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Locating Rooftop Gardens in Chicago's West Side

Chicago is recognized as a leader in green roofs, which cover a flat roof surface with a thin layer of soil and vegetation. The city installed a green roof on City Hall in 2001, and it currently boasts green roofs on more than 300 buildings (Chicago Green Roofs, n.d.). These green roofs offer a number of environmental and financial benefits. By reducing the temperature of the roof, they can help to mitigate the urban heat island effect (Green Roofs, n.d.). The vegetation on a green roof helps to sequester carbon and absorb rainwater, improving air quality and reducing stormwater runoff (Green Roofs, n.d.). Green roofs can even help to lower heating and air conditioning costs by serving as an additional layer of insulation (Green Roofs, n.d.).

Though the city has been recognized for its efforts toward sustainability, Chicago also has been the target of recent criticism related to its food systems. Work by First Lady Michelle Obama and others has drawn attention to so-called "food deserts"—areas without access to fresh produce and other healthy foods (Yaccino, 2011). Food deserts are often created by the lack of full-service grocery stores, but other community-based approaches can help to bring fresh food into areas underserved by grocers. In particular, farmers markets and community gardens give residents of these areas access to fresh produce without relying on traditional food distribution networks.

Though still relatively uncommon, rooftop gardens promise to provide the benefits green roofs while also addressing shortages of fresh produce among urban dwellers. In this model, some or all of the vegetation on a traditional green roof is replaced with fruits and vegetables that can be harvested for consumption. Like all community gardens, rooftop gardens should be between 1,500 and 4,000 square feet in size with plots no smaller than 100 square feet (P-Patch, n.d.). These plots can be cultivated by individuals or by schools and community groups, making the garden a valuable tool for community interaction (P-Patch, n.d.).

In this analysis, I evaluated candidate buildings for rooftop gardens in five neighborhoods on Chicago's West Side: Austin, Humboldt Park, West Garfield Park, East Garfield Park and North Lawndale. I chose these neighborhoods for the study area because they have low average household incomes, suggesting that affordable local produce from rooftop gardens could be beneficial. In addition, the neighborhoods are home to just eighteen buildings with green roofs out of more than 300 green roofs in the city.

In determining the best locations for rooftop gardens, I evaluated six criteria, including the locations of existing green roofs, community gardens, farmers markets and schools; the roof area of the building; and the potential for heat island reduction as determined by the color of the roof. Rooftop gardens are most needed in areas not currently served by community gardens and farmers markets. When located near schools, they offer opportunities for agricultural education as well as fresh produce for student lunches. Rooftop gardens offer the greatest potential for heat island reduction on dark roofs, especially in areas that have few existing green roofs. In order to support a rooftop garden, a building must have at least 1,500 square feet of roof area, and preferably as much as 4,000 square feet.

To begin the analysis, I gathered the necessary data sets. From the city of Chicago's data portal, I obtained shapefiles for neighborhood boundaries, building footprints, zoning districts, green roofs, community gardens, farmers markets and schools. From each of these layers, I exported the features that fell within the study area. Since green roofs are typically installed on commercial and industrial buildings, I used the zoning shapefile to select buildings that were not zoned for residential. From the non-residential buildings, I excluded buildings with roof areas less than 1,500 square feet, and buildings that had existing green roofs or community gardens. The remaining 3,357 buildings became the candidates for rooftop gardens. The locations of the candidate buildings as well as green roofs, community gardens, farmers markets and schools are shown in **Map 1**.

I wanted to know the distance between the candidate buildings and the point features—green roofs, community gardens, farmers markets and schools—so I generated near tables for the candidate buildings using each of these point layers as the near layer. I then converted the Euclidean distance and near angle to a Manhattan distance since it is a better indicator of accessibility.[1]

Using the Manhattan distance, I calculated a score for each building between 0 and 100 for each point feature layer. For the distance to community gardens, farmers markets and green roofs, I attempted to limit the effect of outliers—like the buildings in the northwest corner of Austin, which are far away from almost everything—by limiting the maximum distance to two

[1] Manhattan Distance = sin(90 - abs(90 - abs(Angle))) * Distance + cos(90 - abs(90 - abs(Angle))) * Distance

times the median distance. I then calculated a score between zero and 100 proportional to the distance to the nearest feature.[2] Since the need for a rooftop garden increases as the distance from existing community gardens, farmers markets and green roofs increases, the scores represent how far from each of these features the building is. Thus, the closest buildings receive a score of zero and the farthest receive a score of 100.

For schools, I used a similar process to convert the Manhattan distance to a score, but I inverted the scale to give higher scores to buildings closest to schools. Since children would likely walk from their school to the garden, I limited the maximum distance to ¼ mile (1,320 feet), which is often used as the maximum walking distance in transportation studies. Any building more than ¼ mile from the nearest school received a score of zero, and the school buildings received scores of 100. Buildings closer than ¼ mile received a score inversely proportional to their distance from the nearest school.[3]

I also calculated two additional scores: one based on roof area and another based on heat island reduction. For roof area, I assigned a score of 100 to buildings with 4,000 square feet or more of roof area and a score of zero to buildings with the minimum garden area of 1,500 square feet. Buildings with roof areas between these values received a score proportional to their area.[4]

For the heat island reduction score, I examined both roof color and roof area. I determined roof color using Digital Orthophoto Quadrangles (DOQ), monochrome aerial photographs produced by the U.S. Geological Survey. After merging these raster tiles in ArcGIS, I used the zonal statistics tool to calculate the average color for each building from zero (black) to 255 (white). Since buildings with the darkest roof colors and largest roof area have the greatest heat island reduction potential, I calculated the score based on the product of the roof area up to 4,000 square feet and the opposite of the color value.[5] I excluded from this analysis buildings constructed after 1999, since that is when the DOQs were produced. Post-1999 buildings received the median score of 40.08. The results of the heat island potential analysis appear in **Map 2**.

Finally, to complete my multiple-criteria analysis, I joined all the score tables to the building layer in order to calculate the overall score. To do so, I ranked the layers in order of

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[2] Score = 100 - (100 * (2 * Median - Distance) / (2 * Median))
[3] Score = 100 * (1320 - Distance) / 1320
[4] Score = 100 - (100 * (4000 - Area) / 2500)
[5] Score = 100 * (255 - Color) * Area / (255 * 4000)

importance. The distance from community gardens received the most weight because it determines the need for a rooftop garden. Roof area and proximity to schools received the second and third rankings, respectively, because they determine the feasibility of constructing a rooftop garden and the availability of students to cultivate it. Distance from farmers markets, heat island reduction potential and distance from green roofs received the fourth, fifth and sixth rankings because they represent the ancillary benefits of rooftop gardens.

I combined all of the scores using the rank sum method and classified the overall scores by examining the distribution. Scores below the median—representing 1,679 candidate buildings—received a low suitability ranking. With a maximum score of 85.7, I placed the divide between medium and high at a sharp drop-off in the curve around a score of 71. That yielded 1,469 buildings with medium suitability and 210 buildings with high suitability. The suitability classifications and the top three candidate buildings for each neighborhood appear in **Map 3**.

As might be expected, most of the high suitability buildings are clustered around schools and are located at the edges of the study area, farthest from gardens and farmers markets. Yet significant pockets of highly suitable buildings exist in the interiors of the Austin and West Garfield Park neighborhoods. Because of its remoteness and lack of amenities, the northwest corner of Austin has many buildings that could benefit from rooftop gardens. Overall, the highest suitability scores fall in the Austin and Humboldt Park neighborhoods, suggesting that these areas stand to benefit the most from the addition of rooftop gardens.

Though buildings with large roofs might seem the best candidates for gardens, the analysis reveals that most of the highly suitable buildings are in fact moderately sized. Large buildings offer more roof space than is needed for a garden, and they tend to be in less accessible locations than smaller buildings. Of the large buildings, the most suitable ones tend to be those with the darkest roofs and thus, the greatest heat island reduction potential.

The results of this analysis could be used by the city of Chicago to incentivize the installation of rooftop gardens or by urban agriculture groups to find suitable rooftop locations. In the case of the former, the city could offer tax incentives for installation of rooftop gardens based on the suitability score of the building. In the case of the latter, community groups could use the suitability map to identify potential locations and approach the building owners. In either case, the analysis offers the opportunity to strategically locate rooftop gardens for maximum benefit to the community.

Bibliography

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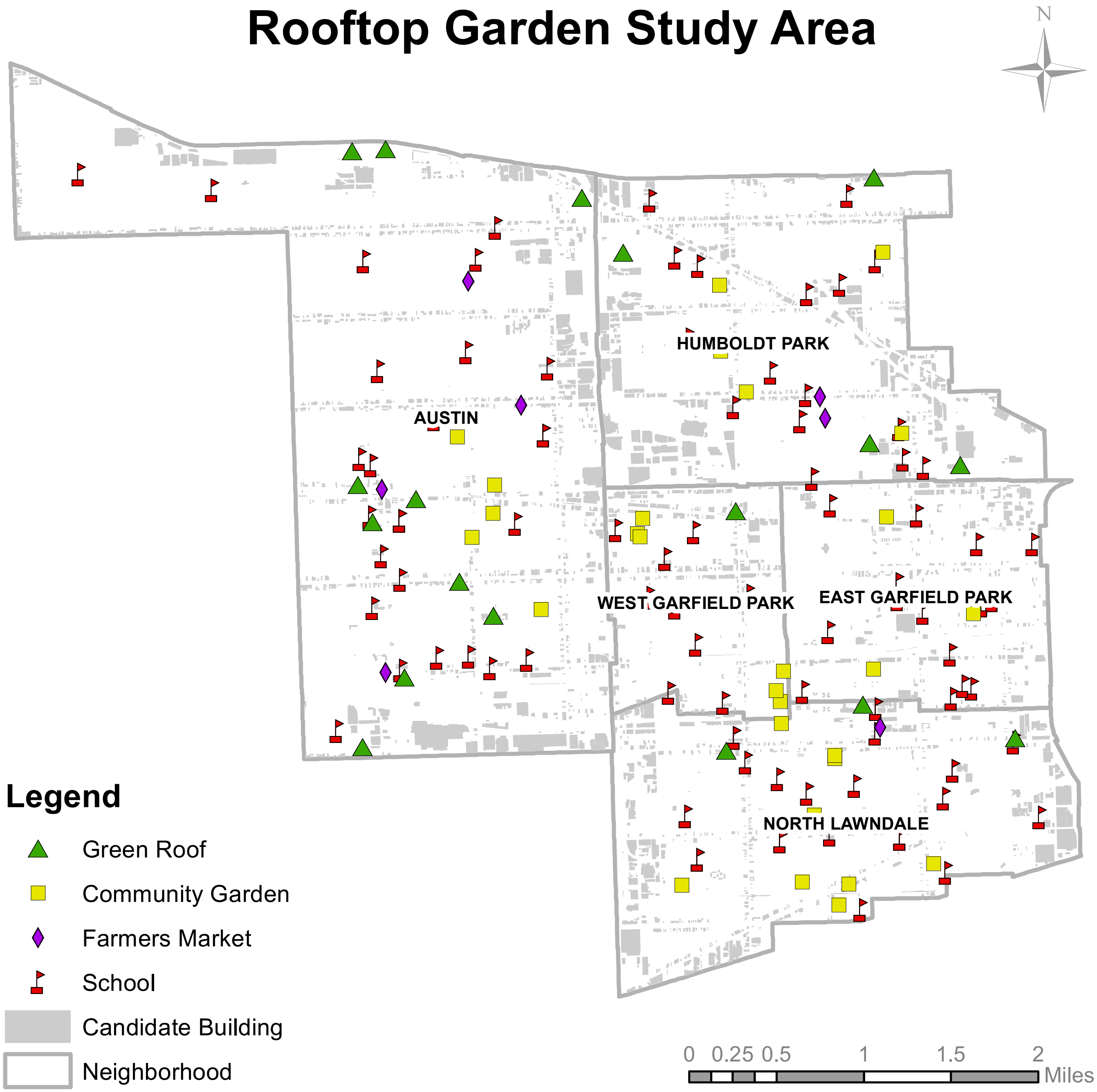
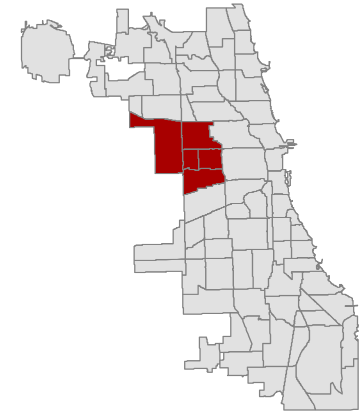
MAP 1

Rooftop Garden Study Area





About the Study Area
The study area consists of five neighborhoods on Chicago's West Side. It includes:

- 18 green roofs
- 28 community gardens
- 7 farmers markets
- 93 schools
- 3,357 candidate buildings

Candidate buildings:

* Are non-residential
* Have a roof area of at least 1,500 square feet
* Do not have a green roof or a community garden

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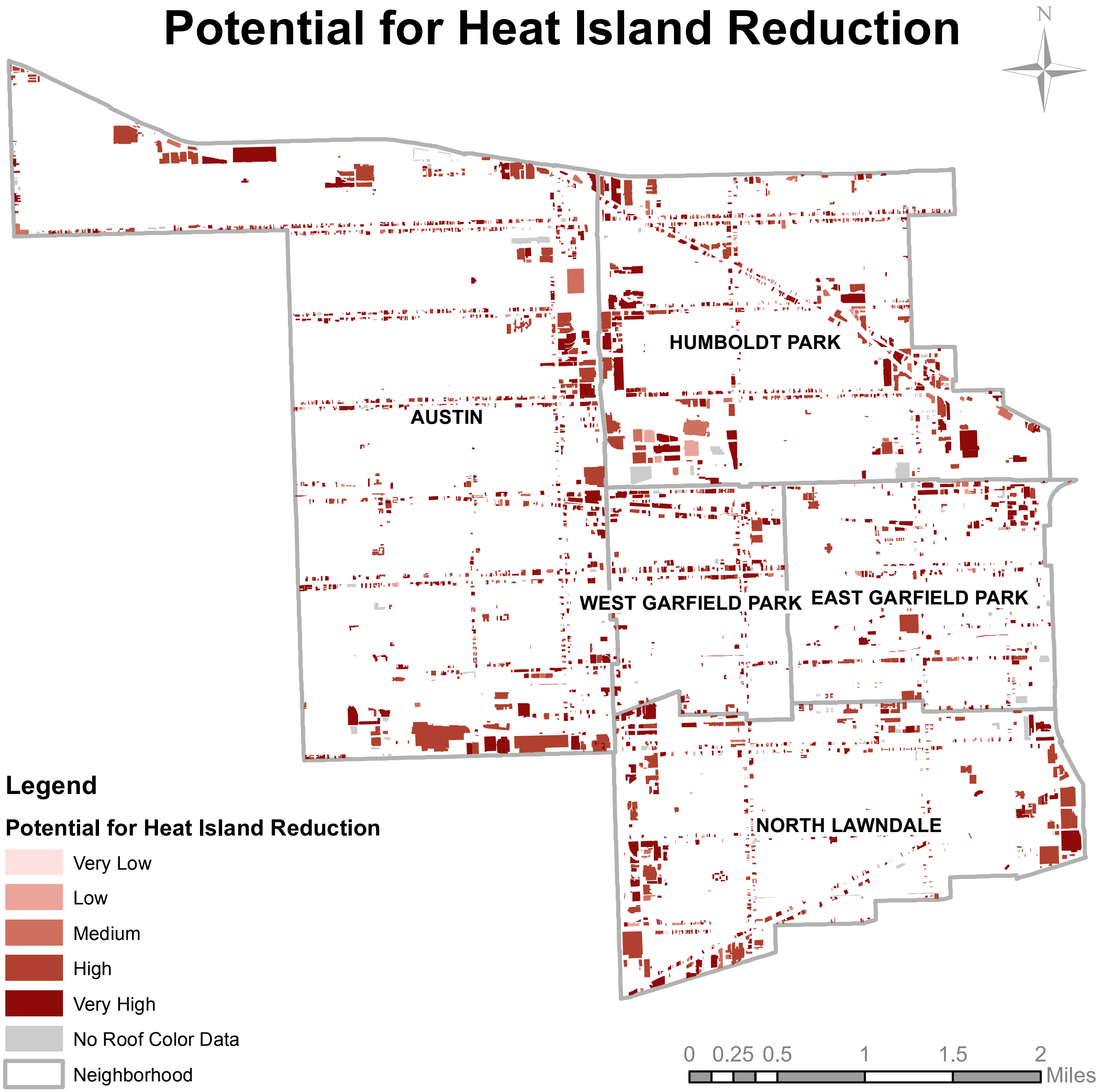
DATA SOURCES
City of Chicago:
Green Roofs, 2012
Community Gardens, 2012
Farmers Markets, 2012
Schools, 2012-2013
Building Footprints, 2012
Community Areas, 2012
Zoning, Nov. 2012

MAP 2

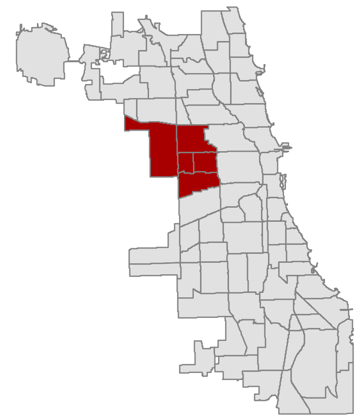
Potential for Heat Island Reduction



Legend

Potential for Heat Island Reduction

- Very Low
- Low
- Medium
- High
- Very High
- No Roof Color Data
- Neighborhood



Reducing the Heat Island

The potential for heat island reduction is calculated by multiplying the surface area of the roof, up to 4,000 square feet*, by the average color of the roof from 0 (white) to 255 (black). The resulting values are divided by quantiles into five categories from very low to very high.

* According to Seattle's P-Patch program, 4,000 square feet is the optimal size for a community garden.

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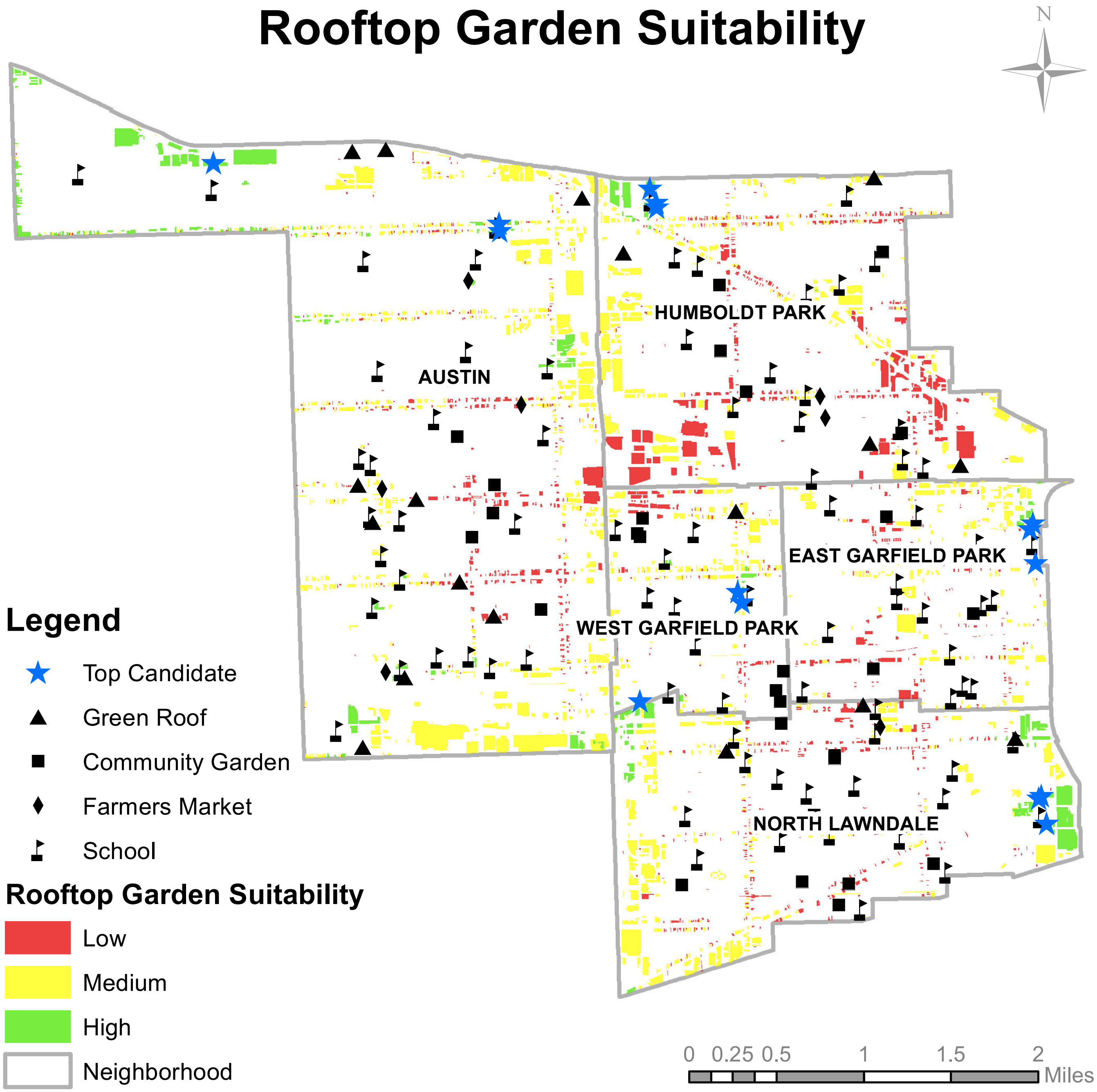
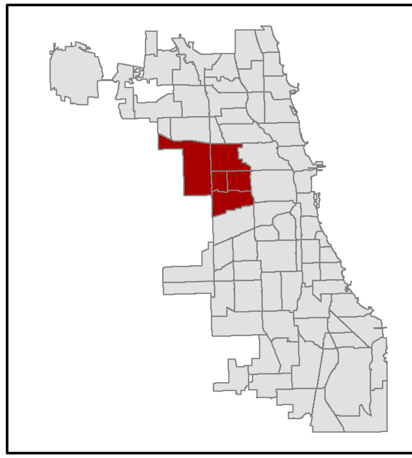
DATA SOURCES

City of Chicago:
  Building Footprints, 2012
  Community Areas, 2012
  Zoning, Nov. 2012
US Geological Survey:
  Digital Orthophoto Quadrangles, 1999

MAP 3

Rooftop Garden Suitability





Determining Suitability

The most suitable buildings for rooftop gardens:

* Are far from community gardens
* Have at least 4,000 square feet of roof area
* Are near schools
* Are far from farmers markets
* Have the potential to reduce the heat island effect
* Are far from existing green roofs

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