Guiding Street Tree Planting to Mitigate Extreme Heat in Worcester

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Sponsored by Worcester Planning Office: Stefanie Covino, Gabrielle Weiss, Brian Pigeon

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Guiding Street Tree Planting to Mitigate Extreme Heat in Worcester

An Interactive Qualifying Project submitted to the Faculty of
WORCESTER POLYTECHNIC INSTITUTE
in partial fulfilment of the requirements for the degree of Bachelor of Science

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ABSTRACT

This report represents work of WPI undergraduate students submitted to the faculty as evidence of a degree requirement. WPI routinely publishes these reports on its web site without editorial or peer review. For more information about the projects program at WPI, see http://www.wpi.edu/Academics/Projects. Our project had the goal of preparing Worcester for increased temperatures given the trend of heat islands to assist the Worcester Planning Office. We used online tools to view streets in Worcester, test community engagement methods, and locate neighborhoods that would most benefit from tree planting. We found that there are many existing trees in Worcester that are too young to provide shade for pedestrians and the trees will require at least 5-10 years before offering suitable cooling effects. In the meantime, we recommend that projects continuing this work interact with community members to implement additional solutions to the heat island issue.

EXECUTIVE SUMMARY

Figure A: Aerial view of Worcester Massachusetts (EpicAerial, 2016)

Climate change has highlighted the importance of planning measures that improve the experience of urban areas. This includes policies and actions for mitigating heat. Heat islands are urban zones that are significantly warmer than surrounding areas due to roads, sidewalks, or buildings made from materials that absorb heat from the sun. Worcester Massachusetts, the second largest city in New England, has recorded temperature variations between these zones to be as much as 16.9 degrees Fahrenheit (Heat Watch Report, 2019). Worcester is invested in reducing the heat island effect by increasing the tree cover in the city. In Figure A, an aerial view of Worcester showcases how there is significant room for improvement in terms of tree coverage.

In August 2008, an infestation of the invasive Asian Long-horned Beetle (ALB) species was discovered in the city's neighborhoods, killing over 35,000 trees. When combined with the effects of climate change such as hazardous weather events, the vulnerability of the treescape becomes even more serious, and diminishes the quality of tree cover in the city. Trees are an excellent way to reduce the effects of climate change as they provide many secondary benefits such as improved property values, shade for pedestrians, and habitats for wildlife. Trees can absorb stormwater runoff, water during a flood, and lower the ambient temperature during heat waves.

Approach

This project was undertaken during the quarantine of 2020, so the method of our project had to be adjusted to be feasible in a remote setting. To collect data, we used creative online strategies to locate specific areas to collect data that would inform our recommendation as to where trees should be planted. We focused on three objectives:

1) Identify heat islands and environmental justice zones
2) Evaluate existing sidewalk and street canopy conditions using remote databases
3) Test options to engage the community in crowdsourced data collection

We used existing heat map data of Worcester and publicly available geographical information for segmenting the city and environmental justice data in OLIVER. Using data and advice gathered through informal interviews with the Worcester Planning Board and WPI faculty Dr. Seth Tuler and Dr. Stephen McCauley, we narrowed down neighborhoods to focus our efforts. We considered areas in the city where people travel, locations that do not cool down throughout the day, and where there is overlap of extreme heat disparities and environmental justice.

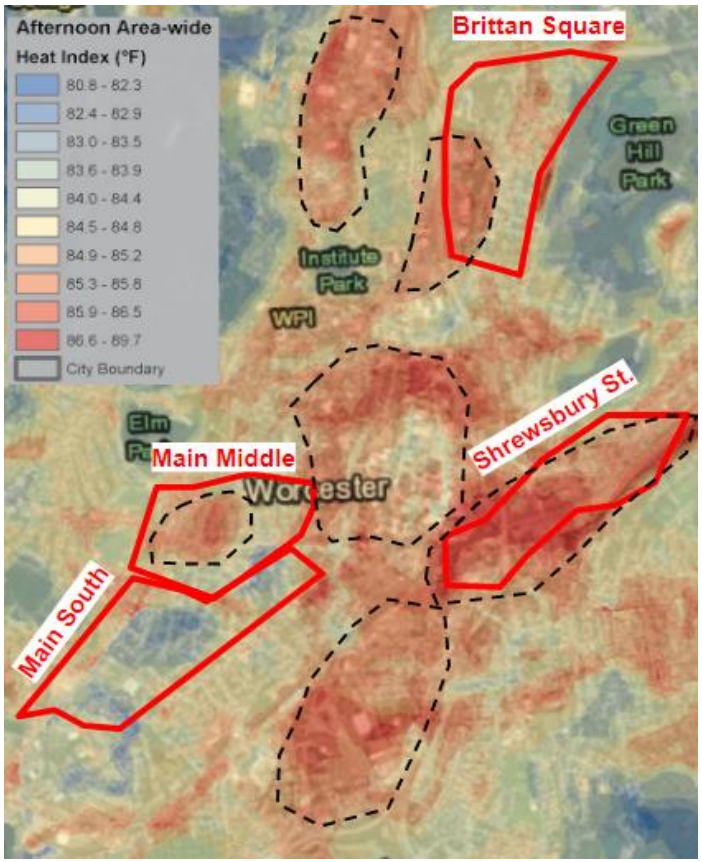


Figure B: Heatmap of Worcester with outlines of selected neighborhoods (CAPA, 2018)

The neighborhoods including Main South, Main Middle, Shrewsbury Street, and Brittan Square provide a snapshot of the current urban canopy state in Worcester, as shown in Figure B. We identified environmental justice neighborhoods using MASS GIS's online mapping tool, OLIVER. We used Google Earth Pro to create a layer of data by pinning street trees and analyzing sidewalks. Trees were analyzed by size and location as shown in the legend and example in Figure C.

Figure C: Tree characterization legend (Google, 2020)

In addition to documenting where trees currently exist, we recorded information to inform where trees could be planted in the future. This included sidewalk width, material, and descriptive factors.

Opportunities for community engagement were highly constrained due to quarantine measures, however we crafted a survey in Google Forms to investigate the perception of the stakeholders of Worcester residents. The outreach for responses promoted the idea of communities bonding together for participatory research in their own neighborhoods.

Results

Brittan Square: Many trees densely line the popular, commercial Lincoln Street. The adjacent residential streets have little cover with sidewalks of mixed materials.

Shrewsbury Street: A large heat island is present in this area most likely due to the MBTA railway nearby and lack of greenery. This commercial area with small businesses and restaurants has greenery islands with young trees that do not offer much shade. This can be seen in Figure D below.

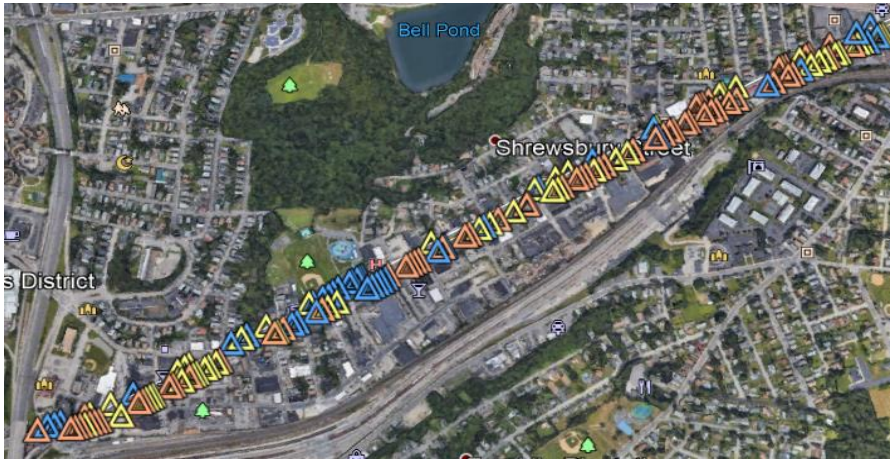


Figure D: Shrewsbury Street Aerial view with pinned street trees (Google Earth, 2020)

Main Middle and Main South: These neighborhoods are enclosed by street with greater vehicle traffic, with the rest being a mix of residential buildings. Many of the street trees in the areas of main roads are small and do not provide shade. For a few blocks there are stretches of no trees despite having wide and good quality sidewalks.

Survey Results: The survey asked Worcester residents their opinions on street tree location and willingness or methods to participate in future research with the city or local organizations. The piloted survey results came back strongly with quite a bit of interest. More than half of the participants were willing to participate in adopting a street tree. Many people had constructive comments with detailed information. If someone were to spend more time collecting data and advertising the survey, there would be an excellent foundation of data to be carried forward.

Further development and conclusions

The lack of an urban canopy appears to be the result of undeveloped trees and large gaps between planted trees. Initial survey results show that all respondents reported too few street trees in their neighborhood and positive responses about the benefits of trees. Many respondents were willing to share street names that they felt needed more urban canopy coverage.

We recommend the City of Worcester create a mailing list of residents interested in continuing this initiative and provide educational material to ensure self-sufficiency with regard to tree care. Since young street trees will require time to develop, relying on alternative cooling methods that could be implemented and used over the next decade would help mitigate the heat island effect. This will be an important step to take as temperatures will continue to rise, and the effects of urban heating are currently unchecked.

Further projects and actions by the city could focus on the aspect of working with local organizations that could get in direct contact with populations most vulnerable to the effects of urban heat. Engagement methods could include tree adoption, projects to promote awareness, and interviews with residents of hot neighborhoods or environmental justice populations.

Our work began during the 2020 coronavirus outbreak and gave us just seven short weeks to conduct this project. Further active data collection could be conducted to map all tree locations in Worcester as this project only focused on a portion of the city. This project will act as a starting point and resource for future work.

ACKNOWLEDGEMENTS

We would like to thank our sponsor, The Worcester Planning Office, particularly Stefanie Covino, Gabrielle Weiss, and Brian Pigeon, for being very supportive and providing invaluable insight for how to approach the project.

We would also like to thank Dr. Stephen McCauley, and Dr. Seth Tuler for their prior work to create a heat map of Worcester, their valuable perspectives on our survey, and their knowledge about community engagement.

Lastly, we would like to thank our advisors Professor Ingrid Shockey, and Professor Uma Kumar for their advice and counseling throughout the project.

AUTHORSHIP

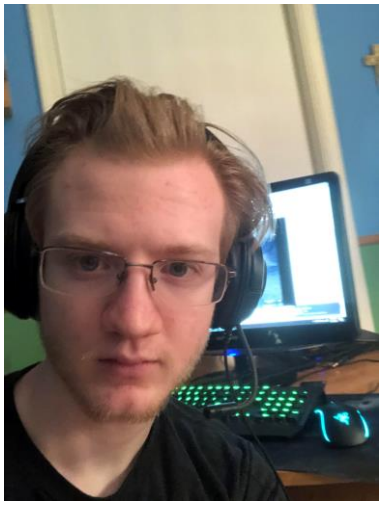
Our entire group contributed to the final report, by each writing sections, and then editing the document as a team. The abstract was written by Phillip Abell and Isaac Abouaf. The acknowledgments and authorship page were written by Isaac Abouaf and the Executive summary was written by David Martindale and Natallie Jesionka.

Hello, my name is Natallie Jesionka. I am studying Mechanical Engineering at WPI. This project has been a great learning experience about the possibilities of what can be accomplished with a little bit of flexibility and internet connection. Originally preparing to study the effects of stubble burning on air quality in northern India, this time of quarantine and travel restriction led our group on a path to help a community closer to home. This project allowed me to learn about how the future of work and school may operate. I also learned to grow comfortable with what resources are available to conduct research, while acknowledging the pitfalls of what this kind of work entails. I learned a lot about remote collaboration, stakeholder analysis, and the importance of street trees!

My name is Isaac Abouaf, and I am studying Robotics Engineering at WPI. This project came as an unexpected turn of events after our IQP to India was cancelled, and it was a drastically different experience to what I was looking forward to. That said, our new project allowed us to help the local community of Worcester and maybe we will be able to see the benefit of our own research in a few years' time as new trees are planted across Worcester. I also learned the power of online tools such as ArcGIS Story maps, Google Earth, and Google Street view which enabled us to not only geolocate trees, but present our findings in a meaningful and visually appealing way. I will be interested to see how things change once the quarantine is lifted, and one day I hope to go to India to experience the culture, landscapes and the food we all spent time learning about.

Hello! I'm Phillip Abell, studying Robotics Engineering at WPI. I am an avid climber both indoors and out, and a skier as well. Of course, I am bummed like the rest of us that we could not travel this term, but hey now I have an excuse to visit Himachal Pradesh next year. I think it's safe to speak for every IQP student this term and say that we were absolutely not prepared for this major shift in our projects. However, I do believe that we made an amazing rebound and adapted to the situation. Many teams bounced back from this adverse situation to create a new work environment to still learn and grow. Though it was hard to do a full length IQP in half the normal time, I still think we learned a lot, especially about how to adapt to crazy new circumstances.

Hello, I'm David Martindale studying Computer Science at WPI. My main interests in my free time are gaming and theater. I was really looking forward to India but I think some advice that I heard before I ever started work on IQP was quite true it's not where you go, or the project you are doing but your team you are doing it with that matters most. I'd love to go to India and have an experience abroad, but I still enjoyed spending time with the people I worked with online.



Contents

Chapter 1: Introduction

As the climate continues to change, heat waves are not only becoming more common but also more intense (Heat Waves and Climate Change, 2020). These extreme heat events can have a serious impact on the city as well as vulnerable residents such as the elderly, individuals with underlying health concerns, and economically disadvantaged neighborhoods that may not have access to air conditioning. Although the central Massachusetts City of Worcester has not historically experienced extreme heat, climate change has already started to bring prolonged heat waves and extreme heat events during the summer months. These events are predicted to become more frequent and intense, leading the city to identify extreme heat and drought as a priority hazard. Consequently, Worcester has formed a plan based on research funded by the Municipal Vulnerability Preparedness (MVP) program to assist them in implementing key climate change resilience adaptations.

Vulnerabilities in urban zones particularly at risk are due to an effect known as heat islands. Heat islands are significantly warmer than surrounding areas (Heat Island Effect, 2020). In Worcester, these recorded temperature variations have been as high as 16.9 degrees Fahrenheit (Heat Watch Report, 2019). Higher temperatures are known to increase health risks, so these pockets could become more dangerous as climate change causes overall temperatures to rise (Heat Waves and Climate Change, 2020). Worcester is invested in reducing the heat island effect by increasing the tree cover in the city. Roads, sidewalks, and buildings are often made from materials that absorb the heat from the sun, which in turn is a contributing factor to the heat island effect. Adding trees and shade gives pedestrians and neighborhoods a better urban canopy and reduces the amount of heat held by roads and sidewalks.

There are numerous considerations to assess before trees can be planted, including prioritizing neighborhoods that would benefit from the program and identifying streetscapes with enough room to support trees. This project was undertaken during the time of quarantine during the COVID 19 pandemic of 2020. Therefore, our data collection was limited to online visualization tools and outreach to assess prioritization and conditions of the sidewalks in Worcester. To meet this goal, our objectives included identifying heat islands and environmental justice zones, evaluating existing sidewalk and street canopy conditions using remote databases, and testing options to engage the community in crowdsourced data collection.

Chapter 2: Literature Review

In this chapter, we outline background information that framed our study. We present research about the heat island effect and how it affects urban populations. We also outline how street trees interact with an urban environment, heat islands, and the city's residents. We begin with some recent history about the urban landscape of the City of Worcester.

2.1 How a beetle changed the landscape of the city

In August 2008, an infestation of the Asian Long-horned Beetle (ALB) was discovered in the city's neighborhoods. The ALB is an invasive species that destroys trees by riddling them with damage. The female beetle lays eggs under the surface of the bark. The hatched beetles then burrow through the tree as they mature, ultimately weakening and often killing the tree.

Figure 1: Before ALB infestation (Law, 2009)

Figure 2: After ALB infestation (Law, 2009)

As Illustrated in the images above, the infestation devastated the tree population of New England and in doing so, dramatically altered neighborhood shade canopies (Moulton, 2018). Streets that had been lined with mature trees were nearly devoid of trees after 2009. The City of Worcester estimated the total loss to be between 35 and 40 thousand trees due to the infestation (Moulton, 2018). The city has been slowly recovering its tree population, but the loss of mature canopy will take decades to replace and regrow.

At the same time as the beetle infestation, the city was in the process of developing a response to climate change, including mapping strategies to encourage adaptation. The loss of trees from ALB greatly reduced an already fragile and aging canopy in the city. When combined with the effects of climate change such as hazardous weather events, the vulnerability of the landscape becomes even dangerous. Among the hazards, prolonged heat waves have become more extreme for residents without a sheltering canopy (Kleinfelder, 2019).

2.2 Mapping existing canopies

In the aftermath of the ALB infestation, the city shows a range in tree cover, including notable zones that did not have many trees to begin with. The existing tree canopy in Worcester varies from neighborhood to neighborhood. An aerial image of the city shows the density of the urban environment – the second largest city in New England. Figure 3 shows how minimal the urban canopy can be in parts of Worcester

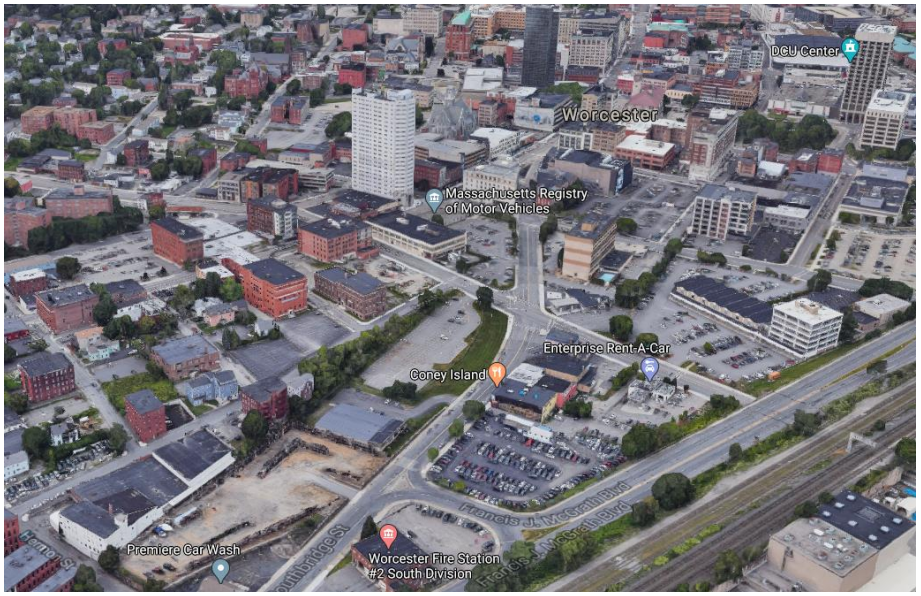


Figure 3: A view of central Worcester showing minimal canopy (Google, 2020)

There are numerous unique streetscapes in Worcester that each have their own story and role. Each street brings its own value to those who use it. Some streets are packed with businesses and restaurants, so those streets play a different role in how a pedestrian experience the city than a residential street, or busy main artery. Our research has sensitized us to these nuances of the urban experience.

2.3 Heating the city: The heat island effect

The City of Worcester Municipal Vulnerability Preparedness Program is one effort meant to improve how Worcester's citizens interact with the city and with each other. The way residents and visitors experience the city is directly shaped by the physical spaces in which they interact (New York City, 2013). The experience of a city engages all senses and correlates with the residents' perceptions of their neighborhood. At one level, trees add visual beauty to the roadside plane and a visual roof to the sidewalks. They create a sense of enclosure and shelter. Adding street trees vastly improve this urban experience, as streets become more inviting, appealing, more comfortable, and reduce the impacts of heat. Trees, however, also mitigate the secondary effects of climate change including stormwater runoff and flooding, and they also lower the ambient temperature during heat waves.

The EPA uses the term Urban Heat Island (UHI) to describe the phenomenon in which air temperature in urban areas is significantly warmer than that of surrounding rural areas. Several factors produce heat islands. There is some disagreement between researchers on how to measure UHI magnitude. Some studies have considered both urban and rural features to characterize UHIs while some have only focused on the city (Martilli, 2020). However, there is strong agreement that built surfaces, such as concrete, asphalt, and bricks, used in the construction of urban areas, absorb more heat during the day than vegetated surfaces and then form a cycle reheating the air which in turn heats up the ground (Armson, 2012). A visual representation of this effect shown in Figure 4, which illustrates the radiant residual heat from buildings that has been measured in cities all over the world (Hostetler, 2019).

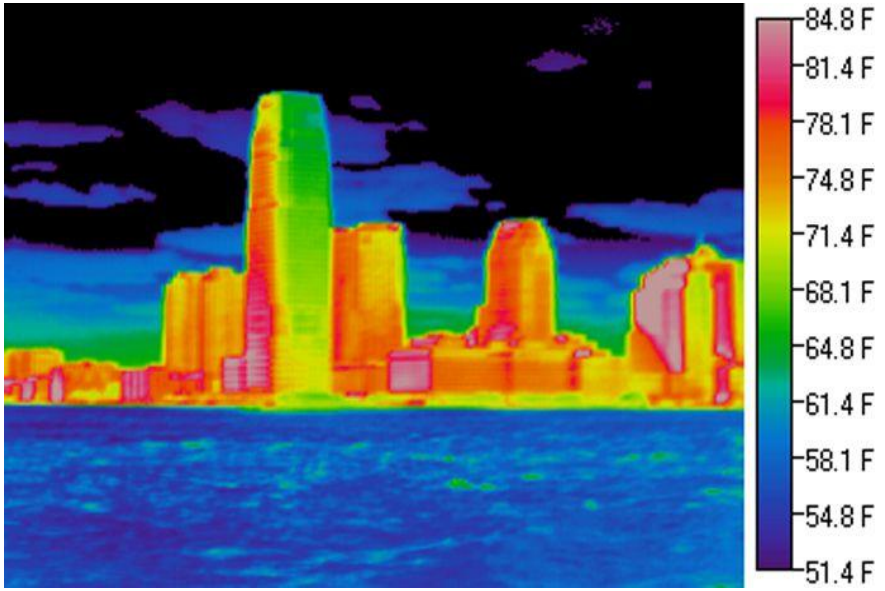


Figure 4: Radiant heat from city surfaces (Ferro, 2013)

Both satellite imagery and ground measurements have been integrated to produce data sets to support the existence of UHIs in Worcester (Hostetler, 2019; Shandas, 2018; CAPA, 2019). A clear view of how Worcester suffers from the UHI effect is shown in Figure 5, where temperature differences of almost 10 degrees Fahrenheit were recorded within a range of less than a mile.

Similar studies have observed uneven temperature in cities with even greater severity (EPA, 2020). From a pedestrian's perspective, this would be a drastic difference in temperature from a comfortable walk on the street to a dangerous heat event. We found it interesting in Figure 5 that the warmest areas coincide with what we intuitively understand as busy areas. Viewing the research done by CAPA provides context to our project. It also gives us intuition on how heat behaves in cities in busy and heavily urbanized areas as you can see in the center of the city in Figure 5.

2.4 Cooling the city: The benefit of trees in an urban area

Fortunately, trees naturally cool the air in a variety of ways. The most well-known and primary effect is they shade sidewalks and roads. This prevents heat trapping by reducing the amount of sunlight hitting the ground and absorbing much less due to their higher albedo. In addition, urban greenspaces enable an effect known as *clotheslining*, which occurs when small areas of tall vegetation are broadsided by wind. Evaporation from trees also provides a cooling effect. Since evaporation is an endothermic process, as water evaporates from trees, heat is also carried away. This is known as the oasis effect and is sometimes harnessed by city planners to combat the heat island effect (Allen, 2004).

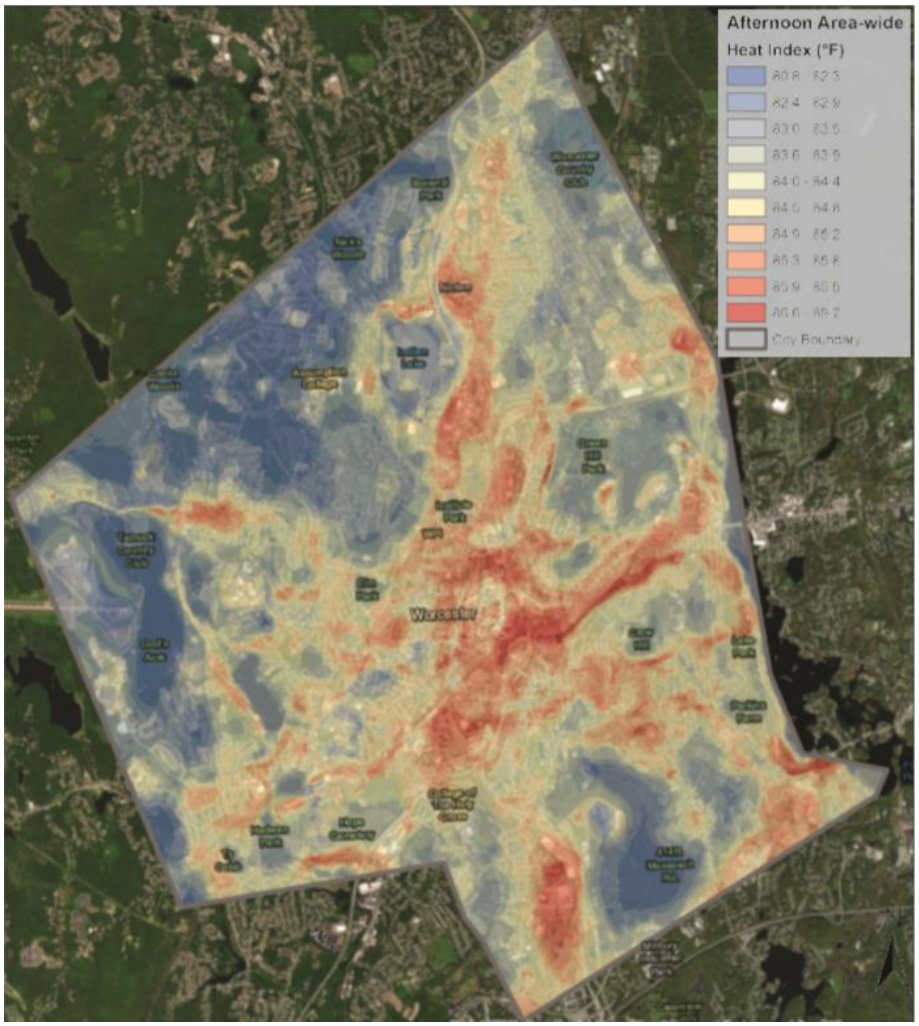


Figure 5: Satellite temperature readings in Worcester Massachusetts, between 3-4 pm (CAPA, 2019)

Cooling the city can have a variety of health benefits for residents. This includes reducing risk of heat stress, heat exhaustion, and heat stroke with symptoms including heavy sweating, weakness, dizziness, visual disturbances, intense thirst, nausea, headache, vomiting,

diarrhea, muscle cramps, breathlessness, palpitations, tingling and numbness of the hands and feet and eventually death if prolonged. However, health effects of heat exposure can also include the weakening of the immune system which especially affects those with preexisting conditions, the young, and the elderly (CCOH, 2020). From a global health and an environmental and social justice point of view, it is suspected that we see increased vulnerability to pandemic events such as COVID-19 in areas with poor air quality and other immuno-compromising qualities (Friedman, 2020).

Trees can save money as well. In a study aptly titled the Energy-Saving Potential of Trees in Chicago this topic was thoroughly researched. On a per-tree basis, the average annual savings could be extrapolated to $20 to $35 dollars for single-family detached homes, about $50 for two-story brick buildings, and $85 for three story brick buildings from just the reduced energy cost of cooling (Nowak, 2017). This reduced energy cost is just one benefit that could help businesses. The affordability of planting trees is a bargain compared with the benefit in the community. Eliminating heat islands can also have indirect economic benefits unreasonably high temperatures may prevent people from walking around the city (CCOH, 2020). Making streets more inviting to pedestrians makes streets more inviting for business.

2.5 Why public participation is important

Planting trees may seem like a positive initiative that helps everyone, but it requires some planning. Trees cool the area they are in, but not the entire city. Therefore, it is important to place them where they can have the most impact. Misplaced trees can adversely affect neighborhoods. They can block signs, make walking paths inconvenient, or affect the value of a home if placed in an unappealing manner. They also may not be desired by the residents. Even though we have shown that there are many benefits, some of those benefits are subjective. Trees also require care and monitoring, which can be greatly improved by those who live there.

2.5.1 Prioritizing environmental justice

Trees placement should benefit the community. By engaging the host community, not only are these issues addressed, but the health of the trees can be more of a partnership. The process of public community engagement is considered a trait of innovative and forward-thinking cities and their advancement. Preliminary steps of data collection about street tree placement can and should include the public. This method of positive feedback encourages feelings of “partners in planning” with the community (Hostetler Science Connected, 2019).

In terms of environmental justice, engaging the community can address inequities that a neighborhood is facing. The uneven distribution of urban canopy has often been found to be a result of numerous socio-economic factors, and therefore ties into the greater

issue of social justice and disparities in access to quality of life (Danford, 2014). Communities suffering from an environmental inequity may not have programming to prioritize improving their immediate environment, as more common daily social and economic struggles are held at a higher priority (Boyd, 2017). Therefore, it is crucial to identify and collaborate with communities to build resilience through a variety of public health approaches.

2.5.2 Collaboration through crowdsourced data

Crowd-sourced data collection has brought new opportunities for participation to communities through social media and apps. Data can now be collected from individuals in the region of interest through means of smart device or internet. When given an avenue to submit information or data, residents can participate in voluntary projects, surveys, experiments, data collection and more. The data can be collected remotely, efficiently, and minimize infringement on personal information. In cities that collaborate in the development and growth process of the city, crowd-sourcing data about issues in the neighborhoods can be extremely beneficial for building partnerships and community interest.

This method has been used around the world and applied in diverse circumstances. For example, in a research experiment about the politics of urban water delivery in India using crowdsourced data, the researchers demonstrated that “people serve as sensors of knowledge which organizations can tap through” (Post, Agnihotri, Hyun, 2018). Similarly, UNICEF monitors real time disease outbreak from healthcare workers, Waze collects traffic condition data from users, Wikipedia is an online crowd-sourced information platform for just about any subject (Post, Agnihotri, and Hyun 2018). Cities and communities are in a constant flow of change. It is a great advantage to have a source of information that can be updated by those who witness the city's progress firsthand. Data collection can be accelerated by reaching out beyond researchers, and by collecting data through a crowdsourced method. Regarding viewing how this could be implemented from a city planning perspective, we found that “citizens use available data and are an increasingly active partner in public sector management. It is therefore meaningful that they participate in data collection as well (Post, 2018)”.

Our project partners have a strong focus on collecting opinions and ideas about street trees and canopy coverage in neighborhoods. By engaging individuals who live in these areas, it is possible to uncover important information from local points of view that those outside the community may not see. However, there are challenges that need to be overcome. Some residents may not have internet, data collection entries may need to be monitored for relevance, and we may only receive feedback from one small section of the city. Understanding the challenges that certain groups face is pivotal to understanding their perspective. This is especially true for issues that potentially affect the daily experience of a significant number of people.

2.6 Summary

In summary, this review identified several important findings that provided a foundation for this study. Street trees interact significantly with an urban environment. They can offset heat islands, and level the pronounced differences in the urban canopy across Worcester. We hope to test the idea of crowdsourcing information from the city's residents to assist with providing a snapshot of the urban canopy coverage.

Figure 6: Elm Park Worcester (Montse Pericot, 2013)

Chapter 3: Methodology

As this project was undertaken during the quarantine of 2020, the goal of our project was to identify and assess a sample of neighborhoods using remote, online, and other creative strategies to map to optimize the best outcome for tree plantings. To achieve this goal, we focused on three objectives:

1) Identify heat islands and environmental justice zones
2) Evaluate existing sidewalk and street canopy conditions using remote databases
3) Test options to engage the community in crowdsourced data collection

Our strategies for data collection are outlined below in greater detail.

3.1 Identify heat islands and environmental justice zones

We took a methodical and analytical approach to viewing the entire City of Worcester to narrow our focus. Dr. Stephen McCauley assisted us with creating a filter for the city to identify four key locations where there appeared to be the steepest temperature gradients for our investigation. We used existing heat map data of Worcester, publicly available geographical information for segmenting the city, and environmental justice data. We prioritized areas that had evidence of heat islands, as well as environmental justice populations.

To inform our environmental justice zones, we used census data and environmental justice data from OLIVER, which is the Massachusetts online and publicly available GIS platform. Since the City of Worcester is most concerned with eliminating prevalent instances of the heat island effect and protecting the city's most vulnerable populations, we opted to identify communities where these two criteria overlapped.

3.2 Evaluate existing sidewalk and street canopy using online databases

Due to the nature of the project in a time of quarantine, our team collected data remotely. We relied on recently archived data, Google Street View, and GIS records that had been collected in 2019 (CAPA, 2019). Using 360-degree views of Worcester streets in Google Maps and Street View, we conducted site assessments of the condition of streets, sidewalks, and trees uploaded in the last two years as shown below in Figure 7.

Figure 7: Street View of arbitrary street (Google, 2020)

We used this information to assess each street, respective sidewalk, and nearby trees to develop evaluation questions found in Appendix A. The street-view observations specifically enabled us to identify if streets in areas of interest could easily accept new trees and to identify needed details for the resident engagement objective. We viewed streets in areas that fit our criteria described in objective 2. To satisfy the Planning Office's goals, we located the street trees on all the main streets. We took screenshots of each street in the prescribed areas to produce a holistic understanding of those areas.

3.3 Test options to engage the community in crowdsourced data collection

With greater focus from data established in objectives 1 and 2, we researched practices to engage the community in a "citizen science" based method for data collection. We developed and piloted an online survey to ask residents to report local tree planting preferences and to ask if they would be willing to assist projects in the city in the future.

We used online surveys to reach out to residents given restrictions in place during the mass quarantine. Surveyed residents were asked about existing street trees, their preferences for tree planting, and their willingness to participate in citizen science uploads about sidewalk conditions for tree planting, and a few additional data points suggested by the City Planners. The surveys were advertised using digital posters including a link and additional information, as seen in Appendix A. The outreach for responses promoted the idea of communities bonding together for participatory research in their own neighborhoods. We also suggested that the City of Worcester would have a better idea of where to improve the tree canopy, to support the idea from our literature review that "more sustainable qualities of urban environment are achieved by direct involvement of the local territorial communities into programming, planning, constructing, managing and further modifying the elements of the landscape system" (Jakaitis, 2011).

The online survey was created using Google Forms, an online platform for creating surveys and viewing response analytics. Sample questions, formatting, and the distribution list can be viewed in Appendix A. The survey was distributed through social media and email lists leveraged from contacts at WPI and in Worcester list-servs.

Not only did the survey provide information on the perception of street trees, and urban heat, but the survey results informed us of participant perception of further willingness to participate in projects in the future.

Figure 8: Generic residential street with street trees, not in Worcester (EllenB, 2009)

Chapter 4: Results and Discussion

This chapter presents results of our research and analysis of existing heat and environmental justice data, data collected on street assessment, and the results of our community engagement strategy followed by a discussion of our data.

4.1 Identifying heat islands and environmental justice zones

Our discussions with the Planning Board and heat island researchers enabled us to narrow the scope of our project to a selection of neighborhoods. We interviewed the authors of the 2019 Worcester Heat Watch Report by CAPA and consulted with experts associated with the City of Worcester planning to identify areas of focus.

The "Heat Watch Report" for Worcester through CAPA Strategies was conducted with the help of Dr. Seth Tuler and Dr. Stephen McCauley who both have experience in environmental studies of this nature. We broadened our approach to the experience of the city: for example, where many people in the city stand, walk, or travel to bus stops. We also considered if, and how much, targeted sites cool down throughout the day and into the next morning. A methodological approach to pinpointing overlap of extreme heat disparities, environmental justice populations, and areas with increased foot traffic was discussed with Dr. McCauley in particular. We determined that the afternoon temperature map is the best choice because the sun is at its peak and most people are affected. This approach was used in conjunction with existing heat and environmental justice maps, to identify neighborhood areas of Main Middle, Main South, Shrewsbury Street, and Brittan Square, which are represented below in Figures 9 and 10. Figure 9 displays an overview map of the online GIS tool OLIVER with the environmental justice layer selected over Worcester, while Figure 10 displays heat map data. Both figures have outlines of the neighborhoods of interest.

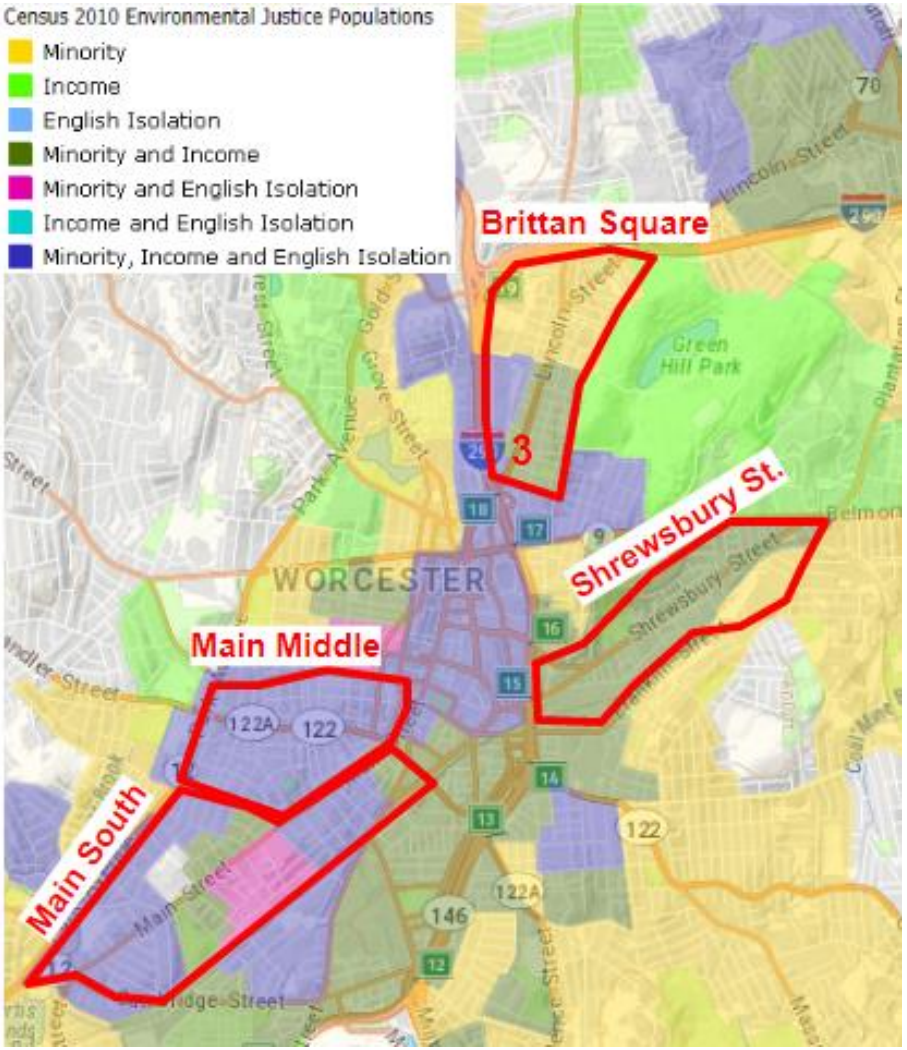


Figure 9: Environmental justice neighborhood (OLIVER, 2010)

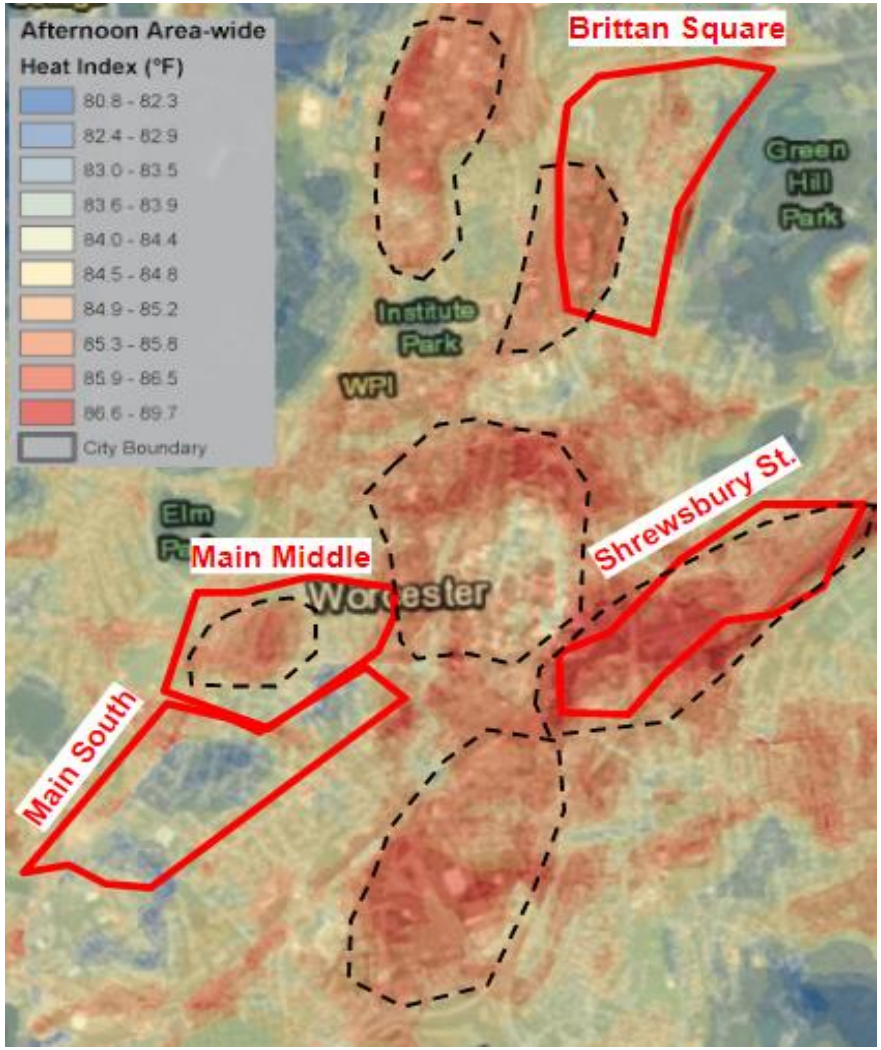


Figure 10: Heat map with overlay of environmental justice neighborhoods locations (CAPA Strategies, 2019)

These areas of interest were chosen from a variety of reasons including the heat data, environmental justice data from OLIVER, and outside research. Figure 8 on the right includes black dotted outlines

of hot areas of interest from the initial run-through of the heat map data. The legend in Figure 11 demonstrates the reason for selecting neighborhoods in high environmental justice areas shown with purple coverage. The variety within the locations we chose provides a good snapshot of the current urban canopy state.

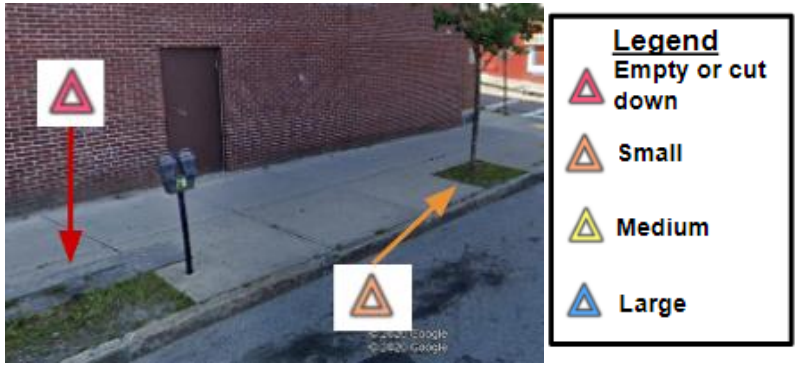


Figure 11: Example of street tree characterization

Once we identified the areas of focus, we experimented with a variety of online tools for street viewing, including ArcGIS, "My Maps" on Google, online GIS, and Google Earth. Google Earth Pro was found to be the most versatile tool to use for this scenario. We created a layer of data by pinning street trees and analyzing sidewalks. Pins of existing trees were color coded based on simple estimated metrics, as seen in Figure 11.

We also added notes for each tree, describing how the tree was situated. For example, we documented sites as: "Gravel in a traffic island," "In a pit," and "Grass area on edge of sidewalk." We also recorded information to inform where trees could be planted in the future. We recorded if sidewalks were on neither, one, or both sides of the street. We also recorded the width and material of the sidewalk for each street. This was information we were guided to collect by the Planning Office.

4.2 Identify existing sidewalk and canopy conditions

The sidewalk and tree data for Brittan Square, Shrewsbury Street, Main Middle, and Main South were collected using existing databases consisting of street-view, and satellite view imagery. We noted down important descriptions about the sidewalk and surrounding areas with regards to the feasibility of planting trees. Sidewalk data has been stored in a spreadsheet which can be searched and filtered for future use.

Brittan Square

Lincoln Street is the main artery that runs through the center of Brittan Square. This street is constructed with wide sidewalks and hosts popular public destinations such as stores, restaurants, and other businesses. We found many trees densely lining this street. Figure 12 below, a picture of Lincoln Street that captures the general sidewalk and canopy condition.

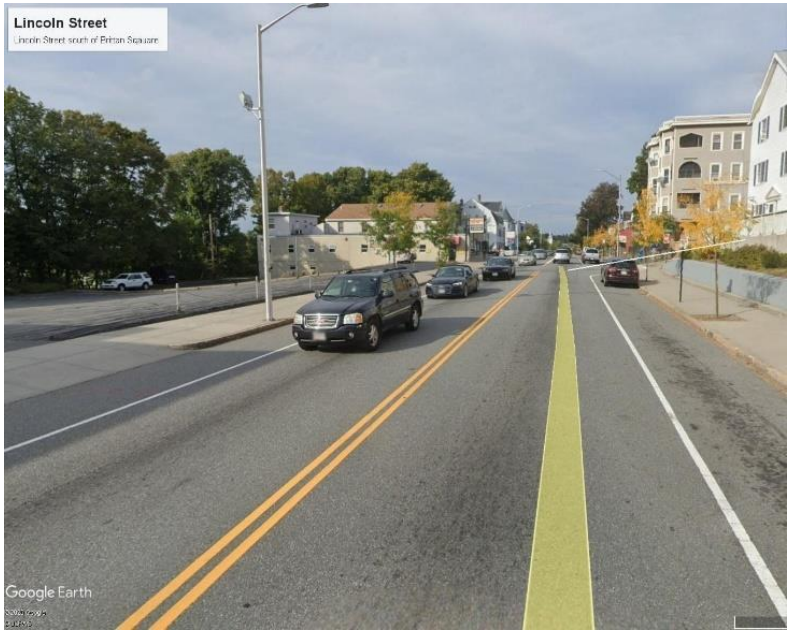


Figure 12: Lincoln Street using street view (Google, 2020)

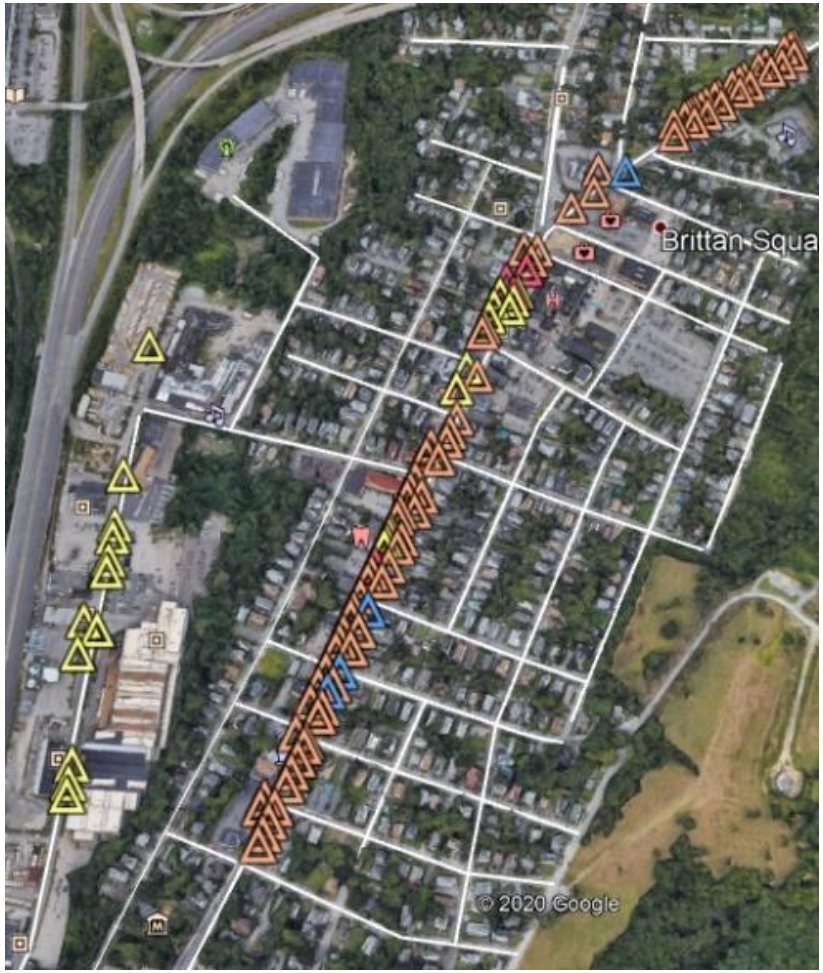


Figure 13: Lincoln Street satellite view (Google, 2020)

The adjacent residential streets, in general and shown in Figure 13, have little to no tree cover, with mostly 5-7-foot sidewalks of mixed materials. Many of these streets do not have much offset between the sidewalk and residential buildings. Scattered lawns and road verges are prevalent throughout the neighborhood. Figure 14 shows what most residential streets in Brittan Square look like. Orne Street is an

accurate model for how many of the residential streets are configured. The sidewalks are ~6 feet and are usually paved. There are some lawns on either side of the street with a few scattered street trees. There are no businesses or pedestrian destinations as these streets are purely residential minus the main streets in the center.

Shrewsbury Street

This long stretch in Worcester is characterized by a significant heat island as shown Figure 10. The heat island appears to follow the shape of the MBTA railway, potentially indicating the large area of cement, train tracks, and lack of greenery might contribute to the heat island in this area. Figure 16 below displays the trees on Shrewsbury St, which is running diagonally from bottom left to the top right of the image. The figure also shows the large industrial area as well as the railway on the right side of Shrewsbury Street

Figure 14: Orne Street, Brittan Square (Google, 2020)

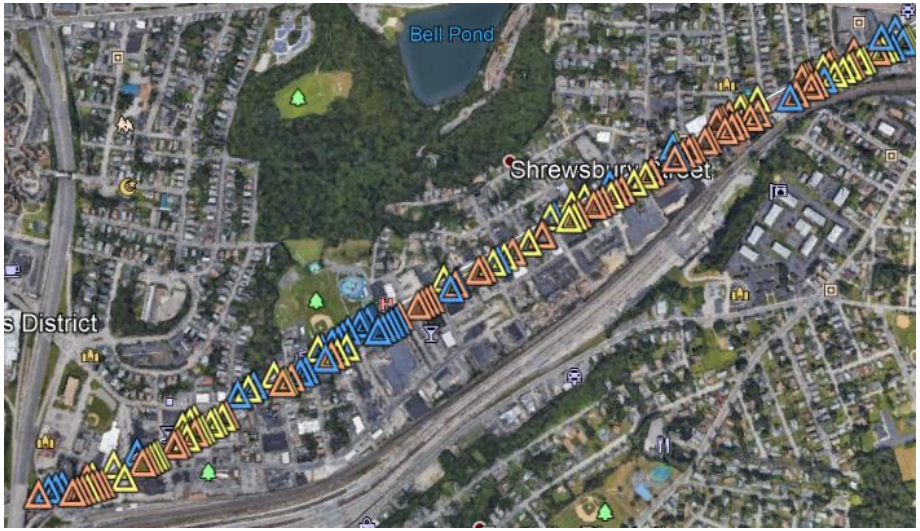


Figure 15: Shrewsbury Street aerial view with pinned street trees (Google Earth, 2020)

Figure 16: Shrewsbury Street commercial area (Google Maps, 2020)

A reason for interest in this location is since Shrewsbury Street is a commercial area where many small businesses such as restaurants, markets, diners and consulting firms depend on customers driving or walking through the area of which an overview can been seen in Figure 15. Figure 16 above is a view of Shrewsbury Street showcasing the commercial nature of the location. One important takeaway from this street view is that many of the trees pinned in the Aerial view prove to be in an early stage of development, offering little to no shade for pedestrians.

Main South

South of main middle, main south has the main streets of Park Ave on its left and Main Street down its center. It was mostly chosen as a location due to it mostly being a minority, income, and English isolation area as well as recommendations from The Worcester City Planners as the heat data did not look critical. Generally, despite the cool temperatures on the heat map it also lacked street trees for long stretches of road. This however is most likely due to the many areas of trees that were not necessarily on the sidewalks but planted on the grass.

Main Middle

This neighborhood is enclosed by streets with greater vehicle traffic, with downtown Worcester being one of the sides. Inside the area, a few roads that may be considered as main roads run through, with the rest being residential buildings including houses and multifamily homes of various situations. It is a diverse mix of walkable neighborhoods, main roads, downtown district, and more. The entire location is in a minority, income, and English isolation area, shown as a purple environmental justice zone previously in Figure 9. The high percentage of an environmental justice population here was a main factor for focusing on this area. An overview of this neighborhood is seen in Figure 18 as a map of the Google data, and Figure 17 from the heat map.

Figure 17: Heatmap of data of Main Middle (CAPA, 2019)

Figure 18: An approximate heat map shown with tree pins

Going up the left side of this area is Park Avenue consisting of a wide street with multiple lanes in areas, wide sidewalk, and businesses lining the sides. All street trees in this area are small, and do not provide much coverage, an example in Figure 19. Heat concentration in this area will most likely decrease in coming years when the trees grow. For a few blocks outside of this lower left area, there are little to no trees, for example Dewey Street which has good quality sidewalks made from asphalt and enough room for more trees.

Figure 19: Small trees line hot Park Avenue (Google, 2020)

As seen in Figure 17 from the heat data, a hot bubble is prevalent in the middle of this neighborhood. Mirroring this data, when marking area points of where street trees are located, there are a great deal less trees on the inner part of the neighborhood then on the edges, where more popular roads are. An example is seen in Figure 19.

Even though it may appear that some places do not have street trees, this may be overshadowed by the fact that private property lining the street has a lot of green area. For example, a neighborhood could be bustling with foliage but technically not have any trees lining the street, and therefore no trees would appear in our data. Figure 20 shows Alden street, which does not have sidewalks and therefore no streets. This street may appear as treeless in our data, but it is clearly well shaded with plenty of tree cover and greenery.

Figure 20: Green area of Alden Street (Google, 2020)

The useful information pertaining to our research not only encompasses where trees currently are or are not, but also areas where it makes sense to plant. Even though this street does not have official street trees, as seen in Figure 20, it would not make sense to plant in areas like this because the trees can be better used where there is little to no canopy coverage overall. Further research into the sidewalks or Middle Main will assist in framing the overall recommendation of prioritizing areas din need of trees.

4.3 Building a community engagement strategy

This project was challenged by the quarantine months of the COVID19 outbreak of 2020. Our opportunities for community engagement to collaborate with data collection were highly constrained. To offset that, we created a survey that could be sent to community

organizations and nonprofits. In collaboration with members of the Worcester Planning Office, we created a survey to collect information that we could not get in person. We have developed a method to remotely collect data about streets and tree pits, so we did not need to ask questions about that in our survey. To create a broader foundation for future research to stand on, we aimed to learn about the public perception of urban heat, trees, and public perception. The data we have collected, and the time we have spent becoming familiar with the status of the streets in Worcester ultimately aided how we recommend interfacing with the Worcester community in the future. Expert interviews, communication with our sponsoring agency, and the street data we have collected all contribute to our understanding on community engagement. Understanding what areas are important to the public provides more context to planning where new trees will go.

The survey asked Worcester residents their opinions on street tree location and willingness or methods to participate in future research with the city or local organizations. The piloted survey results came back strongly with quite a bit of interest. In the week we ran the survey we had over 80 responses. More than half of the participants were willing to participate in adopting a street tree. Many people had constructive comments with detailed information. With continued support to analyze responses and advertise the survey, the results could be used to better engage with the community by taking advantage of its willingness to help.

As of the time of this report, we analyzed the early results of this survey, with the intention that the survey will continue to run. This will provide the Worcester Planning Office, Dr. Steve McCauley, and Dr. Seth Tuler ongoing data on Worcester residents. Based on the 88 survey responses we analyzed, over 92% of respondents stated they liked street trees for their visual appeal as well as the added benefit that they keep sidewalks cooler. Additionally, we found that 77.5% of respondents perceive their neighborhood has having too few trees, as shown in Figure 21 below.

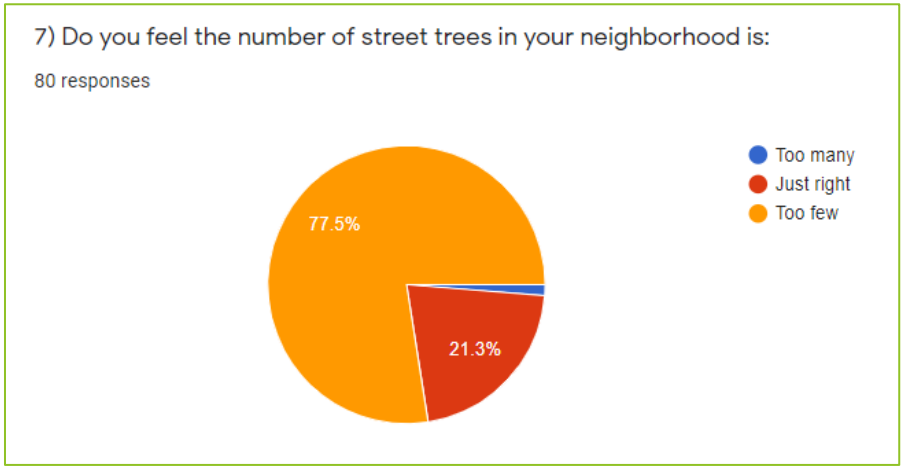


Figure 21: Question 7 responses.

This result indicates there is a significant desire by community members for newly planted street trees which shows that people are also invested in this issue. In fact, we found that 83.5% respondents were willing to adopt planted trees by watering them and taking care of them, which can be seen in Figure 22 below.

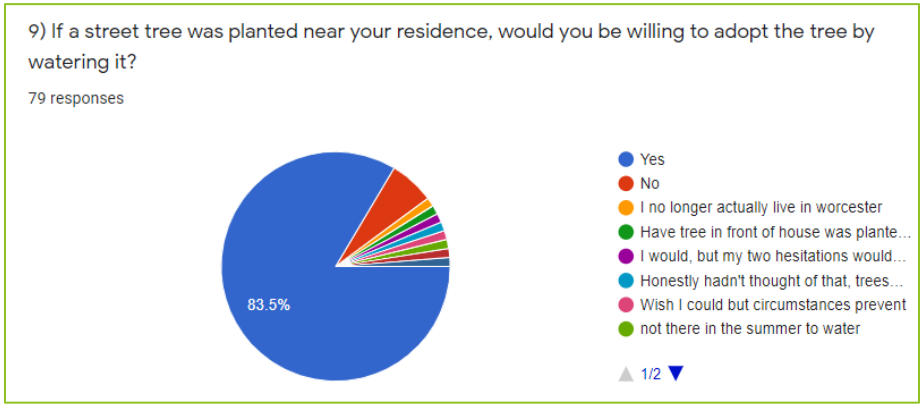


Figure 22: Question 9 responses

This result shows how willing residents of Worcester would be to help maintain the urban canopy. Only 6.3% respondents responded "No" to adopting trees, with 10.2% of respondents providing understandable hesitation or concerns for why they may need more information or assistance to adopt trees. Below is a quote from a respondent who highlighted a concern they have.

> "I would, but one of my hesitations would be that the water bill could be expensive - it'd be nice to have some incentive, even a small one."

In general, we found that people wrote similar concerns, mentioning the monetary cost of water as well as the cost of time and effort required to maintain a tree. Additionally, we found that respondents were eager and willing to help gather future information for the city, with 77% of respondents indicating that they would answer surveys, 57.9% of respondents were willing to upload photos to a website or app, and 40.8% of respondents were willing to participate in online forums. Lastly, 26.3% of respondents would be interested in attending city council or planning meetings. We also found that there is strong support for new parks, playgrounds with trees, shaded bus stops, and most of all, rooftop gardens, to which 77.5% of respondents were in favor as can be seen in Figure 23 below.

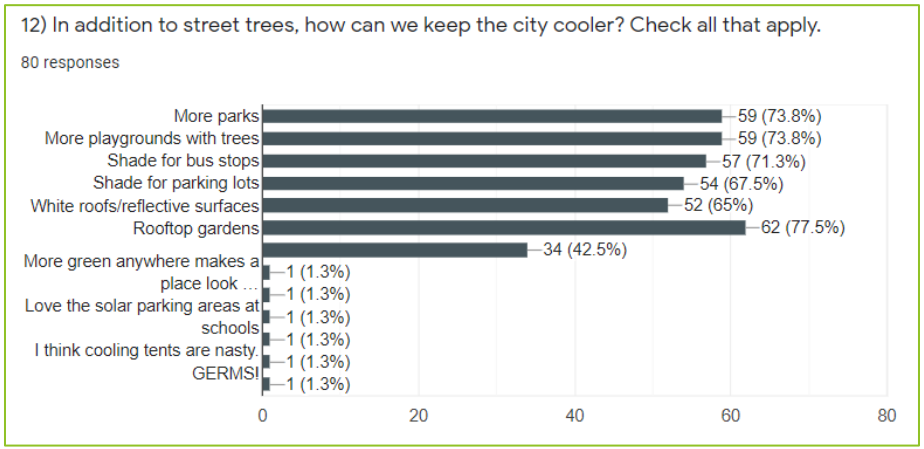


Figure 23: Question 12 responses

Overall, the survey was marked as a success given the quick and impressive response rate, and we were pleasantly surprised to see how willing and eager respondents were to get involved and help make Worcester a greener city. We believe this survey showcases that it would be worthwhile for the city to use residents as a valuable

resource to complete some of the tasks that the city does not have enough resources to handle.

4.4 Discussion of collected data and results

Part of this project was to develop a virtual system of data collection. However, this approach has the caveat that it requires a non-trivial amount of expertise using GIS. Due to project constraints, we did not have time to learn this tool before we needed to begin collecting our data, however despite some pros and cons of that process, the option is still a viable solution for data collection. It was also helpful to think of where it is not easy to put trees, as this information helps with understanding the limits of urban canopy coverage. We also thought of how trees and communities will adapt to each other as time passes, and how vulnerable populations such as the elderly, sick, and young react to the environment around them.

Among the difficulties in a virtual assessment process, we found that collecting street and tree data carries with it logistical and technical challenges. Developing a creative and effective workflow to efficiently build our data set proved to be more difficult than collecting the data. The biggest problem was to find a way to organize, store, and display the data we collect. After many rounds of trial-and-error, learning new tools, and consulting with our Worcester city collaborators, we decided to use Google Earth to view the existing street images and place tree markers, a simple spreadsheet to record our findings, and QGIS, an open-source GIS platform, to then compile all of the data of trees and streets of the various neighborhoods into a publicly available and searchable database which can be viewed or analyzed using any GIS or Google Earth platform. This option allowed for synchronous work on different tasks in a simple way. After we adopted this method, we could collect and archive data. This enabled us to create a table of information for each street in a format such as shown below in Figure 24.

Figure 24: Empty street data table example

Among the opportunities from using these visualization tools, was that we could see some predictive indicators. The heat island neighborhoods had at least one main street that was lined with businesses, wide sidewalks to invite foot traffic, and very little tree

canopy. This supports our findings so far that zones with few green spaces or urban canopy could produce heat islands. Surprisingly, we found that in Brittan Square, Shrewsbury Street, and Main Middle, major streets did in fact have planted street trees, despite the heat data suggesting otherwise. We expected that these areas would not have any trees or greenery, which would explain why these areas develop heat islands. The remote view proved that these trees are young and are not yet large enough to provide shade or noticeable cooling effects. The trees are placed in tree pits in an adequate density at an estimated 50 feet apart on many of the main roads we researched. Though trees could be planted in between existing trees to create a denser canopy, this would not solve the existing problem as the planted trees will also be too small to provide short term benefits. We do not know what species of tree is planted along these trees so we cannot form an accurate prediction as to how large these young trees can become. Given that the trees grow to a moderate size to give shade, if this study were repeated in 10 years with no streetscape improvement, the same areas would be measurably cooler, and the canopy would be significantly developed.

We ran the survey right through the end of our project. We received positive feedback on the survey from those that we distributed the survey too. We were successful in creating an engaging survey that would complement our map data. Since the survey ran after we completed our project, we did not analyze the data. However, we created a digital poster that can continue to be a foundation for this work as seen in Appendix B. We sent the survey with the intention that it would be continued by the Worcester city planners or other projects.

Chapter 5: Recommendations and Conclusion

Pinpointing which factors, if any, are correlated to tree cover in Worcester, and discovering if those areas contain substantial heat islands, has contributed to our recommendation on what areas need streetscape improvement. Equally, this research has informed our recommendation to the City of Worcester on effective strategies to work with the population and present our findings in a meaningful and impactful way.

Care for new trees

We recommend that the City of Worcester or other local organizations create stewardship opportunities with residents for street trees in busy areas, specifically in Main Middle where several trees have evidently died or been removed. Using the survey that we piloted to connect to neighborhoods, create an electronic or traditional mailing list of interested groups. Using educational material created by the Worcester Tree Initiative, provide options for Worcester residents to plant and care for trees. This would help trees reach a point of self-sufficiency and large enough to provide significant shade. This could also mean collaboration with the Worcester Tree Initiative to use the street tree data collected from this project, as well as working with the community.

Additional cooling strategies

Since young street trees will require time to develop, relying on alternative cooling methods that could be implemented and used over the next decade would help mitigate the heat island effect. This will be an important step to take as temperatures will continue to rise, and the effects of urban heating are currently unchecked. Unfortunately, green spaces that have an impact on temperature take time to grow. Cities around the world have been implementing innovative ways to combat urban heating. Rooftop gardens can usually be retroactively installed on existing buildings that provide similar cooling effects to trees. A more expensive strategy would be to paint rooftops and streets with light-colored paint to reflect heat as opposed to absorbing it (Oldfield, 2018). We strongly recommend reaching out to the community with our proposed survey to collect new ideas and understand which strategies would be most beneficial to the community while current trees grow.

Additional observations

During our research, we noticed that many of the hottest heat islands followed the paths of wide roads with a great deal of traffic. Additionally, now that much of the world is in quarantine, it raises an interesting question of whether there will be incentives to allow employees to work from home, permanently if they wish. It is difficult to say what exactly will change due to the extended time in quarantine, but it may be possible to use this moment in time to shape the future in a positive way. People that work from home would

reduce the number of commuters on the roads, leading to fewer vehicle emissions as well.

Recommendations for further research

Our work began during the 2020 coronavirus outbreak and gave us just seven short weeks to conduct this project. These two factors put limitations on what we could accomplish, and we wish to suggest additional directions that can be explored to continue what we have started. We were not able to test many methods of community outreach due to limited social interaction mandates. Follow-on projects and actions by the city could focus on the aspect of working with local organizations that could get in direct contact with populations most vulnerable to the effects of urban heat. These strategies of community engagement could also be assessed in terms of effectiveness and lead to a better understanding of how members of the Worcester community best engage with the city. Engagement methods could include tree adoption, projects to promote awareness, and interviews with residents of hot neighborhoods or environmental justice populations.

Since we spent a large portion of our time developing tools for data acquisition and organization, further active data collection could be conducted to map tree locations in Worcester as this project only focused on a portion of the city. Additionally, to create a complete dataset, all neighborhoods including the neighborhoods we focused on could benefit from the mapping of all trees, not just street trees. This data would provide a more accurate understanding of what areas could most benefit from tree planting.

We recommend that our survey and its data be used in the future. The survey data at the time of the completion of this project, has not been analyzed. Coding of the survey results would add more context to our project as well as add another layer of data that includes public perception. It will be important to understand how receptive the Worcester community is to improve its streetscape.

Conclusion

We hope that the data we collected will be useful to the City of Worcester but hope most of all that this project will act as a starting point and resource for future work. The lessons we learned and information we gathered could make it easier for students or community volunteers to feel oriented, and have an excellent foundation for creative solutions. We are thankful for the support of our professors and the amicable nature of our sponsors. To all readers, stay aware of how impactful trees are to our planet and get involved in your local community to make a difference in issues like this one.

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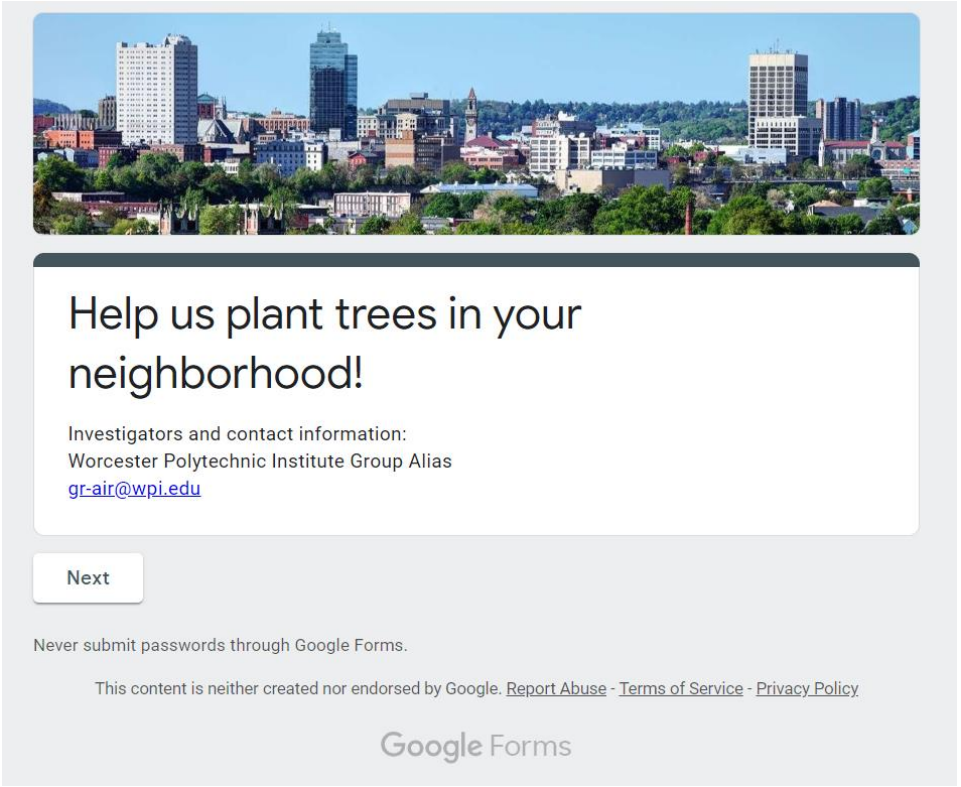
Appendix A: Street Tree Survey

Poster attached to emails and social media posts to encourage responses for the online survey leveraging crowdsourcing of and public opinion



Help us plant trees in your neighborhood!

Consent Agreement for our survey:

Who we are: We are a team of students from WPI collaborating with the City of Worcester to understand urban heat and trees.

Purpose: Your answers will help inform where trees may potentially be planted in the city. Your answers are non-identifying.

Procedures to be followed: This survey will ask you to reflect on your opinions and experiences with the heat during warmer months in Worcester as well as your willingness to see more trees planted on sidewalks. Your participation in this research is voluntary.

Confidentiality: Any publication or presentation of the data will not be used to identify you.

Back Next

Help us plant trees in your neighborhood!

This survey will help the city manage heat islands.

What are heat islands?

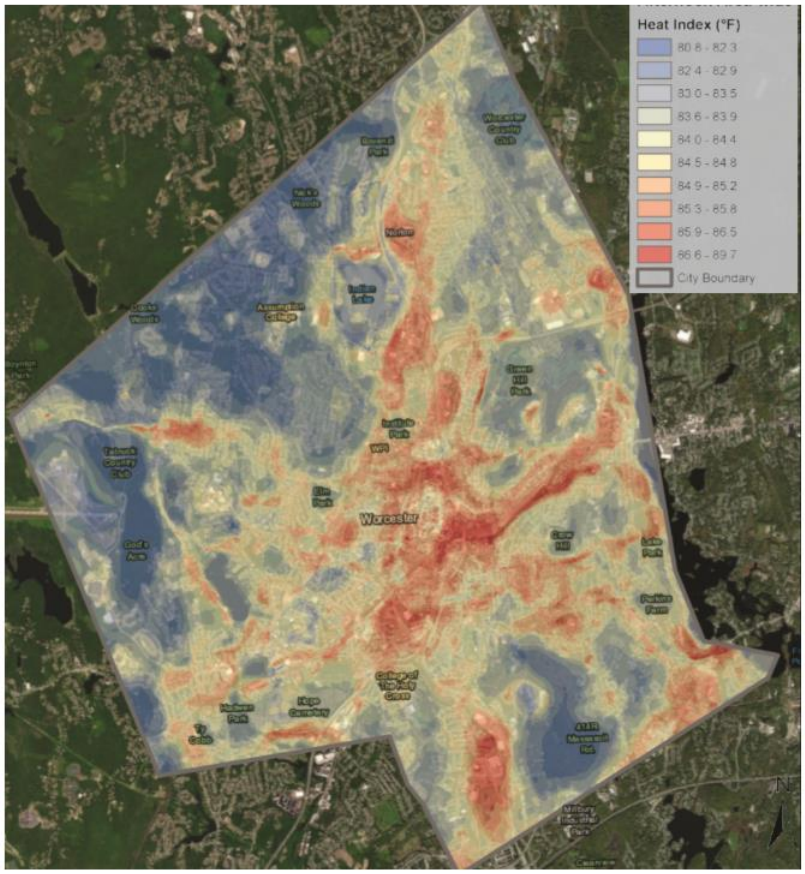
Cities can become over 10° F warmer than surrounding rural areas in the summer. This is known as the urban heat island effect, and has been observed in Worcester. It is caused by concrete and asphalt absorbing heat directly from the sun.

How do heat islands affect us?

High heat can have adverse mental and physical health effects on people and pets. Trees help mitigate the heat island effect and provide shade as well as social, emotional, and economic benefits.

Heat map data for the City of Worcester

Below you can view the heat map of Worcester, which highlights the coolest areas of the city in blue, and the hottest areas in dark red.



Back Next

Help us plant trees in your neighborhood!

Is Worcester too hot?

1) How much time do you spend outside in Worcester every day during the Summer?

- ◯ 0-10 minutes
- ◯ 10-30 minutes
- ◯ 30 minutes - 1 hour
- ◯ 1-3 hours
- ◯ 3+ hours

2) Has heat in Worcester ever affected an aspect of your daily life? Check all that apply.

- [ ] Yes, I didn't go somewhere because it was too hot outside.
- [ ] Yes, I have had to go to a cool building or shaded area.
- [ ] Yes, I avoided exercising outdoors due to the heat.
- [ ] No, there is enough shade where I live to go outside without getting too hot.
- [ ] No, it is not too hot in the summer.
- [ ] No, I tend to stay in air conditioned areas anyways.
- [ ] Other: _____

Back Next

Help us plant trees in your neighborhood!

Where should we focus our efforts?

3) Which of the following best describes you? Choose all that apply.

- [ ] I live in Worcester
- [ ] I work in Worcester
- [ ] I go to school in Worcester
- [ ] Other: _____

4) How often do you walk outside in Worcester during the summer?

- ◯ Every day for at least a mile
- ◯ Every day for less than a mile
- ◯ A few times per week
- ◯ Rarely
- ◯ Never

5) If you feel comfortable, please provide your zip-code below: This information will be used to understand which areas of Worcester we are receiving responses from. This will not be used to identify you.

Your answer

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Help us plant trees in your neighborhood!

How do you envision your street?

6) Do you like street trees? Check all that apply.

- ☐ Yes, they are nice to look at.
- ☐ Yes, they help keep the sidewalks cooler.
- ☐ Yes, they provide wildlife habitat.
- ☐ No, they litter the sidewalk with leaves and branches.
- ☐ No, they do not look nice.
- ☐ No, they get in the way.
- ☐ Other:

7) Do you feel the number of street trees in your neighborhood is:

- ○ Too many
- ○ Just right
- ○ Too few

8) Can you help us identify streets or neighborhoods in Worcester that you think need more trees? Please list them here:

Your answer

9) If a street tree was planted near your residence, would you be willing to adopt the tree by watering it?

- ○ Yes
- ○ No
- ○ Other: _____

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Help us plant trees in your neighborhood!

Want to get involved?

10) Would you be interested in collecting information for the city?

Citizen scientists can help collect data, analyze results, and solve problems about their own neighborhoods.

- ○ Yes
- ○ No
- ○ Other: _____

11) In what ways would you be willing to help? Check all that apply.

- ☐ None
- ☐ Uploading photos to a website or app
- ☐ Answering surveys
- ☐ Participating in online forums
- ☐ Attending City Council, Planning, or other public meetings
- ☐ Other: _____

12) In addition to street trees, how can we keep the city cooler? Check all that apply.

☐ More parks

☐ More playgrounds with trees

☐ Shade for bus stops

☐ Shade for parking lots

☐ White roofs/reflective surfaces

☐ Rooftop gardens

☐ Other:

☐ Cooling Stations (Publicly available places with air conditioning or water cooling)

13) What other thoughts or comments do you have? We would love to have your feedback!

Your answer

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Help us plant trees in your neighborhood!

Thank you for your time!

You can see the final project by emailing a request to our contact information or by using keywords in the search at https://digitalcommons.wpi.edu/iqp/

For any questions you may have about street trees, feel free to reach out to planning@worcesterma.gov
For any questions related to urban heat islands in Worcester, please contact mccauley@wpi.edu

We look forward to a cooler, greener city!

Appendix B: Poster Deliverable