and surface vegetation, that feed into the heat risk component of the environmental vulnerability metric are classified into six classes and a ‘0’ class in order to succinctly depict the true variation in temperature and vegetation gradient without over-simplification of the raw data. These files come in as high resolution aerial imagery files referred to as rasters that the NASA Landsat program regularly collects. The temperature data, originally raw thermal band 6 data received by the Landsat satellite, has been converted into units of heat from its original raw form. In order to do this, the data is first converted into radians and then these values are converted to degrees Kelvin and degrees Fahrenheit. A full explanation of this process and the different spectral bands, including thermal band 6, that Landsat satellites receive can be found in Appendix A, LANDSAT Imaging Background and Data Calculations.

The classes of these components are then given a score of 0, 1, or 2. The surface temperature decision layer data points are scored as 0 if they fall within the classes of 0 - 2; a score of 1 if they fall within the classes 3 or 4; and a score of 2 (having the greatest need) if they fall within the classes of 5 or 6, those of the highest temperature readings. The surface vegetation decision layer is scored inversely to surface temperature. Areas with greater prevalence of surface vegetation fall into a lower class (1 or 2) and are given a score of 0, mid-range surface vegetation receives a score of 1, and little to no surface vegetation or areas with an original raster value of
‘0’ are given the score of 2. Both surface temperature and surface vegetation are corresponding layers of information — they impact one another. For the purposes of this research these two decision layers are added together to generate the heat risk component of the environmental vulnerability metric. The score range of this cumulative layer is 0 - 4 and, similarly to the water risk component, is converted to a score range of 0, 1 - 2 that enables it to either further highlight areas of need or allow certain areas to fall away if they are not vulnerable to heat risk.

4. Core Targeted Areas

This thesis recognizes and celebrates that there are many different ways that “core targeted areas” for intervention within cities can be identified. In this research, the final socio-economic need and environmental vulnerability metrics and their components are used as inputs into iterations of the suitability model that enable use of the environmental vulnerability components as multipliers instead of as core targeted areas on their own. The argument for this is that urban agricultural interventions will most likely not be used to only tackle heat risk or water risk. They will be utilized and invested in for their health, economic, ecological, and social benefits. In this regard, the water risk, heat risk, and cumulative environmental vulnerability metrics are used as multipliers in the various iterations of the suitability model listed below.

**Round One:**  \((\text{Access + Health + Economic})\)

**Round Two:**  \((\text{Access + Health + Economic}) \times \text{Environmental Vulnerability}\)

\((\text{Access + Health + Economic}) \times \text{Water Risk}\)

\((\text{Access + Health + Economic}) \times \text{Heat Risk}\)

**Round One** is understood as being the baseline condition from which the other iterations vary. In a scientific research study this would be referred to as the “control condition.” **Round Two** explores changes to the areas of socio-economic need identified in **Round One** by using the environmental vulnerability metric and its components. These deviations are introduced as a means of identifying areas in New York City that a city department or neighborhood organization might be most interested in addressing through a new, proposed intervention. Existing food
justice, urban agriculture, and health related not-for-profits and larger city-integrated organizations and their goals are discussed in this chapter of the results section.

The different raster files generated in the three rounds of map calculations are spatially joined to New York City’s tax lot database, MapPLUTO. Doing this is useful for a number of reasons, but most clearly enables the cumulative raster cell scores generated through the map calculations to be applied directly to each of the tax lots in the city. In order to do this without skewing the data, the final rasterized layers are converted to vector point files—each point having an appropriate score from the original raster—the mean score of which are then spatially joined to the tax lots within which they fall. Going through these steps enables each of the tax lots to show an accurate correlating score to the original scored raster files. Core targeted areas are identified from the scored tax lots.

5. Available and Appropriate Areas for Urban Agriculture

The final step of this analysis identifies physical acreage within the core targeted areas of need that are both available and appropriate for the three different types of potential urban agriculture being evaluated. Appropriate rooftop area, vacant land, parking lots, transportation and utility easements, existing parks and community gardens, NYCHA green space, and greenstreets are all evaluated as potential areas for hypothetical future intervention. Rooftop area is considered for both privately owned and publicly owned buildings but is only considered if it meets appropriate building criteria. Structural stability based on year built (between 1900-1970), minimum square footage (10,000 SQ FT or more), and maximum heights (10 stories or less) are each considered as appropriate building criteria factors. The viability portion of this analysis identifies which types of intervention (ground level soil-based farm, rooftop farm, or rooftop greenhouse) have the potential to be developed given the sites available. **Table 5, Urban Agriculture Typologies - Relative Spatial and Resource Requirements and Benefits**, on page 62 discusses relative characteristics of these three different types including their comparative resource consumption rates, spatial needs, and potential benefits.
This thesis recognizes that there are highly varying degrees of availability and appropriateness for developments such as these. In urban spaces—especially New York City—there are many legal barriers and unfortunate constraints to the development of private property for urban agriculture. Each of the sets of information used here offers an estimate for what might be available given land-use designations of specific lots as well as lot area estimations. Aerial and ground surveys would need to be completed as next steps in order to generate the most accurate and resolved data on these spaces. This step is outside of the scope of this thesis but is obviously a critical one that would immediately follow a mapping study such as this.

This thesis concludes with a discussion chapter that compares the different core targeted areas identified in each round of map calculations and then discusses these in relation to future budgetary intentions found in *New York City’s Five-Year Fiscal Plan* and the city’s environmental protection goals as outlined in *OneNYC*. Looking at the appropriate and available sites for intervention, this portion of the discussion section refers back to content within the literature review on critical differences between the three types of urban agriculture being evaluated, including potential benefits, drawbacks, and production capacities. This is discussed in relationship to the socio-economic need and environmental vulnerability of these neighborhoods. The discussion chapter culminates with a series of recommendations for planning policy, public participation and engagement practices, and future urban agriculture focused site suitability mapping in New York City and other cities throughout the world.
RESULTS - PART 1

SOCIO-ECONOMIC NEED

The socio-economic need metric is broken down into three components: access to fresh produce, health factors, and economic factors. Each of these three components, referred to as “access,” “health,” and “economic” throughout most of the research, are further broken down into sub-components or decision layers that are listed in Tables 1 and 2 in the methodology and relevant data chapter.

Access to Fresh Produce

The access component consists of three different decision layers with score ranges of 0 or 4. The decision layers shown in Maps 2, 3, and 4 below.

Maps 2 and 3 (left and right):
Access to Fresh Produce - Decision Layer 1: USDA Food Deserts by 1/2 Mile Metric (2015)
Access to Fresh Produce - Decision Layer 2: New York City FRESH Incentive Zones


If a census tract is considered a food desert according to the United States Department of Agriculture (USDA) then it is given a score of 4. If it is not considered a food desert then it is
given a score of 0. If a census tract is considered as being within a FRESH Zoning boundary then it is given a score of 4. If it is not considered within a FRESH Zoning boundary then it is given a score of 0.

Map 4:  
*Access to Fresh Produce - Decision Layer 3: Subway Stops with 1/2 Mile Walking Radius*

Map 5:  
*Access to Fresh Produce - Combined Decision Layers and Scores*

Sources: Author, NYC Subways Stops and Subway Lines, New York City Department of Information Technology and Telecommunications, 2012, and “New York City Census Blocks for 2010 US Census,” New York City Department of City Planning, February 2017

If an area is within the 1/2 mile walking radius boundary that has been drawn around the subway stations then it is given a score of 0. If it is not considered within a FRESH Zoning boundary then it is given a score of 4. The final access component map includes each of the three prior decision layers, each original raster file added together resulting in the culminating scores of 0, 4, 8, and 12. There is no gradient within the sub-ranges of 1-4, 5-8, and 9-12 because of how the original decision layers were scored. In this map, we can see that large portions of South Manhattan, West Queens, and West Brooklyn have relatively high access to fresh produce. There is a greater presence of areas with lower access in Staten Island, the Bronx, Eastern Brooklyn and Eastern Queens. Areas of greatest need (mapped in dark green) are concentrated in North Staten Island and South Bronx.
Health Factors

The *health* component consists of four different decision layers with score ranges of 0 - 4. The decision layers are shown in Maps 6 - 9 below.

**Maps 6 and 7:**
*Health - Decision Layer 1: % of Population with Obesity*
*Health - Decision Layer 2: % of Population with Diabetes*

*Sources: “Community Health Profiles DOHMH 2015,” New York City Department of Health and Mental Hygiene GIS Center, 2015*

These maps show relatively consistent trends in health data collected and reported by the New York City Department of Health and Mental Hygiene. Higher rates of obesity and diabetes are concentrated in the areas of the city that also experience some of the greatest poverty and lowest median income levels (as shown in Maps 11 - 14). This co-location is prominently seen in many health districts within the Bronx, Northeast Brooklyn, Northeast Manhattan, and Southern Queens. Similar areas have lower population counts reporting that they have consumed fruits or vegetables recently. There is more irregularity when looking at the amount of grocery store square footage / 100 people. We can see that there is a negative correlation in certain health districts between current square footage of fresh food retail and high rates of obesity, diabetes, and reported produce consumption. This could be attributed to a number of factors. Most of these
health districts are within areas that are currently considered FRESH Incentive Zones which may have resulted in relatively recent investments. Additionally, while fresh food retail options may be provided, high cost of produce has the potential to limit what a household can purchase.

Maps 8 (upper left), 9 (upper right), and 10 (lower left):

*Health - Decision Layer 3: % of Population Reporting Consumption of Fruit or Vegetables*

*Health - Decision Layer 4: Square Footage of Fresh Food Retailers / 100 People*

*Health - Combined Decision Layers and Scores*

Sources: “Community Health Profiles DOHMH 2015,” New York City Department of Health and Mental Hygiene GIS Center, 2015, and author (for map 10 to the left)
In the final health component map, the results of adding together all four decision layers is shown. The total score range is 0 - 16 with the full gradient of scores applicable. The Crown Heights and Prospect Heights, Bedford Stuyvesant, Bushwick, and East New York and Starrett City health districts in Brooklyn, and, Mott Haven and Melrose, Hunts Point and Longwood, Morrisania and Crotona, Belmont and East Tremont, Fordham and University Heights, Kingsbridge Heights and Bedford, Williamsbridge and Baychester, and Morris Park and Bronxdale health districts in the Bronx each display the highest rates of health risk.

**Economic Factors**

The economic component consists of three different decision layers with score ranges of 0 - 4. The decision layers shown in Maps 11 - 13 below.

**Maps 11 and 12:**

*Economic - Decision Layer 1: % of Population Under the Poverty Level*

*Economic - Decision Layer 2: % of Households Receiving SNAP Benefits*

Each of the decision layers used to generate the *economic* component show similar results when identifying census tracts that experience the highest rates of poverty, lowest median income rates, and highest rates of food stamp or SNAP recipients. Large portions of the Bronx and scattered but large portions of Brooklyn are included. Many census tracts in Northeast and far-Southeast Manhattan are receiving scores in the 3 - 4 range. Additionally, scattered census tracts in Queens and Staten Island also score highly when considering factors of economic need.

**Map 13 and 14:**

*Economic - Decision Layer 3: Median Income*  
*Economic - Combined Decision Layers and Scores*


The economic decision layers chosen here are of serious priority to a number of different not-for-profit organizations working throughout the city in low income neighborhoods. It is estimated that there are approximately 58,681 not-for-profits in the city, of which 225 focus on food, agriculture, and nutrition and 500 focus on environmental quality, protection, and beautification.
At the union of these two categories are a sub-set of not-for-profits that target the neighborhoods receiving the highest scores in all of the economic component maps through both health and environmentally related programs and projects. Such not-for-profits include organizations such as the New York Restoration Project who’s goal is to create beautiful and safe open space by transforming open areas to agriculture sites in neighborhoods that are economically deficient or the smaller-scale La Finca Del Sur in the South Bronx that targets communities that are economically less stable in South Bronx neighborhoods.

These three decision layers each feed into the final economic component map with a score range of 0 - 12. In Map 14 the census tracts receiving the highest score of 12 are highlighted in red in order to distinguish these areas. Out of 2,166 census tracts in New York City, 644 census tracts have a score of 10 - 12. This is approximately 30% of all of the census tracts in the city. Out of these 644 high economic need census tracts, approximately 259 are also areas of greatest health related need and 182 census tracts are either completely within or touch the boundary of the lowest access areas (scores of 8 and 12). In Map 15, all three components that make up the socio-economic need metric have been added together with a final, cumulative possible score range of 0 - 40 and actual score range of 0 - 39. No areas received the highest score of 40. Unsurprisingly, the areas of greatest socio-economic need are also areas where we see the greatest presence of public housing (marked in black), owned and operated by the New York City Housing Authority (NYCHA), in the city.

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Numbers extracted from the March 2017 download of the “Exempt Organization Business Master File” from the Internal Revenue Service (IRS). For more information on registered not-for-profit organizations in the United States, refer to the IRS website (www.irs.gov/charities-non-profits/exempt-organizations-business-master-file-extract-eobmf) and the description of their data listing “Exempt Organization Business Master File.” This file is continuously updated with changes to businesses’ “exempt” status and gives detailed information on where the business is located and what they offer.
Map 15: Socio-Economic Need Metric - Access, Health, and Economic Components Combined

ENVIRONMENTAL VULNERABILITY

Flood Risk

Map 16:
*Water Risk - Decision Layer 1: Current FEMA FIRM for New York City*

Map 17:
*Water Risk - Decision Layers 2: CSO Locations and CSO Drainage Areas*
*Water Risk - Decision Layer 3: Impermeable Surfacing as Understood Through Urban Soils*


The first decision layer that was scored to go into the *water risk* component of the *environmental vulnerability* metric is the Federal Emergency Management Association’s “Flood Insurance Rate Map” for New York City. The areas in this decision layer were given a score within the range of 0 - 2 depending on their designation of low-to-no risk, mid-risk, and high-risk. Area X (minimal flood hazard) is given a score of 0. The areas considered having a 0.2% annual chance of flooding are given a score of 1 and the areas with the greatest risk of flooding annually, 1% or greater (including areas AE, VE, A, and AO), are given a score of 2. From Map 17 it is apparent that there are substantial swaths of land in New York City that are both highly impermeable (or considered an urban soil with a very low degree of permeability) and a combined sewer overflow...
area (areas where both stormwater and sewage water will flow out through a combined sewer outfall point in a storm event). These areas, when visualized together show where risk areas can occur.

Map 18:
Water Risk - Combined Decision Layers and Scores

Combined together, the cumulative score given to each of the areas falls within the score range of 0 - 4 which is then reduced down to 0 - 2 so that when used as the multiplier in the following chapter it will either allow areas to fall away if they are not within a water risk zone or it will allow the score of certain areas to as much as duplicate if it is within a high risk area.

**Heat Risk**

**Maps 19 and 20:**

*Heat Risk - Decision Layer 1: Surface Temperature on July 4, 2010 (Degrees Fahrenheit)*

*Heat Risk - Decision Layer 2: Tree Canopy (in classes)*

Both decision layers that are input into the *heat risk* component are shown through a gradient of risk that is mapped into six classes. These classes are then given scores with the 0 - 2 score range, similar to the scoring of the water risk decision layers. The areas of the highest heats are, unsurprisingly, the areas that co-locate with the least amount of tree cover. Again, unsurprisingly, these areas of high heat are also areas that positively correlate to the areas of urban soils, thus making the connection that areas of low vegetation correlate with higher surface heat.
Map 21:
Heat Risk - Combined Decision Layers

Sources: Author, utilizing boundaries from “New York City Census Blocks for 2010 US Census,” New York City Department of City Planning, February 2017

The two decision layers are combined in Map 21 and, again, the cumulative score is reduced to the 0 - 2 range so that it can be used as a multiplier in the following chapter. Areas with the lowest identified surface temperatures and greatest amount of tree cover are given a score of 0 and allowed to fall away. Areas with the greatest heat risk and lowest amount of tree cover are given the highest score of 2 and all other areas fall into the score range of 1 - 2.
Map 22: Environmental Vulnerability Metric - Water Risk and Flood Risk Components Combined

Sources: Author, utilizing boundaries from “New York City Census Blocks for 2010 US Census,” New York City Department of City Planning, February 2017

Map 22 Environmental Vulnerability Metric shows the combination of the heat risk and water risk components together. The cumulative scores, falling within the 0 - 2 range, are displayed above to highlight all areas of environmental need that have a score of 1.51 - 2. This range is broken down into sub ranges to enable some distinction and highlight the areas with the greatest collective vulnerability from floodwaters, high heat, and low vegetation.
RESULTS - PART 2

The following sections of results include more deeply looking into the areas of socio-economic need and environmental vulnerability in New York City as outlined in the prior sections. The water risk, heat risk, and environmental vulnerability multipliers, identified in the last section, are utilized to address the most challenges simultaneously but first, “control” or “baseline” core targeted areas are identified from the socio-economic metric.

**Round One:** \((Access + Health + Economic)\)

**Round Two:** \((Access + Health + Economic) \times Environmental Vulnerability\)
\(\times Water Risk\)
\(\times Heat Risk\)

Within this section, it is found that there are numerous lots and rooftops that have the potential to offer area for urban agricultural intervention that can be sited in a way where socio-economic need and environmental vulnerability is targeted. While other studies have have utilized community district boundaries and other area-based boundaries to identify opportunity this thesis specifically uses the tax lot boundaries of the city, as visualized through the New York City MapPLUTO database, to highlight the lots of the city that have the greatest need or could benefit the most from an agricultural project located within that identified area. This has benefits and drawbacks (to be reviewed in the discussion). The main benefit is that the MapPLUTO database is one of the most extensive databases that the city maintains. It contains over 70 fields of both lot and building details, as well as information on zoning, land-use, and building details. In this regard, the data is shown through a lot-level resolution that can have benefits when analyzing potential for clustering and adjacency of rooftops and open or vacant areas. Again, it is important to consider the realities behind physical location of an intervention, proximity to its target populations, realistic use, supply and demand, as well as production and distribution chains. This thesis advocates for a combination of GIS supported MCDA, city-wide policy development, public participation and engagement processes, and strategic placement of new urban agricultural projects for them to offer co-benefits and, ideally, address the populations of greatest need.
CORE TARGETED AREAS (Round One): ADDRESSING SOCIO-ECONOMIC NEED

Map 23: Core Targeted Areas (Round One) - Addressing Immediate Socio-Economic Need

Sources: Author, utilizing original New York City tax lot boundaries from “New York City, MapPLUTO 16v2,” New York City Department of City Planning, December 2016

Before using the environmental vulnerability multipliers, the core targeted areas that address socio-economic need only are identified. This study is defining core targeted areas as lots that are in the upper 25% of all potential scores. For the socio-economic need metric, this means that the lots have a final score of 30.1 - 39. ArcMap is used to estimate the lot area of these lots. The total
lot area of the core targeted areas (score of 30.1 - 39) that address socio-economic need only is 247,064,220 SQ FT. Of these 23,071 lots, 211 are considered to be in the MapPLUTO’s land-use category of ’09’ OPEN SPACE AND OUTDOOR RECREATION. When subtracted, the total area calculation of these core targeted areas is 223,046,943 SQ FT. Out of the roughly 23,000 lots with high socio-economic need, 4750 are classified as having an environmental vulnerability score of 1.75 - 2, thus having very high environmental vulnerability according to this model. The total area of these lots is 60,726,467 SQ FT. Given these numbers, approximately 27.2% of all lots identified as having the highest socio-economic need are also at greatest risk of environmental vulnerability in the city. This is not a small number and, in fact, shows a clear co-location and potential correlation between income, access, and health rates among multiple other socio-economic factors with the built and natural environment that exist in the city.

The core targeted areas that most critically could benefit from an urban agricultural intervention are outlined with the red buffers drawn into Map 23. The buffers are drawn to be 250’, 1/8 mile, and 1/4 mile away from the targeted lots to give an idea of the amount of immediate surrounding space that could also be targeted for an intervention. These lots fall into these neighborhoods:

- **Bronx**: Hunts Point, Longwood, Morrisania, Soundview, Castle Hill, Schuylerville, Concourse Village, Claremont Village, East Tremont, Belmont, West Farms, Van Nest, Morris Park, Pelham Parkway, Edenwalk, Williamsbridge, Baychester, and Port Morris
- **Manhattan**: East Harlem
- **Queens**: South Jamaica and Hollis
- **Brooklyn**: Bedford Stuyvesant, Weeksville, Crown Heights, Starrett City, New Lots, and East New York, Edgemere, Flatlands, Sea Gate, and Coney Island
- **Staten Island**: Howland Hook, Port Ivory, Arlington, New Brighton, Port Richmond, Park Hill, and Grimes Hill
CORE TARGETED AREAS (Round Two): ADDRESSING THE MOST CHALLENGES SIMULTANEOUSLY

A more direct way to see which areas of socio-economic need have the greatest environmental vulnerability, involves utilizing the environmental vulnerability metrics as multipliers instead of analyzing where union exists between the two sets. As the multipliers are used there is a clear reduction in the number of lots and corresponding square footage of area that is both socio-economically vulnerable and at risk for flooding, high heats, or both according to this model.

Map 24A: Socio-Economic Need and Environmental Vulnerability

Sources: Author, utilizing original New York City tax lot boundaries from “New York City, MapPLUTO 16v2,” New York City Department of City Planning, December 2016
**Map 24A** highlights the core targeted areas that received a score of 60 - 78 when all of the components of the socio-economic metric remained the same and were multiplied by the environmental metric (scored 0, 1 - 2). The number of lots that are being highlighted as *core targeted areas* substantially drops from the corresponding socio-economic numbers. While all lots are still those that are considered as having high socio-economic need, the ones receiving the highest scores of 60 - 78 are the lots that are also environmentally vulnerable for both flooding and heat risk. These are the lot areas and the neighborhoods to focus on for any organization interested in specifically targeting areas that are both socio-economically and environmentally vulnerable. The total number of lots identified in this step is 1929 and the overall area is 37,747,501 SQ FT. This is close to an 80% reduction in area from the original socio-economic area calculation. It is far more specific.

**Table 4: Core Targeted Areas - Total Lot Area**

<table>
<thead>
<tr>
<th></th>
<th>Socio-Economic Need</th>
<th>(Socio-Economic) * Environmental Vulnerability</th>
<th>(Socio-Economic) * Heat Risk</th>
<th>(Socio-Economic) * Water Risk</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of Lots</td>
<td>22,860</td>
<td>1,929</td>
<td>2,728</td>
<td>146</td>
</tr>
<tr>
<td>Area of Lots (SQ FT)</td>
<td>223,046,943</td>
<td>37,747,501</td>
<td>47,257,858</td>
<td>4,940,963</td>
</tr>
</tbody>
</table>

**Table 4** summarizes the number of lots and the total cumulative area of the lots throughout each of the iterations of mapping with the varied environmental vulnerability multipliers. The results show co-location of areas at risk for high surface heat and low tree cover and areas that display high socio-economic need. **Map 24B**, on the following page, shows exactly where these core targeted areas are. While heat vulnerability is scoring high, the water multiplier does not score as highly. There are only a total of 146 lots and 4,940,963 SQ FT of vulnerable lot area that are both of high socio-economic risk and receiving a high score for the water vulnerability. This is fascinating to see as it shows that when combining the water and heat risk components into the environmental multiplier that this actually generates a lower number of lots and less total square footage identified as being of the highest risk and need groups.
Maps 24B and 24C show the results of modifying the multiplier to be only heat risk and water risk, respectively. There are approximately 20 times as many lots that score highly for socio-economic risk and heat risk than those that score highly for socio-economic risk and water risk. The neighborhoods that are found to be the most at risk, or consistently identified as core targeted areas throughout each of the mapping iterations are found in the Bronx and in Staten Island. In Staten Island, Port Ivory and Arlington are found to consistently receive the highest

Sources: Author, utilizing original New York City tax lot boundaries from “New York City, MapPLUTO 16v2,” New York City Department of City Planning, December 2016
scores. In the Bronx, Hunts Point, Longwood, and Port Morris are consistently found to receive the highest scores and are considered core targeted areas during the next steps when evaluating appropriate and available areas for agricultural intervention.

Map 24C: Socio-Economic Need and Flood Vulnerability

Sources: Author, utilizing original New York City tax lot boundaries from “New York City, MapPLUTO 16v2,” New York City Department of City Planning, December 2016
AVAILABLE AND APPROPRIATE AREAS FOR URBAN AGRICULTURE

In addition to identifying the sites in New York City that have the potential to socio-economically and environmentally benefit the most from urban agriculture, this thesis evaluated the square footage of appropriate and available area for urban agriculture in the core targeted areas identified. Roof areas of buildings, vacant lots, parking lots, transportation and utility easements, outdoor space and recreational areas, the green space that surrounds NYCHA (New York City Housing Authority) owned buildings, existing community gardens, and greenstreets are all evaluated with corresponding area measurements found in Figures 4 - 6 below. Three different data sources are used in the identification of these areas.

The MapPLUTO database gives lot area and building shape area estimates as well as information on ownership type. It also gives information on the year that buildings were constructed and the numbers of stories that a building contains. Individual buildings are identified for specific characteristics within the larger generic fields included in the database. A building is identified as appropriate for potential urban agriculture on its roof area if it was built between the years of 1900 - 1970, if it is ten stories or less, and if it has a roof area of 10,000 SQ FT or more. This study additionally has calculated the total potential roof area of buildings with a smaller footprint then 10,000 SQ FT in acknowledgement of the idea that smaller roof areas could be combined and utilized in one project that would generate a cumulative roof area of over 10,000 SQ FT. The MapPLUTO database in addition to the NYC Planimetrics 2016 geodatabase and NYC DOITT’s Greenthumb Community Gardens dataset are each utilized to generate the area estimations for available and appropriate spaces that are on the ground-level. Each of these sets of information offers an estimate for what might be available given land-use designations of

5 MapPLUTO includes multiple ownership types for both their lot and building data. These types include Type C - City Ownership, Type M - Mixed City & Private Ownership, Type O - Other (Public Authority, State or Federal Ownership), Type P - Private Ownership, Type X - Mixed (Excludes property with a C, M, O, or P ownership code; Fully tax exempt property that could be owned by the city, state, or federal government; a public authority; or a private institution), blank - Unknown (Usually Private Ownership)

6 Buildings built between 1900-1970 were built when structural requirements for buildings ensured that they were capable of withstanding a greater roof live loads (50lbs/ft2) (Ackerman et al., 2013, p. 1-12). 10,000 SQ FT number is the most general number used that experienced project managers state is the minimum floor area required for a project to be successful and financially viable (Ackerman et al., 2013, p. 1-12).
specific lots as well as lot area estimations. Aerial and ground surveys would need to be completed as next steps in order to generate the most accurate and resolved data on these spaces. While MapPLUTO is collected and maintained for taxation purposes, NYC’s Planimetric set is developed and maintained as a spatial set of information which feeds into the development of many other subsets of geospatial data such as NYC’s Open Space and Parks file.

Lots in either file that are classified as ‘VACANT,’ ‘PARKING,’ ‘TRANSPORTATION / UTILITY,’ ‘OUTDOOR SPACE & RECREATION,’ or owned by NYCHA have been selected. Their area (with any building footprint area deducted) is calculated. If the remaining area is over 2500 SQ FT then the site is identified as a space for potentially viable urban agriculture. If the remaining area is less then 2500 SQ FT, the site is still included if the total building coverage of the lot is less then 50% of the total lot area. Greenstreets have been selected from the planimetric geodatabase if they are within 250’ of the core targeted lots as many of these areas are not technically lots and therefore did not receive a score that would enable them to be selected originally. Existing community gardens are geovizualized and then evaluated for their estimated area based on the information included in the DOITT’s most updated listing of all community gardens in New York City that are included in the Greenthumb database.

The total roof area of the 25,890 buildings that are within the socio-economic need core targeted areas is 67,806,046 SQ FT. The next iterations of mapping yield reduced numbers. There is approximately 15,227,548 SQ FT of roof area calculated when evaluating the core targeted areas of socio-economic risk and environmental vulnerability, 1,425,264 SQ FT of roof area within the socio-economic need * water risk core targeted areas, and 19,344,665 SQ FT of roof area within the socio-economic need * heat risk core targeted areas. In the following chart appropriate roof areas at 10,000 SQ FT or larger and under 10,000 are shown for each of the mapping iterations. For complete numbers of all area calculation estimates refer to Table 6 in Appendix B, Appropriate and Available Area for Urban Agriculture in Core Targeted Areas.

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7 These numbers are utilized for a number of reasons. Out of all of the community gardens listed in the Greenthumb database the mean lot size is 13,087 SQ FT and the median lot size is 2,493 SQ FT. The maximum and the minimum areas are 579,947 SQ FT and 26 SQ FT respectively. These lot areas acted as baseline measurements that informed why certain lot areas were identified in this step of the analysis.
Out of the roughly 67,800,000 SQ FT of potential roof area evaluated in the socio-economic need core targeted areas, only 17,000,000 SQ FT of roof area fall within the criteria of being on buildings that have a footprint of 10,000 SQ FT or more, were built within 1900 - 1970, and are 10 stories or less. Approximately 70% of the total rooftop area that meet these criteria are on buildings that are privately owned (listed in the MapPLUTO database as either ‘blank’ or ‘P’ in the ownership type field). Approximately 22% of this rooftop area is of city, state, or institutional ownership and 8% is listed as being of mixed ownership. When analyzing building ownership in the other core targeted area mapping iterations the percentage breakdown remains similar.

When evaluating roof area on buildings with a footprint of less than 10,000 SQ FT but that still meet the height and year built criteria, the numbers fluctuate. When evaluating the socio-
economic need core targeted lots, there is approximately 27,000,000 SQ FT of appropriate roof area identified that are on building footprints under 10,000 SQ FT. This is almost twice as much area as was calculated when only looking at buildings with footprints over 10,000 SQ FT. When evaluating for the same category on core targeted lots identified in the following iterations, it is found that the total roof area of the buildings under 10,000 SQ FT is less than the potential roof area identified of the buildings that are 10,000 SQ FT or higher. This number is consistently less. Throughout all of these calculations, private ownership is consistently more common than public or mixed ownership. That being said, the 5,767,266 SQ FT of publicly owned rooftop area on buildings of both size criteria within the socio-economic need core targeted lots is not a small number. There is much that could be done with this space if ground surveys positively show viable roof area for implementation and if the city would like to invest in this way.

**Figure 5: Available and Appropriate Vacant Lot Area (Calculation Estimates)**

*Sources:* Author, “New York City, MapPLUTO 16v2,” New York City Department of City Planning, December 2016,
There is approximately 18,850,000 SQ FT of vacant lot area identified in the socio-economic need core targeted areas. This number, through the additional iterations of mapping goes down and gets far more specific as those lots are evaluated for environmental vulnerability, water risk, and heat risk. Core targeted lots that are socio-economically vulnerable as well as scoring highly for heat risk have a total of approximately 1,300,000 SQ FT of vacant lot area that has the potential to be developed upon confirmation by a ground survey. This number substantially drops to roughly 200,000 SQ FT when looking at the lots that are socio-economically vulnerable and scoring highly for water risk. The area calculations for the core targeted area lots that are socio-economically vulnerable and environmentally vulnerable (both at risk for high heat and flooding) are very close to the heat risk only calculations but just slightly lower. These vacant lots have far greater private ownership than public ownership. Approximately 4,000,000 SQ FT of vacant area is publicly owned within the socio-economic need only core targeted areas.

**Figure 6: Available and Appropriate Lot Area (Calculation Estimates)**

*Sources:* Author, “New York City, MapPLUTO 16v2,” New York City Department of City Planning, December 2016,
Out of all of the other lot types evaluated, transportation and utility easements, existing outdoor space and recreational areas, and the green space surrounding NYCHA properties came up as having the highest area calculations when looking at lots within the socio-economic need core targeted areas. There is more NYCHA green space available then there is appropriate rooftop area on buildings that have a 10,000 SQ FT footprint or more in the core targeted areas that are socio-economically vulnerable. When evaluating the other core targeted areas, lots identified as parking areas and transportation and utility easement areas have the greatest area estimates. The amount of available parking area is larger then the potentially available transportation and utility easement area in the evaluation of socio-economically vulnerable lots that are also scoring highly for heat risk. This is not surprising as the areas with the greatest heat risk are typically those with the least amount of surface vegetation and greatest amount of impermeable surfacing.

In total, within the socio-economic need core targeted areas, there is almost 100 million square feet of vacant, parking, transportation and utility easement, outdoor space and recreational, NYCHA green space, community garden, and green street area that could be investigated further. While it is assumed that a ground survey would reduce this number, this, as a baseline condition offers an optimistic view on what the potential availability for development could be.

APPROPRIATE TYPES OF URBAN AGRICULTURE IN THESE NEIGHBORHOODS

The core targeted neighborhoods display a number of different characteristics and a variety of available and appropriate ground and roof-levels areas that make them excellent opportunities for future agricultural developments. Given that these neighborhoods both display a genuine need for greater amounts of fresh produce as well as the potential to benefit from smaller ground-up, community integrated projects, this thesis advocates for use ground level and rooftop soil-based agriculture with rooftop greenhouses (as described in the literature review and in Table 5) that have the potential to function well on their own but ideally offer greater co-benefits if part of a larger system of networked agricultural spaces. While many different neighborhoods have been identified that could potentially benefit from an urban agricultural project or intervention, the Hunt’s Point, Longwood, and Morrisania neighborhood areas in the Bronx were consistently a
Table 5: Urban Agriculture Typologies - Relative Spatial and Resource Requirements and Benefits

<table>
<thead>
<tr>
<th>Relative spatial and resource requirements and benefits</th>
<th>Soil-based Ground-level Farms</th>
<th>Rooftop Farms</th>
<th>Controlled Environment Agriculture (Rooftop Greenhouses)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Space requirement</td>
<td>2500 SQ FT is the mean area of all community gardens listed in DOITT's Greenthumb database for NYC. Numbers fluctuate both above and below this.</td>
<td>10,000 SQ FT minimum is the number advocated for in the Urban Design Lab's 2011 and 2013 publications.</td>
<td>Varied square footages depending on cost-benefit assessment. A minimum amount of square footage would be necessary in order to benefit from the up-front costs of the hydroponics and aquaponics installation. For the purposes of this study, 10,000 SQ FT as a minimum area requirement is used.</td>
</tr>
<tr>
<td>Energy requirement</td>
<td>low</td>
<td>low</td>
<td>high</td>
</tr>
<tr>
<td>Water requirement</td>
<td>similar to that of traditional farming if the intention is to produce high yields</td>
<td>similar to that of traditional farming if the intention is to produce high yields</td>
<td>high</td>
</tr>
<tr>
<td>Nutrient requirement</td>
<td>low</td>
<td>medium</td>
<td>high</td>
</tr>
<tr>
<td>Sunlight needed</td>
<td>medium</td>
<td>medium</td>
<td>high - if possible to offset the cost of artificial lighting that is predominantly used in these spaces</td>
</tr>
<tr>
<td>Construction and maintenance costs</td>
<td>low</td>
<td>medium</td>
<td>high</td>
</tr>
<tr>
<td>Proximity / accessibility to public</td>
<td>very high - great for public engagement, being outside, job creation, encouraging healthier patterns of eating through experiential education and other socio-economic benefits</td>
<td>can be if designed to be if the public knows about these spaces - because they are not at the ground-level, many people may not be aware that they exist</td>
<td>typically very low - in order for these spaces to truly produce high consistent yields, they need to be relatively private spaces that are controlled environments and not typically accessed by the public regularly,</td>
</tr>
<tr>
<td>Growing season</td>
<td>Late spring, summer, early fall</td>
<td>Late spring, summer, early fall</td>
<td>All year</td>
</tr>
<tr>
<td>Production capacity</td>
<td>low to medium</td>
<td>medium to high</td>
<td>very high</td>
</tr>
<tr>
<td>Potential to capture rainwater</td>
<td>high</td>
<td>high</td>
<td>low - unless this becomes a designed feature of the roof such as a rain water cistern or catchment barrels</td>
</tr>
<tr>
<td>Potential to re-use excess waste heat from buildings</td>
<td>n/a</td>
<td>n/a</td>
<td>relatively high if designed to offer this</td>
</tr>
<tr>
<td>Potential to thermally insulate buildings</td>
<td>n/a</td>
<td>medium - high depending on design employed and structure’s roof load capacity</td>
<td>medium - high depending on design employed and the percentage of roof surface area that it covers</td>
</tr>
<tr>
<td>Potential to lower high summer heats through modified surface reflectivity</td>
<td>high</td>
<td>high</td>
<td>low - medium</td>
</tr>
<tr>
<td>Constraints to development</td>
<td>Soil contamination / toxicity, low solar access, pests</td>
<td>Soil / growing medium challenges, pests, wind, structural capacity of building, private owner development constraints and legalities, maintenance</td>
<td>Upfront cost is high, cost of maintaining and running the space throughout cold winter months is high, structural capacity of the building needs to be able to hold the load of the water tanks, private owner development constraints</td>
</tr>
</tbody>
</table>

Sources: Author’s personal professional work and synthesized research from the Urban Design Lab (2011 and 2013) and Cohen, N., Kristin Reynolds, Rupal Sanghvi - Five Borough Farm (2012) on relative or comparative rates of resource use, spatial needs and benefits of the three different types of urban agriculture being analyzed
core targeted area and have been chosen to be looked more closely at in an effort to identify which type of agriculture might offer the greatest benefit given the need of these neighborhoods.

**Map 25A:**
*Hunt’s Point / Longwood / Morrisania - Core Targeted Area Lots*

These neighborhood areas are an excellent case study for showing variation in challenges that a variety of urban agricultural types could address. This area has many lots and entire city blocks that are identified as having exceptionally high socio-economic vulnerability as well as being

**Sources:** Author, utilizing original New York City tax lot boundaries from “New York City, MapPLUTO 16v2,” New York City Department of City Planning, December 2016 and building footprint boundaries from “New York City, MapPLUTO 15v1,” New York City Department of City Planning, 2015
both at risk for high heat and/or flooding. The area and number of lots at risk for high heat far outnumber the lots at risk for flooding as can be seen in Map 25A. While this area came up as consistently being a core targeted area throughout each of the mapping iterations, it also displays potential for clustering of appropriately identified rooftops and contains a high prevalence of transportation and utility easement space as well as vacant area and parking areas. Additionally, these neighborhoods are home to Hunt’s Point Market, the largest food distribution center in the country that supplies food to all of New York City. It would be an excellent space to target for urban agricultural interventions because collecting and distributing food is already done in large capacity within this neighborhood.

Map 25B shows the different available and appropriate lot types and roof areas. Buildings that are educational facilities are outlined in black and spaces that offer food programs and residential facilities for adults and families are identified with a black circle. Strategically locating projects near these facilities or on top of the schools may increase potential for distribution and engagement benefit. In this selected area, there is 5,920,000 SQ FT of appropriate roof area that is on buildings with footprints of 10,000 SQ FT or more, 2,353,000 SQ FT of vacant lot area, 1,006,400 SQ FT of parking area, and 7,484,000 SQ FT of transportation and utility lots.

Directly targeting the substantial amount of vacant lot areas and parking lots within all of the core targeted areas can have a number of substantial benefits. Developing these as ground-level open air farms and more intensive community gardens has the potential to reduce urban heat island in the summer, offer potential social, economic, and community strengthening benefits, and produce fresh produce during the growing season in New York City. If located within a flood zone, or, in an area that has very little ground vegetation, these interventions can also potentially offer flood mitigation benefits as discussed in the literature review.

Working with New York City Transportation and Utility offices to develop under-utilized space that they own is another option that could yield a substantial amount of potential space. Many of these lot areas are quite large and have access to regular sunlight — a necessity for smaller gardens but even more so for production greenhouses where it’s important to use as much natural
light as possible to offset the cost of artificial lighting that is typically used. Lots that are this large have potential to be utilized for ground level farms and greenhouses. All lots would first need to be evaluated for toxicity / potential ground contamination. Given that these spaces are located further away from schools and other community facilities, it would make more sense to utilize them for intensive production where the growing environment needs to be controlled.

Map 25B:  
*Hunt’s Point / Longwood / Morrisania - Available and Appropriate for Urban Agriculture*

**Sources:** Author, utilizing original New York City tax lot boundaries from “New York City, MapPLUTO 16v2,” New York City Department of City Planning, December 2016, building footprint boundaries from “New York City, MapPLUTO 15v1,” New York City Department of City Planning, 2015, and “Facilities Database,” New York City Department of City Planning, 2015.
The amount of both privately and publicly owned appropriate roof area for urban agriculture (>10,000 SQ FT footprint) offers much to be discussed in regards to future projects. Given that these are roof-level and not ground-level they have the potential to be evaluated on the amount of sunlight that they receive and also on the amount of energy that the building that they are on is consuming. It would be best to develop intensive production greenhouses (most likely hydroponic) on the roofs of the buildings that receive the greatest access to continuous sunlight and that consume the most energy. As discussed in the literature review, these buildings have the potential to offer the greatest amount of anthropogenic waste heat to recycle into the greenhouse thus achieving total energy use savings. While these projects have the potential to produce a lot

Sources: Author, utilizing original New York City tax lot boundaries from “New York City, MapPLUTO 16v2,” New York City Department of City Planning, December 2016, building footprint boundaries from “New York City, MapPLUTO 15v1,” New York City Department of City Planning, 2015 and “Facilities Database,” New York City Department of City Planning, 2015.
of food, they need to be intensely monitored and in this regard are not as good for community engagement. For private owners wishing to produce food this might be the best option. For public owners wanting to develop a roof that has enough area, developing a combination of an outdoor green roof farm and an indoor controlled hydroponics farm would be a great option that would offer benefits both in terms of food production as well as social and community benefits.

**Map 25C and 25D** above show the appropriate and available lot and roof areas of core targeted lots that have high socio-economic need and heat risk (25C) as well as socio-economic need and water risk (25D). Different urban agriculture interventions could address the different challenges that these lots face. For the lots that are specifically coming up as being at risk for flooding, urban agriculture that directly changes the surface condition of the ground can be directly beneficial. Ground-level farms developed in vacant lots or lots that are used for parking will address ground permeability potentials. Roof top farms also have the potential to be a source of water catchment. Greenhouses on roofs, unless incorporating a water-catchment system, will not be able to address issues around flooding as well. Areas that are coming up as being at risk for high heat are more numerous and could benefit from almost all of the intervention types discussed. Targeting both the ground-plane and upper roof areas of buildings have the potential to lower overall heat in the city. A green roof adds an extra layer of insulation on a building, thus having the potential to reduce total energy consumption and lower total anthropogenic waste heat emitted into the environment. Controlled environmental agriculture on roofs will use greater amounts of energy but potentially be able to utilize some of the host-building’s waste heat. Developing projects on the ground-level that are open air and change the surface condition have the potential to lower excessive heat conditions in these areas.

In review, through analysis of this neighborhood alone, it is visible that there is potential to develop interventions that are specifically tailored to both the socio-economic need and environmental vulnerability of lots or city blocks.
DISCUSSION

This thesis reviews the pressing need for more healthy and resilient food systems offered through urban agriculture in New York City and asks where future urban agriculture projects should be sited such that they address areas with the greatest socio-economic need and environmental vulnerability simultaneously. In order to do this, a geospatial multi-criteria decision making model is developed and utilized that includes multiple layers of information on the current state of food access, rates of health, economic need, and water and heat risk that New York City currently exhibits. The results of this model, run multiple times, are applied to each of the tax lots in New York City, identifying exactly where the greatest need and vulnerability exists.

FINDINGS

It is found that there are multiple neighborhoods that have high rates of socio-economic need and environmental vulnerability. The neighborhoods that display the greatest overall need, both socio-economically and environmentally — either at risk for high heat, flooding, or both — include:

- **Bronx**: Hunts Point, Longwood, Morrisania, Soundview, Castle Hill, Concourse Village, Claremont Village, East Tremont, Belmont, West Farms, Van Nest, Morris Park, Edenwalk, Williamsbridge, Baychester, and Port Morris
- **Queens**: South Jamaica and Hollis
- **Brooklyn**: Bedford Stuyvesant, Weeksville, Crown Heights, Starrett City, New Lots, and East New York, and Coney Island
- **Staten Island**: Howland Hook, Port Ivory, Arlington, Park Hill, and Grimes Hill

The neighborhoods that specifically exhibit both high socio-economic need, as well as water and heat risk when mapped individually include Port Ivory and Arlington in Staten Island and Hunt’s Point, Longwood, and Port Morris in the Bronx. These are the neighborhoods that should be targeted for future urban agriculture development.
In addition to identifying the sites in New York City that have the potential to socio-
economically and environmentally benefit the most from urban agriculture, this thesis evaluated
the square footage of appropriate and available area for urban agriculture in the core targeted
areas identified. It is found that there is close to 112 million square feet or almost 2,600 acres of
potentially appropriate and available developable space for urban agricultural projects in the core
targeted areas showing the greatest amount of socio-economic need. This includes area
calculations taken of appropriate rooftops that are 10,000 SQ FT or larger, vacant lots, parking
areas, transportation and utility easements, existing open green and recreational space, the green
space surrounding NYCHA lots, greenstreets, and existing community gardens. The greatest
amount of available area includes vacant lots, transportation and utility easements, NYCHA
green space, and existing parks and recreational facilities. When evaluating the lots that exhibit
socio-economic need for environmental vulnerability as well, it is found that there is a total of 15
million square feet (~350 acres) of appropriate and available area in lots that are the most at risk
for high heat and close to 2 million square feet (~46 acres) of appropriate and available area in
lots that are most at risk for flooding. These numbers are not taking into account square footage
of building roofs that are under 10,000 SQ FT. If these are considered as well, then the numbers
in each of these categories substantially increases.

The most appropriate types of urban agriculture in these neighborhoods should very depending
on the degree and type of socio-economic need and environmental risk that they have as well as
the available and appropriate area that can be utilized. Urban agriculture, through its varied
types, has the capacity to target these challenges collectively or be tailored to specific conditions
depending on the physicality and type of the project, its relationship to the ground-plane, its
management and engagement structure, as well as any policies or programs that may be
developed in relation to it. Based on the results above and the high degree of co-location
identified in Results Section Two between lots that have high socio-economic need and greatest
risk to high heat, this thesis recommends investment in both strategic siting and development of
projects that address excessively high summer heats while targeting socio-economically
vulnerable populations. Doing this can be done in a number of ways, but most clearly can be
achieved by increasing the amount of permeable surfacing and vegetative ground and roof cover that are typically deficient in areas experiencing the highest temperatures. The following sections include recommendations that could be developed to increase the potential for this to happen.

RECOMMENDATIONS

Vacant Lots and Parking Area Initiatives

Vacant lots and parking areas offer substantial square footage throughout the core targeted areas for development and investment. Many of these lots are listed as privately owned although some of them are publicly owned. 70 - 80% of all vacant lot areas identified in the four sets of core targeted area mappings are privately owned. While ground and aerial surveys would first need to be completed to affirm the accuracy of this information, this thesis recommends the development of a system that enables distribution of ownership information of these vacant lots so that neighbors or owners can potentially work together to develop these spaces. While this thesis recognizes that ownership information is included in the MapPLUTO database, it acknowledges that this is a specialized type of information that may not be accessible or understandable to all people. Offering other incentive-based programs to owners or developers interested in incorporating urban agriculture within these lots may also have beneficial effects. It should be noted that New York City is already one of the most supportive cities for urban agriculture in terms of it’s zoning policies and local laws that currently offer tax support and lowered zoning restrictions that encourage the installation of green roofs and greenhouses. Leasing publicly owned land that is not currently being used is another option to look into as there is the potential for the city to make some money in this way that could then feed back into supporting more strengthened urban agricultural programs.

A different analysis that this thesis advocates for is a parking lot use survey of the different parking areas identified within the core targeted areas. There are many parking lots in New York

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8 These laws and tax incentives include: Local Law 49 of 2011, which adds greenhouses to the list of rooftop structures that can be excluded from building height limitations; Resolution 527, which calls on the State Legislature to extend the Green Roof Tax Abatement to live food-producing plants as well as low-maintenance sedums; and the zoning tax amendment approved by the City Council that allows greenhouses to be exempt from floor area and height limits on commercial buildings (Cohen et al., 2012, p. 116).
City, especially within more peripheral parts of the city that may not be utilized to the extent that they could be. Parking studies, including “The Inner Ring: Residential Parking Study” (2013) completed by New York City Department of City Planning highlights that within neighborhoods in the Upper Manhattan, South Bronx, western Queens, and northern and central Brooklyn that car ownership is overall less than in the city as a whole. They advocate for waiving required parking for smaller buildings and sites, thus lowering the total effective parking requirement that many of these zoning districts still have (New York City Department of City Planning, 2013). Evaluating the use of the parking lots within the core targeted areas can potentially show low-use rates and act as a catalytic mechanism for the re-envisioning of these lots as community gardens, farms, or spaces for productive greenhouses if they are large enough in area and get enough sunlight.

**Green Roof Development Initiatives (Public and Private Owners)**

The overall square footage of appropriate roof area within the core targeted areas is high. It is assumed that upon aerial and ground survey completion that this number would be reduced. In the socio-economic need core targeted areas there is approximately 17 million SQ FT of roof area that is on buildings with a footprint of 10,000 SQ FT or more and that were built during 1900-1970 and are ten stories or less. When using the same criteria to evaluate buildings with smaller footprints but that are still appropriate, there is approximately 27 million SQ FT of space that could be evaluated for potential development. This thesis recommends that, in additional to the current zoning and tax related benefits offered, that New York City offer support to building owners and developers through green roof and greenhouse viability evaluations that would include a structural analysis, solar catchment study, and connection to contractors, architects, and builders who specialize in this work. Additionally, it is recommended that a system be developed by the city but, potentially, administered through community boards that helps building owners within a certain proximity to one another develop implementation strategies for connected or “networked” green roof and greenhouse spaces that have the potential to support one another, especially if the building owner has a property with less then a 10,000 SQ FT footprint.
Green Space Development of Area Surrounding NYCHA Properties

The property area that New York City Housing Authority (NYCHA) owns and operates is substantial. In total, there is an estimated 18 million SQ FT of appropriate ground-level area surrounding the NYCHA properties that are within the socio-economic need core targeted areas. Most of these green spaces are surrounded by fences that keep people from engaging with these areas and perpetuate their low use. This being said, having the green areas as they currently exist is better for reducing high temperature conditions then having the spaces be paved or asphalt. Developing more of these spaces, similarly to NYCHA’s Red Hook Farms, has the potential to offer more engagement of residents and community and better utilization of these plots of land.

PLANNING IMPLICATIONS AND POLICY PROPOSALS

Given city-wide, municipal intentions as outlined in OneNYC and New York City’s current 5-year budgetary plan that calls for $17.7 billion dollars to go to environmental protection (City of New York, Mayor’s Office of Management and Budget, 2017), it is clear that a substantial amount of funding will be directed towards the development of green infrastructure that primarily addresses flooding, among a variety of environmental concerns. Utilizing this funding to support projects that have the capacity to address water and heat risk as well as socio-economic need will be ideal. This is not a new recommendation for New York City as, like many other U.S. cities, federal mandates to reduce combined sewer overflow has resulted in the city utilizing urban agriculture as a form of green infrastructure on multiple sites (Cohen, 2014).

This thesis calls for:

(a) more rigorously applying urban agriculture as green infrastructure throughout the city in areas that are environmentally and socio-economically vulnerable. Enabling urban agriculture to address multiple challenges simultaneously through critical siting will allow it to offer the greatest amount of diverse benefits that it can. For this to occur

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9 A large portion of this money is coming from the Federal Emergency Management Agency (FEMA) and from the U.S. Department of Housing and Urban Development (HUD) and is specifically intended as money to aid in the development of systems and spaces that either still need to be rebuilt after Hurricane Sandy or provide resiliency from future super storms and sea level rise that will impact the city (City of New York, Mayor’s Office of Management and Budget, 2017, p. 25).
successfully, urban agriculture needs to be integrated into the current environmental resiliency plans that New York City is actualizing and developing.

(b) **Developing a comprehensive city-wide plan for the development of urban agriculture as a networked system of open spaces and productive greenhouses.** The ecological and social strength of one project or intervention has the potential to be multiplied through its engagement or connection (both physically as well as programmatically and policy-wise) to other projects going on throughout the city.

(c) **Developing open space zoning districts, ecological corridor zoning / eco-district zoning could help to facilitate the creation of networked productive green spaces throughout the city.** Zoning for continuous ecological corridors that have high ecosystem service value has the potential to generate these types of networked spaces that have the capacity to function on their own but offer much more benefit when being linked into part of a city-wide system of green open spaces and production facilities.

For these goals to be achieved, a comprehensive map outlining all existing urban agricultural projects in the city needs to be developed. As a substantial potential future resource this should be a priority project that the city pursue. Having a maintained and well-developed set of spatially located data that identifies the current state of New York City agriculture would be beneficial to the city and other organizations pursuing work in this realm. Utilizing geospatial multi-criteria decision making can help aid in the process of strategically siting new urban agricultural infrastructures in neighborhoods throughout the city where they have the potential to offer the greatest benefit if developed in tandem with with social programs and policies that support engagement and use. While this thesis celebrates the potential of mapping it acknowledges that GIS supported MCDA is only one part of the larger planning process for city-wide land-use decisions. Further developing this model to include an analysis of the benefits of clustering or networked systems, confirming findings through ground and aerial surveys, and strategically working with the community groups identified would be some of the next steps discussed below.

**THE POWER, POTENTIALS, AND LIMITATIONS OF MAPPING**

*Spaces of Production, Spaces of Distribution, and Spaces of Engagement*

This thesis cannot ensure that the siting of an intervention, on its own, will generate a direct effect on the surrounding population. It is the belief of the thesis that there is a greater chance of
this being achievable through deliberate and strategic placement of a project but, that location alone will not ensure success. It is the policies and programs that are developed in tandem with the physical project that will ensure that the communities surrounding the site of intervention will benefit. And, of course, the caveat to this is that engagement and participation cannot be forced. If prices of fresh produce are not in an appropriate range, or, if the programs developed in association with the project are not tailored to the needs, availability, or interest of the neighborhood then it might not be successful or result in the engagement and utilization that it intended to achieve. This thesis recognizes that there are limitations to what mapping can achieve but also huge potentials to what mapping can show and how this information can be shown.

**Potentials of Mapping and Adapations of the Current Mapping Model**

For the most part, data used in this research is mapped at a relative high resolution—as in the degree of specificity of the information was high. If possible, it would have been better to have worked with health related information that had greater granularity. The health district boundaries that the Department of Health and Mental Hygiene use are quite large and as a result the data is not as refined as it could be. For the *access* component of the *socio-economic need* metric, utilizing bus stop locations as well as subway stops may have slightly modified this decision layer and made it more specific. This being said, access to public transportation, as a decision layer, offers its own caveats — offering public transportation in certain locations does not ensure that those living in close proximity have the financial capacity to utilize it. In fact, it could be argued that many of the identified communities with high socio-economic need may not have the financial means to consistently use public transportation, thus diminishing the accuracy of utilizing a decision layer such as this one.

The total, final resolution of this mapping model was enabled through the availability of high resolution data. Utilizing varied scales and resolutions of data has definite implications for planning, policies, and projects that are developed from mapping models such as this. Rasterizing and aggregating up to different sized boundaries can have varied uses. Going from vector data to raster data in the methodology enables clear input on the scale of resolution of the
data being shown and the scale of the decision making unit. The framework that the methodology employs allows for the reconciliation of spatial data that comes in different units — census level, lot level, health district level and LANDSAT level granularities of information can be utilized simultaneously. In this regard, the potential of this methodology exists in the raster-based process that allows the analyst to consider what the appropriate scale of the information and of the analysis needs to be. The analyst can aggregate and reconcile information into the most truly useful resolution.

In this study, joining the final scored raster files to the tax lot MapPLUTO database for New York City allowed for lot-level granularity of areas with the greatest socio-economic need and environmental vulnerability, water risk, or heat risk depending on what was mapped for. In comparison, utilizing spatial boundaries such as community district boundaries in order to gain a better understanding of areas with the greatest amount of need and the potential available and appropriate land for development in these spaces might have given a greater selection of areas to evaluate. It could be argued that utilizing the tax lots results in a degree of specificity that, when mapping for site suitability for certain conditions, might cause the elimination of areas that are both potentially developable and could produce the desired effect due to their proximity to the more specific “area of need.” It can also be argued that spot zoning for specific lots is not realistic in New York City’s political landscape or in models of landownership that we use in the United States. If this process was going to be done again, aggregating the spatial boundary up to be city blocks instead of tax lots might offer some differentiation in results and also be more appropriate for interventions that are attempting to directly tackle environmental issues which do not necessarily need to be located on a specific lot in order to generate a benefit that could effect that lot.

Scale and resolution of data has great impact for planners practicing in the age of information. There is a clear need to balance socio-economic vulnerability with pluralism but also participation of the communities being studied. Mapping and data collection is one part of the decision making process but it is not the end goal. While the data used here supports lot-level and high resolution decision making, it ultimately identifies areas of opportunity which can be
starting points for participatory processes and a set of community engagement practices that may be able to address issues such as constraints on private owner development in the potential siting of urban agriculture. How findings of this type of mapping study are actualized on the ground or made actionable should be done with community involvement. Data and its spatial location acts as the evidence base for policies developed by governments and political leaders but it also can act as a means to identify opportunities that empower communities to lobby for types of investment or incentives that directly address them and offer co-benefits. Communities and community boards can take findings resulting from these type of mapping methodologies and lobby for certain kinds of investment and development that support them or lobby against investment that they do not need or that does not provide co-benefits. The mapping model itself has the potential to become a community empowerment strategy and a tool that can be further tailored towards their needs.

For planners it is important to leverage the resolution of data being utilized at the scale of the engagement. This analysis develops findings and demonstrates a process that could not be the entire planning process on this topic but that does clearly identify neighborhoods and areas of opportunities for public engagement. The scale of the data-driven component of the analysis is appropriate for the city level. After rasterization and layering, census tracts boundaries are appropriate because larger areas or swaths of space in the city that have very real need can be identified through data at this resolution. When the neighborhood-level maps are analyzed, the much finer lot-level resolution of data can identify the critical spots for developing and supporting community engagement processes. Working with this scale of data enables the capacity to directly target specific buildings on identified lots and offers a high resolution starting point for a future analysis of the benefits of clustering of green rooftops and soil-based rooftop farms. The scale of the information should be particular to its use within the planning process.
The Language of Mapping

Above all, this thesis displays the power of mapping as a tool that can be utilized for a variety of different intentions. There are clear differences between mapping for potential and mapping for need. In this thesis, mapping for need before locating potential areas for development allowed for areas of need and vulnerability to be the focus of the research. Utilizing a raster-based GIS supported MCDA methodology allowed for a degree of specificity that can be utilized in many different planning and development contexts. While this study specifically looks at the need and potential for urban agriculture, GIS supported MCDA can be used for a wide array of other planning issues. Mapping, as a tool, has the potential to be a common language between disciplines that utilize traditionally disparate languages —

“A […] strategy [for planners seeking sustainable development] is to bridge the chasms between the languages of economics, environmentalism, and social justice. Linguistic differences, which reflect separate value hierarchies, are a major obstacle to common solutions. All too often, the economists speak of incentives and marginal rates, the ecologists speak of carrying capacity and biodiversity, the advocate planners speak of housing rights, empowerment, and discrimination, and each side accuses the others of being ‘out of touch.’”

- Campbell, 1996, p. 305

In the face of the challenges that planners regularly address, multi-criteria mapping models can merge the languages of multiple disciplines through spatial logics and visualization that allows for various criteria to be shown, weighted, and utilized simultaneously towards one end goal or project. It is an immensely powerful tool that, if used correctly, can help to strategically shape and refine our visions and plans for holistically harmonized socially, ecologically, and economically just cities and systems.
WORKS CITED


## DATA CITED

### General Data:

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<td>Used to show location of areas where zoning and/or tax incentives are applicable to owners and developers</td>
<td>“Fresh Zoning Boundary,” New York City Department of City Planning, November 2016. Web. Retrieved from <a href="http://www1.nyc.gov/site/planning/data-maps/open-data.page">http://www1.nyc.gov/site/planning/data-maps/open-data.page</a></td>
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<td>NYC Subway Locations</td>
<td>Subway stations and a 1/4 mile spatial buffer are used to show neighborhoods with low-access to public transportation</td>
<td>“NYC Subways Stops and Subway Lines,” New York City Department of Information Technology and Telecommunications, 2012. Web. Retrieved from <a href="https://data.cityofnewyork.us/Transportation/Subway-Stations/arg3-7z49/data">https://data.cityofnewyork.us/Transportation/Subway-Stations/arg3-7z49/data</a></td>
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<td>% of Population Who Consumed Fruit or Vegetables within the Past Day</td>
<td>Used to identify community health districts with the lowest reported values of fruit and vegetable consumption</td>
<td>“Community Health Profiles DOHMH 2015,” New York City Department of Health and Mental Hygiene GIS Center, 2015. Web. Retrieved from <a href="http://data-nychdmh.opendata.arcgis.com/datasets/fa12249f3af74d628af48c2be12501f4_0">http://data-nychdmh.opendata.arcgis.com/datasets/fa12249f3af74d628af48c2be12501f4_0</a></td>
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<td>Combined Sewer Overflow Drainage Areas</td>
<td>CSO drainage areas are used to identify areas where the stormwater drainage system and sewer drainage system are combined.</td>
<td>“CSO Drainage Areas.” Open Sewer Atlas, November 2016. Web. Retrieved from <a href="https://openseweratlas.tumblr.com/data">https://openseweratlas.tumblr.com/data</a></td>
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<td>Surface Permeability as a Function of Soil Type</td>
<td>Used to identify areas in the city where the soil type is considered to be within the ‘urban’ category. This category includes multiple entries, all of which have a very low permeability score relative to other soil types.</td>
<td>“Soildb_US_2003.” USDA Natural Resources Conservation Service - Web Soil Survey, Version 3, May 2014. Web. Retrieved from <a href="https://websoilsurvey.nrcs.usda.gov/app/WebSoilSurvey.aspx">https://websoilsurvey.nrcs.usda.gov/app/WebSoilSurvey.aspx</a></td>
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APPENDICES

Appendix A, LANDSAT Imaging Background and Data Calculations

The Global Land Cover Facility (GLCF) provides earth science data and products that visualize global environmental systems. One of GLCF’s main outputs is remotely sensed satellite data that explain land cover from the local to global scales. Land cover includes the vegetation, geologic, hydrologic or anthropogenic features on the planet’s land surface. These features include forests, urban area, croplands, deserts, etc. which are measures and categorized using satellite imagery.

Landsat (name referring to Land + Satellite) imagery has been collected and available since 1972 from six satellites in the Landsat series. These satellites include three primary sensors: MSS (Multi-spectral Scanner), TM (Thematic Mapper), and ETM+ (Enhanced Thematic Mapper Plus) that have developed over the past 30 years. These satellites collect high resolution visible and infrared imagery, with thermal imagery and a panchromatic image also available from the ETM+ sensor.10

This thesis uses thermal band 6 TM data from July 2010. The raw form of this data is a raster file, the cells of which each contain a color and corresponding numeric range of 1 - 255. This data needs to be processed in order to be understood as temperature. The table below shows the original values of the raster cells and values generated through each of the calculations used to get to the final temperature results.

Table 6: Temperature Data Calculations

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<tr>
<th>Raster Cell Score</th>
<th>Converted to Radians $\frac{(15.303-1.238)}{(255-1)}(\text{raster cell score}-1) + 1.238$</th>
<th>Converted to Degrees K</th>
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<td>310.21</td>
<td>98.97</td>
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<tr>
<td>167</td>
<td>10.43</td>
<td>312.65</td>
<td>103.54</td>
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<td>170</td>
<td>10.59</td>
<td>313.86</td>
<td>105.55</td>
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<td>172</td>
<td>10.71</td>
<td>314.66</td>
<td>106.99</td>
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<td>175</td>
<td>10.87</td>
<td>315.85</td>
<td>109.13</td>
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<tr>
<td>215</td>
<td>13.09</td>
<td>330.91</td>
<td>136.25</td>
</tr>
</tbody>
</table>

For more information on band designation and the function of these satellites visit http://glcf.umd.edu/data/landsat/

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### Appendix B. Appropriate and Available Area for Urban Agriculture in Core Targeted Areas

<table>
<thead>
<tr>
<th>Area of Roof (Total within core targeted areas)</th>
<th>Socio-Economic Need</th>
<th>(Socio-Economic) * Environmental Vulnerability</th>
<th>(Socio-Economic) * Water Risk</th>
<th>(Socio-Economic) * Heat Risk</th>
</tr>
</thead>
<tbody>
<tr>
<td>Area of Roof &gt; 10,000 SQ FT (Total)</td>
<td>16,981,771</td>
<td>5,618,818</td>
<td>891,911</td>
<td>7,860,313</td>
</tr>
<tr>
<td>Area of Roof &gt; 10,000 SQ FT (Privately owned)</td>
<td>12,014,934</td>
<td>4,836,623</td>
<td>891,911</td>
<td>6,108,652</td>
</tr>
<tr>
<td>Area of Roof &gt; 10,000 SQ FT (City, state, or institutional)</td>
<td>3,784,816</td>
<td>322,758</td>
<td>0</td>
<td>1,440,999</td>
</tr>
<tr>
<td>Area of Roof &gt; 10,000 SQ FT (Mixed ownership)</td>
<td>1,182,020</td>
<td>459,437</td>
<td>0</td>
<td>310,662</td>
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<tr>
<td>Area of Roof &lt; 10,000 SQ FT (Total)</td>
<td>26,916,530</td>
<td>3,902,908</td>
<td>232,921</td>
<td>5,333,657</td>
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<tr>
<td>Area of Roof &lt; 10,000 SQ FT (Privately owned)</td>
<td>24,108,529</td>
<td>3,747,655</td>
<td>220,422</td>
<td>4,958,683</td>
</tr>
<tr>
<td>Area of Roof &lt; 10,000 SQ FT (City, state, or institutional)</td>
<td>1,982,450</td>
<td>25,300</td>
<td>5,813</td>
<td>204,501</td>
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<tr>
<td>Area of Roof &lt; 10,000 SQ FT (Mixed ownership)</td>
<td>825,550</td>
<td>129,953</td>
<td>6,686</td>
<td>170,474</td>
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<tr>
<td>Vacant Area</td>
<td>18,840,268</td>
<td>1,156,993</td>
<td>207,882</td>
<td>1,295,217</td>
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<tr>
<td>Vacant Area (Privately owned)</td>
<td>12,943,382</td>
<td>968,599</td>
<td>160,757</td>
<td>990,994</td>
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<tr>
<td>Vacant Area (City, state, or institutional)</td>
<td>3,938,358</td>
<td>122,236</td>
<td>818</td>
<td>129,758</td>
</tr>
<tr>
<td>Vacant Area (Mixed ownership)</td>
<td>1,958,528</td>
<td>66,157</td>
<td>46,307</td>
<td>174,465</td>
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<tr>
<td>Parking Area</td>
<td>6,742,344</td>
<td>1,464,028</td>
<td>77,798</td>
<td>2,351,815</td>
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<tr>
<td>Transportation and Utility Easements</td>
<td>28,399,285</td>
<td>6,756,480</td>
<td>619,156</td>
<td>2,052,844</td>
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<tr>
<td>Outdoor Space and Recreation</td>
<td>20,463,340</td>
<td>226,488</td>
<td>5,010</td>
<td>239,342</td>
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<td>NYCHA Green Space</td>
<td>18,181,255</td>
<td>55,107</td>
<td>0</td>
<td>210,242</td>
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<tr>
<td>Community Gardens</td>
<td>1,551,028</td>
<td>129,348</td>
<td>4,871</td>
<td>598,779</td>
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<tr>
<td>Greenstreets</td>
<td>527,087</td>
<td>153,084</td>
<td>3,632</td>
<td>350,036</td>
</tr>
</tbody>
</table>

**Sources:** Author, “New York City, MapPLUTO 16v2,” New York City Department of City Planning, December 2016,