Introduction

Tree cover and greenspaces are a form of green infrastructure that cities have adopted in an attempt to address climate change vulnerability and adaptation (Foster et al. 2011). In this context, the analysis of tree loss has received a great amount of attention (Nowak and Greenfield 2018, 2020; Elmes et al 2017; Rogan et al 2013; Donovan et al 2015) whereas the retention of existing greenspaces and canopy cover has been relatively ignored. The present study addresses this knowledge gap by mapping tree cover loss and retention in the City of Worcester, MA at the neighborhood level between 2010 and 2015 in the context of public vs private land ownership. The evaluation of tree retention separately from tree loss is relevant given that the cooling effects of young, newly planted trees is lesser than that of older, well-established trees. While studies on tree loss focus on evaluating the areas where trees were removed, tree retention focuses on identifying areas where tree presence has been consistent over time and recognizing patterns that might help expand retention to other areas of the analyzed space.

Research Questions and Hypotheses

1. How has tree cover in the City of Worcester changed between 2010 and 2015 by neighborhood in the context of public vs private land ownership? 
   **HYPOTHESIS:** There has been a great amount of tree cover loss in the City of Worcester between 2010 and 2015. The loss has been more pronounced in privately owned land than in publicly owned land, and a higher rate of tree cover retention is evident in publicly owned land.

2. What do the findings of question 1 suggest about tree retention in the City of Worcester and how can they best be used to inform a tree retention ordinance? 
   **HYPOTHESIS:** Tree-wide tree cover retention ordinance should expand tree retention in privately owned land and have strong enforcement mechanisms to ensure the replacement of trees removed.

Study Area: the City of Worcester

The study area is the City of Worcester, in Worcester County, Massachusetts. Worcester is the second largest city in New England with a total area of 99.5 km² and a population of 184,508. Most of the land use change in the city has been from urban forest to low density residential land uses. The City is organized in 38 neighborhoods which are listed on the right side. Their respective numbers are labeled in Figure 1.

Tree Ordinances

Massachusetts has a relatively long history of public shade tree protection. The first ordinance dates back to 1872, Chapter 190 establishes the powers of the tree warden and allows communities to hold elections for this role (MA DCR, 2017). 

City of Worcester Ordinance

In line with this, the City of Worcester adopted Section 28 on the Protection of Public Trees in 2009. Its main focus is the protection of public shade trees from cutting, trimming, or removal in whole or in part without prior written approval of the tree warden. The enforcement of these regulations is performed by the Commissioner of Public Works and Parks through a penalty of $300. However, according to officials of the Worcester Tree Initiative this ordinance is rarely enforced.

Table 1 shows a comparison of tree ordinances in other Massachusetts cities.

Table 1 - Massachusetts Selected Ordinance Comparison

<table>
<thead>
<tr>
<th>Neighborhood</th>
<th>Tree Ordinance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Worcester</td>
<td></td>
</tr>
<tr>
<td>Other Cities</td>
<td></td>
</tr>
</tbody>
</table>

Glossary

- Retention – canopy cover that was present in 2010 and remains unchanged through 2015
- Change – differences in canopy cover between 2010 and 2015
- Loss - canopy cover that was present in 2010 but is no longer present in 2015
- Gain - canopy cover that was not present in 2010 but is present in 2015
- Retention for the studied period of time was 26.26 km². After normalizing the amount of loss and Salisbury Street Area had the highest amount of retention after normalization.

Data

All canopy cover layers used in this analysis exclude conservation areas for greater accuracy in the modeling of change and retention.

To minimize the distortion of the data, all layers were projected to NAD 1983 State Plane Massachusetts FIPS 2003 (Meters)

Table 2 - Data Description Table

<table>
<thead>
<tr>
<th>Dataset / Source</th>
<th>Date</th>
<th>Spatial Resolution</th>
<th>Temporal Resolution</th>
<th>Use in Analysis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tree Canopy Cover</td>
<td>2010-2015</td>
<td>Vector Data</td>
<td>-</td>
<td>Tree cover distribution in 2010 and 2015</td>
</tr>
<tr>
<td>MassGIS Standardized Assessors’ Parcels</td>
<td>2020</td>
<td>Vector Data</td>
<td>-</td>
<td>Distinction between public and private land ownership</td>
</tr>
<tr>
<td>City of Worcester Ownership Data</td>
<td>2020</td>
<td>Excel</td>
<td>-</td>
<td>Distinction between public and private land ownership</td>
</tr>
<tr>
<td>MassGIS Open Space Layer</td>
<td>2020</td>
<td>Vector Data</td>
<td>-</td>
<td>Conservation areas</td>
</tr>
</tbody>
</table>

Results

The canopy cover for 2010 was 34.46 km² and 32.34 km² for 2015, resulting in a change of 2.12 km² made up by 6.08 km² of gain and 8.20 km² of loss. The amount of retention for the studied period of time was 26.26 km². After normalizing the amount of loss and Salisbury Street Area was the neighborhood with the highest retention and Green Island was the neighborhood with the lowest retention. Columbus Park had the highest loss and Great Brook Valley Area had the lowest loss. Finally, Grafton Hill had the highest gain and Green Island had the lowest gain.

Summary

1. Tree cover in the City of Worcester saw a change of 2.12 km², made up by 6.08 km² of gain and 8.20 km² of loss. Most of the loss was seen in privately owned land, with 17.2% of tree cover in 2010 (5.93km²), compared to 2.3% (0.74km²) in publicly owned land, and 4.3% (1.50km²) in ROW areas. However, most of the retention happened also in privately owned land with 58.8% of tree cover in 2010 (20.22km²), compared to 11.2% (3.68km²) in publicly owned land, and 6.27% (2.16km²) in ROW areas. At the neighborhood level, Columbus Park had the highest amount of loss and Salisbury Street Area had the highest amount of retention after normalizing by the area of each neighborhood.

2. The results of this research project indicate that, in order to better protect public shade trees, the City of Worcester needs to re-evaluate its tree retention policy. In addition, a revised version of its current ordinance should consider the expansion of its mandate to protect not only tree cover in Right of Way areas but also in privately owned land (e.g. Springfield’s ordinance).