# Greening our Building Tops

## A Suitability Analysis on Citywide Vegetated Green Roofs Implementation in Boston

## Introduction

**Why Vegetated Green Roofs?**

Studies have shown that vegetated green roofs are effective in reducing energy consumption of buildings, mitigating urban heat island effect and air pollution. Green covers also control stormwater overflow by increasing water retention with plants and reducing impervious cover. **40% of world-wide energy use** is associated with the construction and maintenance of buildings. Buildings are also responsible for **33% of greenhouse gas emission** globally (Berardi, GhaffaruabHoseini and GhaffarianHoseini 2014). A study on changes in tree cover and impervious cover in the City of Boston found that buildings account for higher percentage of increase in impervious cover amongst all. In the City of Boston, buildings from 2003 and 2008 accounted for **16.7%** increase in impervious cover.

Apart from environmental concerns, existing green roof locations show a disproportionate pattern in which clusters appear in downtown Boston area (Figure 1). While in neighborhoods with diverse social characteristics and higher vulnerability to climate change, do not have a proportional number of green roofs.

In view of this, this analysis develops two vulnerability indexes to prioritize areas in need of more green covers. Buildings with feasible structural capacity for vegetated green roofs are also selected to identify the most applicable sites.


Figure 1. Locations of existing green roofs in Boston

## Methodology

1. Identify buildings feasible for vegetated green roofs
2. Develop fuzzy suitability layers to identify areas with high social and environmental vulnerability
3. Overlay the buildings layer on the suitability layers to show areas and buildings of opportunity

**Ideal structural criteria for vegetated green roofs (Assume building tops are the only places to implement vegetated roofs)**

| | |
|---|---|
| **Roof Slope** | Less than 30 degrees |
| **Building stories** | Less than 15 stories |
| **Roof size** | Greater than 2,000 SF |

**Criteria for areas with high social vulnerability**

- High population of Low to No Income
- High population of Disabled
- High population of Old Adults
- High population of Children
- High population of People of Color
- High population of Low English Proficiency

**Criteria for areas with high environmental vulnerability**

- High Land Temperature
- High % of impervious cover

The **social vulnerability index** used was based on Climate Ready Boston, a report published by the City of Boston on enhancing climate resilience. The index was developed by a quantitative analysis of the relationship between social factors and vulnerability in the context of Boston.

The **environmental vulnerability index** used in this analysis was developed based on the research from the Climate-Smart Cities program. The program has chosen several indicators to identify areas with high vulnerability to climate change. The indicators used in this analysis are directly related to land temperature and impervious cover as green roofs are proven to be effective in tackling these two environmental concerns. **Criteria for buildings suitable for green roofs** is based on a Green Roof Planning Study for the City of Boston published in 2009.

Two **fuzzy suitability overlays** were created based on the environmental and social criteria mentioned above. Fuzzy overlays were used as it addresses inaccuracies when boundaries between classes are not clear. The results from fuzzy overlays give a more accurate and precise situation compared to weighted overlays.

## Results

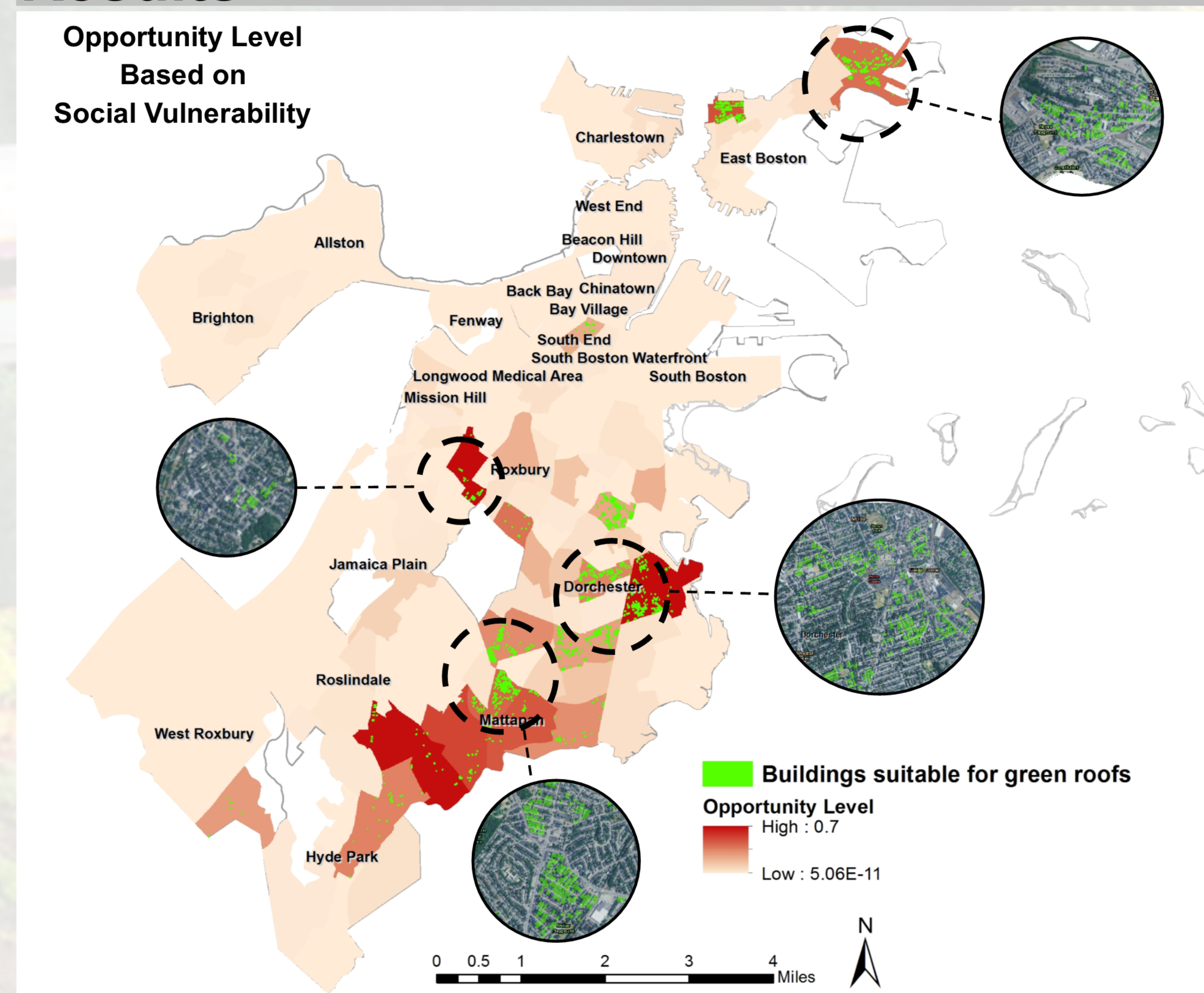


Figure 2. Map showing areas of high social vulnerability

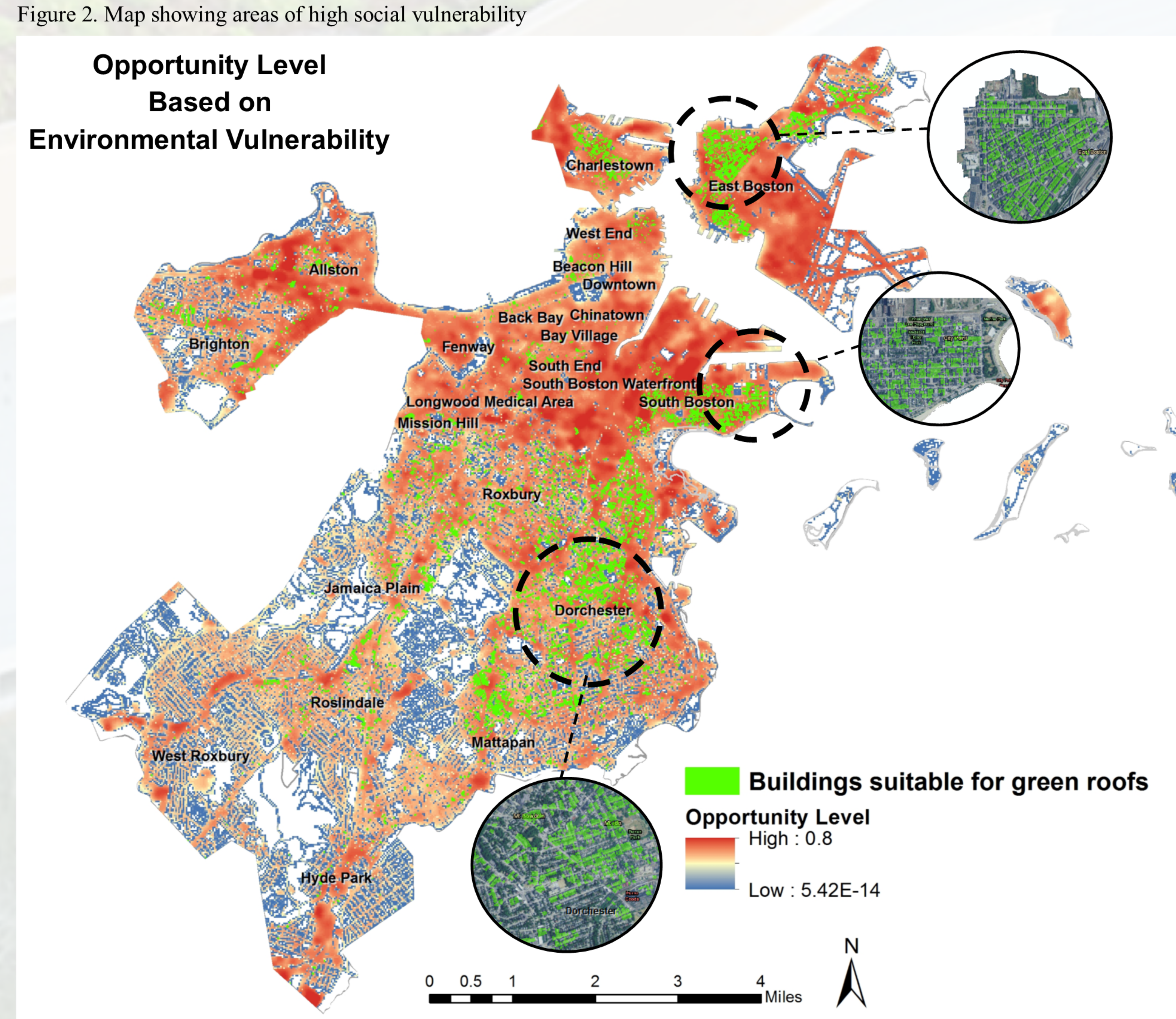


Figure 3. Map showing areas of high environmental vulnerability

We can see a distinction between areas with high social and environmental vulnerability with a few overlapping. According to the social vulnerability map (Figure 2), areas with the highest social vulnerability are located in Roxbury, Dorchester and Mattapan. Areas with the second highest level of social vulnerability is East Boston and the areas bordering Roxbury and Dorchester.

According to both maps (Figure 2 & 3), **East Boston** turns out to be socially and environmentally vulnerable. Unfortunately, if we refer back to Figure 1, there is only one green roof in the area. In terms of social vulnerability, **Dorchester** is the most vulnerable neighborhood.

For environmental vulnerability, area with the highest vulnerability is located in the downtown area and East Boston, meaning that areas with highest land temperature and percentage of impervious surface are located in downtown, Allston and East Boston. This result is not surprising as the downtown area is the most urbanized. Other areas of high environmental vulnerability are scattered around Dorchester.

Regarding priority areas, **East Boston, Dorchester and Mattapan should be prioritized** for green roofs implementation. East Boston and Dorchester are high in both social and environmental vulnerability. Mattapan should be prioritized over South Boston because it is one of the areas with high social vulnerability but currently there is no green roofs around the area.

According to the statistics results, **the total number of buildings suitable for green roofs is 14,515**. The total number of suitable buildings in environmentally sensitive areas is 12,514 while the total number of suitable buildings in socially vulnerable areas is 2,001. In Dorchester, there are a total of 3,165 buildings eligible to implement green roofs. In East Boston, there are total of 1,980 suitable buildings. In Mattapan, there are a total of 331 suitable buildings.

Most of the suitable buildings are multi-family residential buildings. In spite of enhancing resilience on a neighborhood scale, prioritizing multi-family residential buildings could be beneficial to a community in a way that households could reduce overall energy consumption and enhance the longevity of rooftops in the long run as well.

## Conclusion and Limitations

To conclude, this analysis shows us a mismatch of places needed green roofs and places where existing green roofs are located. Also, the total number of suitable buildings suggested that there are plenty of opportunities to implement green roofs in an area-wide or neighborhood scale. The City of Boston should consider using green roof technology to tackle environmental concerns and enhance climate resilience. Different green roof neighborhood plans could be developed according to respective neighborhood characteristics and resources. Incentive programs could also be incorporated to incentivize private implementation of green roofs.

This analysis is based on the assumption that building tops are the only places to develop vegetated green roofs. However, in reality there are other areas in a building that could build vegetated green roofs. There are a lot of examples of vegetated green roofs located at a roof deck of a building. This analysis failed to identify roof decks because such database is not available. If roof decks are taken into account, there would be more opportunities for implementing green roofs in an area-wide scale.

## References


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**Cartographer**: Judy (Ka Lum) Fung

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**Map Projection:** Massachusetts State Plane 2001

**Data source:** MassGIS, City of Boston GIS, greenroofs.com, Apex Green roofs, LiveRoofs, Recover Green Roofs, MAPC, The Trust for Public Land

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