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Examining Local Climate Zones in the Context of the Urban Heat Island Effect; A case study in Worcester Massachusetts

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Introduction

The Urban Heat Island Effect (UHI) has gained prominence over the years in cities concern of global climate change. One aspect of the UHI that is becoming more apparent is the impact of urban morphology on surface temperature. Specifically, how building height and density interact with the trapping of heat. To study this 17 Local Climate Zones (LCZ) were created (Stewart and Oke, 2012). Now, anyone can create training sites for an urban area and use the Local Climate Zone Generator to classify these zones. This study will examine the local climate zones of Worcester, Massachusetts and delve into their relationship with surface temperature using Landsat-8 imagery. Using these data, the study will be able to investigate the microscale effects of the UHI and look at the intra-urban temperature variation created by the urban morphology of Worcester.

Research Objectives

1. Use local climate zones to examine the microscale effects of the UHI and the intra-urban temperature variation created by the urban morphology of Worcester.
2. Determine which climate zones have the highest surface temperature
3. Use the information about local climate zones to inform where UHI mitigation methods would be the most impactful (ex. White roofs, solar panels, and tree planting)

Examples of landuse types in Worcester

Study Area

Worcester is a dense urban area with relatively high canopy cover for a city of its size. Yet, during the summer months, the Urban Heat Island Effect can become highly pronounced. Heat waves are becoming more common in higher latitudes and the city of Worcester will be continually impacted as will human health.

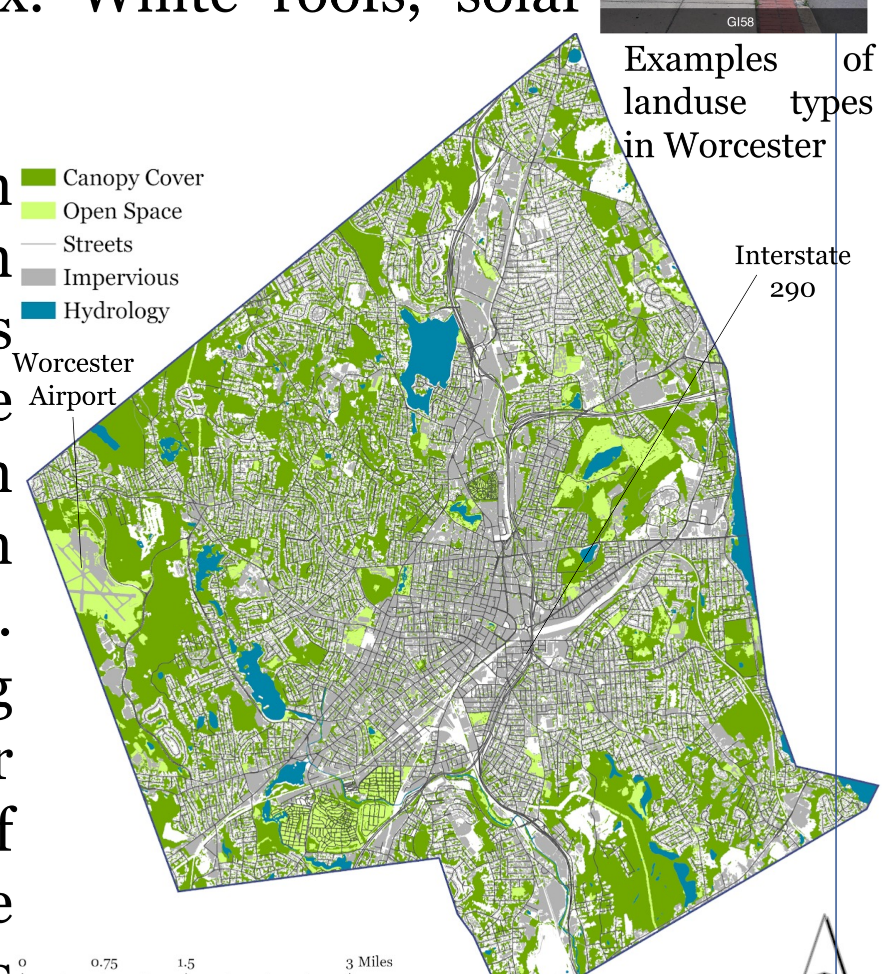


Figure 1: Shows the canopy cover, impervious surface and open areas in Worcester, MA.

This is a comparison of Worcester's triple deckers to a single-family home, approx. 35 feet in height. At one point 50% of Worcester's population resided in them.

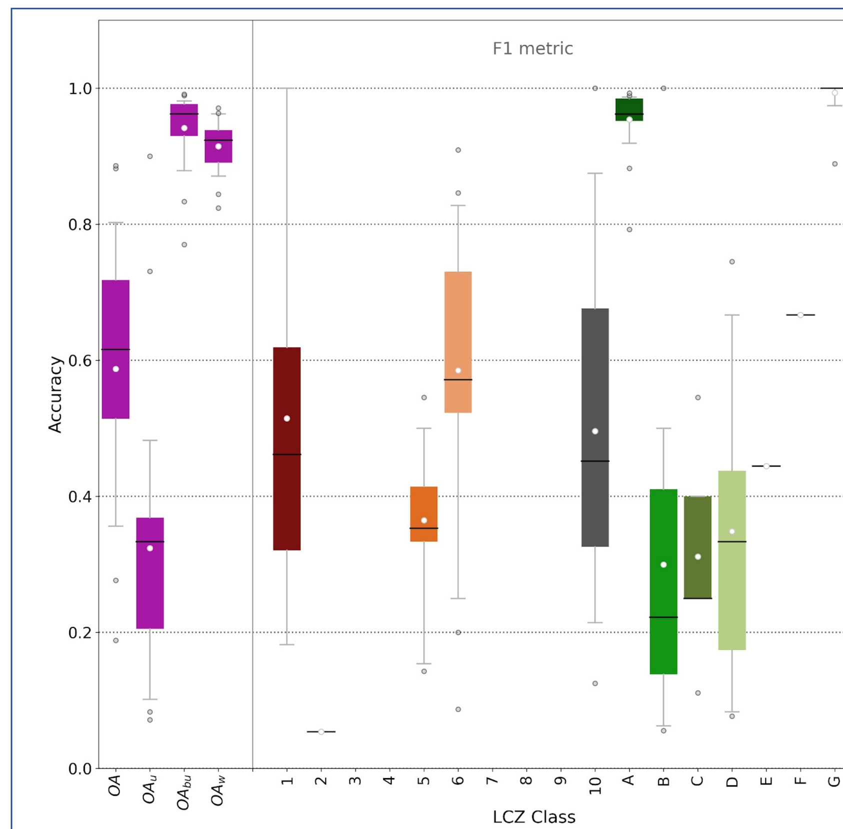


Figure 2: Boxplot of model accuracies from the LCZ's

Methods

For surface temperature I used Landsat-8 data acquired from Google Earth Engine. Worcester hydrology, street centerlines and other shapefiles were acquired from MassGIS. The training areas for the Local Climate Zones Generator were made in Google Earth and the LCZ generator was adapted by WUDAPT. LIDAR data was also used for building height. The boxplot on the left shows the accuracies for the random forest model. OA is the overall accuracy results of all classifications (0.59); OAu is the overall accuracy of all built-up classes (0.32); Oabu is the overall accuracy of built versus natural classes (0.94); Oaw is the weighted accuracy (0.91).

Local Climate Zone and Temperature Analysis

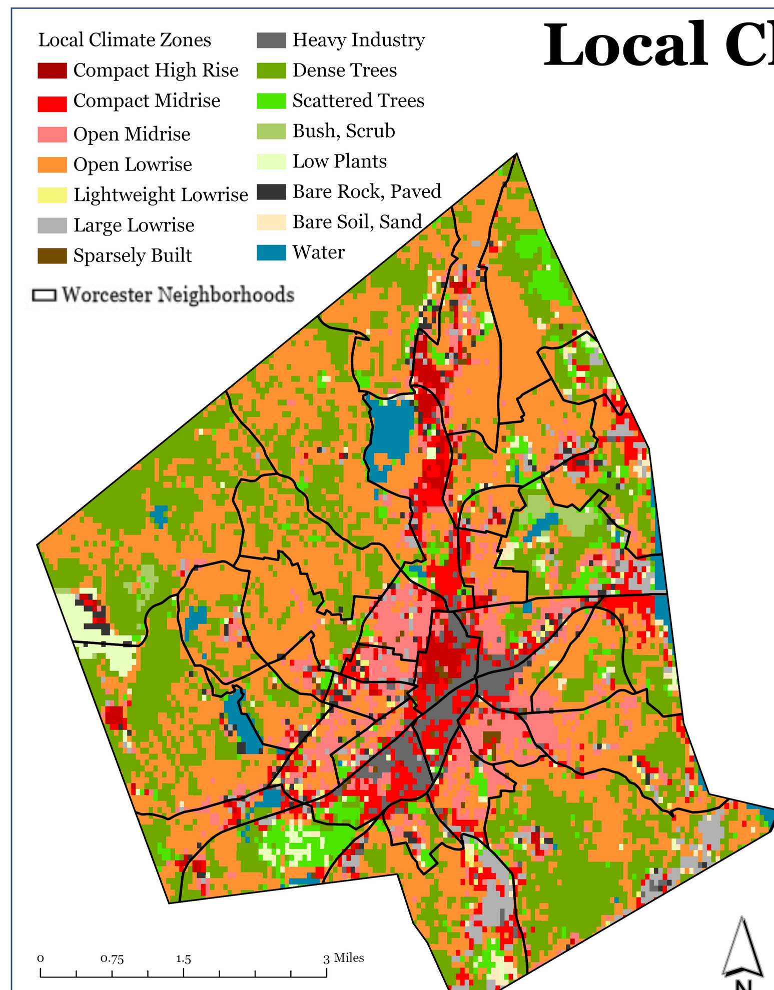
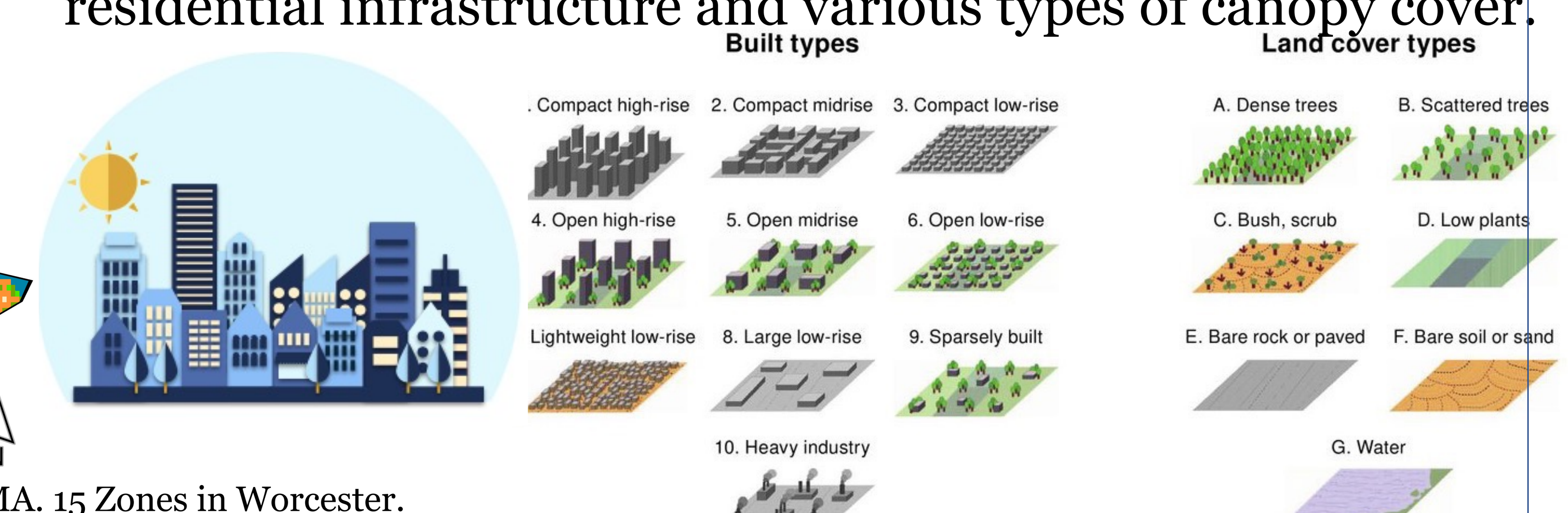


Figure 3: Local Climate Zones of Worcester, MA. 15 Zones in Worcester.

The figure on the left depicts the 15 Local Climate Zones for Worcester, MA. These zones vary from built to nature features and are used to interpret the intra-urban temperature variation associated with the UHI. In the center of Worcester there is lots of compact built infrastructure, while the rest of the city is broken up into more open residential infrastructure and various types of canopy cover.



The Local Climate Zones, separated into built and natural land cover types

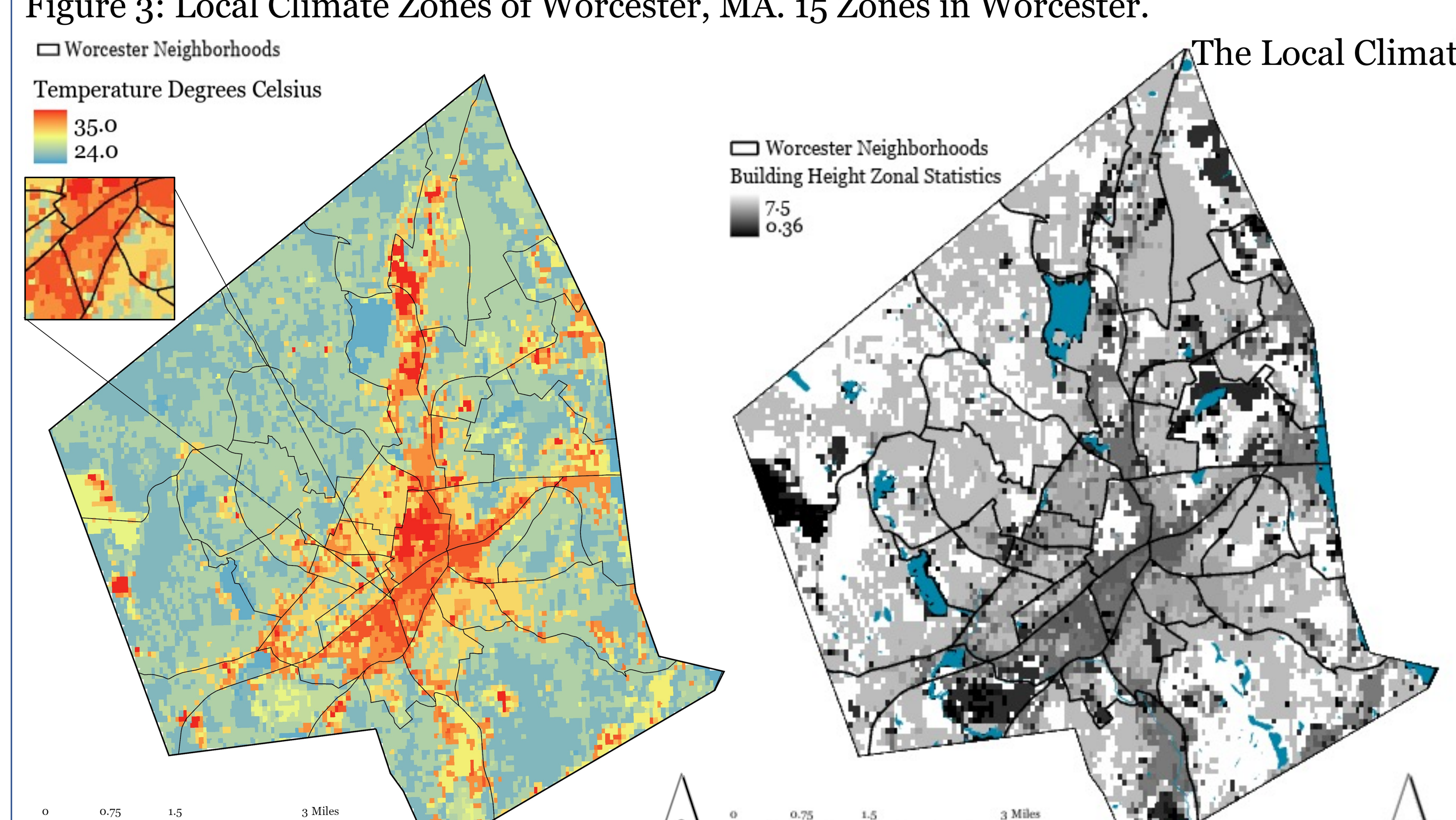


Figure 4 and 5: Zonal Statistics for LCZ's with Surface Temperature, and Building Height

Figures 4 and 5 show the results of zonal statistics using the 15 climate zones of Worcester and a Landsat-8 surface temperature image captured on June 6th, 2020 as well as building height from LIDAR data.. While Green Island and Central Business District have the hottest surface temperature out of all the Worcester neighborhoods. The Central Business District also has the highest buildings in Worcester, according to Huang and Wang 2019, compact buildings obstruct ventilation which induce the trapping of heat and pollutants. This may be why in Figure 6. The compact high rise zone has the highest surface temperature.

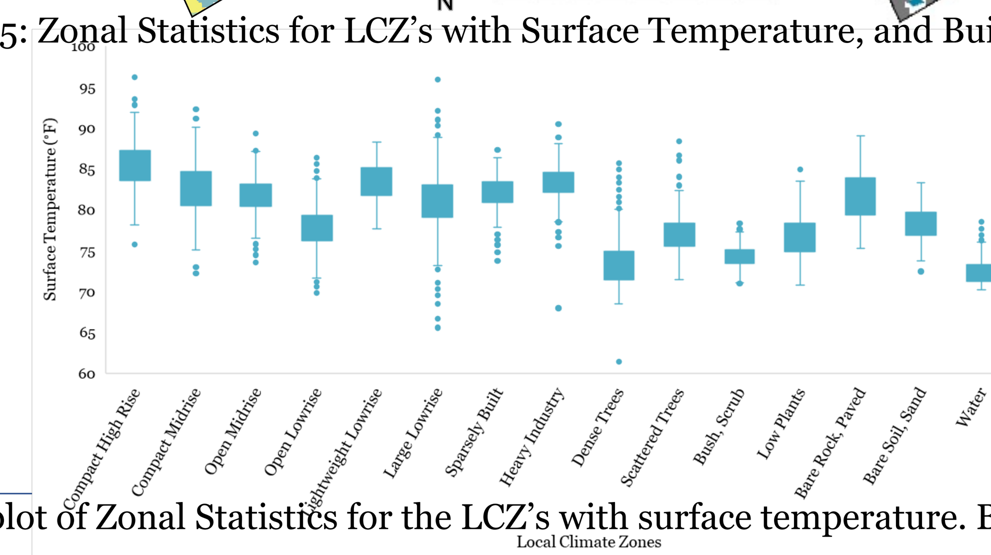


Figure 6: Boxplot of Zonal Statistics for the LCZ's with surface temperature. Built classes on the left and natural landcover classes on the right.

Urban Heat Island Mitigation

White Roof and Solar Panel installation has proven to be effective in increasing the albedo and cooling down urban areas. They have also been known to lower air conditioning bills during the hot summer months. The series of images below show a distribution center in Worcester before and after the installation of a white roof and solar panels. The surface temperature difference from 2010 to 2020 is 33° F cooler. The distribution center is 13.44 Acres.

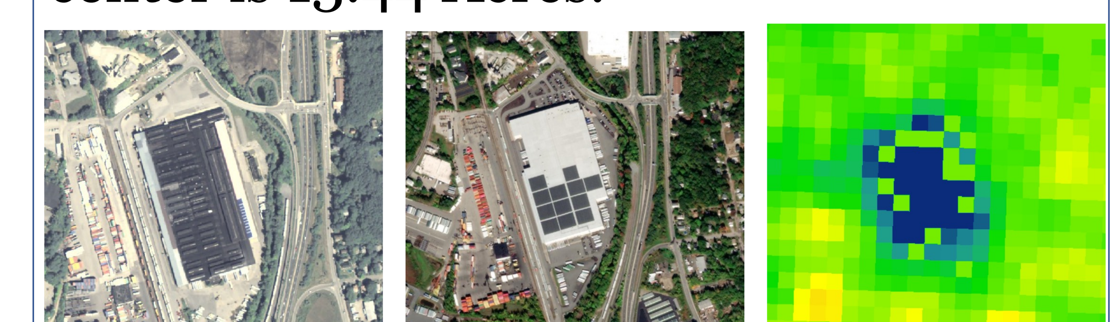


Figure 6: Images show Distribution Center from 2010 and 2020 with Surface Temperature Image Difference

Discussion

As seen in Figure 6, urban morphology can greatly impact surface temperature. The plots on the left side show the built classes, ranging from 86 to 95° F, while on the right are the natural landcover classes, apart from paved surface, these classes range from 76 to 88° F. Water with its properties of latent heat proves to be the coolest climate zone, with dense trees coming in second. The coolest built zone is open lowrise at 86° F. Open lowrise zones are likely to have more private tree cover since the buildings are less dense and single-family homes, versus multi-family homes that are compact with no room for trees. The unique aspect of local climate zones is it allows us to consider building height and density to determine their impacts on the UHI effect. With this analysis we can now determine which areas to target for mitigation efforts. Areas such as the Green Island neighborhood with only 9.2% canopy cover and 71% impervious surface would greatly benefit from white roofs, solar panels, and tree planting programs.

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