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Greening the Gateway Cities: Summer Internship with the Clark University Human Environment Regional Observatory (HERO) and Massachusetts Department of Conservation and Recreation (DCR)

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A Master's Paper

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And accepted on the recommendation of

John Rogan, Academic Advisor

ABSTRACT

Greening the Gateway Cities:

Summer Internship with the Clark University Human-Environment Regional Observatory (HERO) and Massachusetts Department of Conservation and Recreation (DCR)

Zhiwen Zhu

This report provides a detailed account of my internship experience with the Clark University Human-Environment Regional Observatory (HERO) and Massachusetts Department of Conservation and Recreation (DCR) in the summer of 2017. This internship concerns the urban tree health assessment in three ‘Greening the Gateway’ cities in Massachusetts. During the internship, I conducted tree survey field work, database management, mapping, tree survey data analysis and urban tree plantation benefits microclimate simulation. During the internship I worked with the professors and students at Clark University and University of Massachusetts, Amherst, and the staff from Department of Conservation and Recreation (DCR), Worcester Tree Initiative (WTI) and U.S. Department of Agriculture. This internship was a very valuable and beneficial experience for me. From the work performed through the internship, I was able to better understand the importance of teamwork, learn how GIS could be applied in urban forestry, learn new geospatial database management skills, and learn new skills of microclimate

simulation using ENVI-met. I believe what I have learned from the internship prepared me for my future career in GIScience. I will bring the knowledge and skills learned in this internship to my future jobs, and further improve my GIS knowledge and skills of collaborating with others.

John Rogan, Ph.D.

Academic Advisor

ACADEMIC HISTORY

Name: Zhiwen Zhu **Date**: December 2017

Baccalaureate Degree: Bachelor of Engineering in Remote Sensing Science and Technology

Source: Wuhan University **Date:** June, 2008

Other degrees, with dates and sources:

Master Degree: Cartography and Geographic Information System

Source: Graduate University of Chinese Academy of Sciences **Date:** July, 2011

Occupation and Academic Connection since date of baccalaureate degree:

Project Assistant, Wildlife Conservation Society China Program, Beijing, China, October 2012 – May 2014

DEDICATION

I dedicate this final paper to my parents, wife, daughter and brother, who have offered their continued support and guidance throughout my study at Clark University.

ACKNOWLEDGEMENTS

My deepest gratitude and thank you to Prof. Rogan, Prof. Martin, Prof. Bebbington, Prof. Eastman, Mathew Cahill, Arthur Elms, Marc Healy, the HERO students, and my classmates at Clark University. To Prof. Rogan, thank you for continued advice, help and support. Without your support, I wouldn't be able to finish my master's studies at Clark University. To Prof. Martin, thank you for your help and guidance in the HERO program and my study at Clark University. To Prof. Bebbington, thank you for your support and help for me during my studies. To Prof. Eastman, thank you for your teaching and help for me. I learnt lots of GIS knowledge from you. To Arthur Elms and Marc Healy, thank you for your help in the HERO program. I felt proud of working with you together. To the HERO students, thank you for your great work. I had a great time of working with you. To all my classmates at Clark University, your presence makes my life and study at Clark University happier and more meaningful.

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CHAPTER 1: INTRODUCTION

The ‘Greening the Gateway Cities Program” (GGCP) was established by the Massachusetts Department of Energy and Environmental Affairs (EEA) to improve the current condition of low tree canopy found in the Commonwealth’s Gateway Cities due to their urban character and history of manufacturing. Besides EEA, the Department of Conservation and Recreation (DCR), the Department of Energy Resources (DOER), the Department of Housing and Community Development (DHCD) and local organizations participate in the program. Through tree planting, the communities in the gateway cities are expected to receive reduce heating and cooling costs, decrease water runoff, improved air quality, increase property values and improved public health.

My internship with the Clark University Human-Environment Regional Observatory (HERO) and Massachusetts Department of Conservation and Recreation (DCR) provided me an opportunity to apply my GIS expertise to urban forestry. I worked with Prof. Rogan, Prof. Martin, two PhD students and six undergraduate students at Clark University, Mathew Cahill and field staff at DCR, Prof. Eisenman and two graduate students at University of Massachusetts, Amherst from May to August 2017. We conducted eight-week of tree health assessment field work and data analysis in three Greening the Gateway cities in Massachusetts, and six-week of tree planting benefits simulation for a 180 m by 180 m block in Chelsea, MA. From this internship, I understood the importance of teamwork, how GIS could be used to solve practical problems in urban forestry, and I learnt new skills of geodatabase management using ArcGIS and Microsoft Access, and creating map series using ArcGIS Data Driven Pages.

I addressed the four topics in the internship. (1) I collaborated with Prof. Rogan, Prof. Martin and two PhD students to design and organize tree survey field survey work. We first had a few meetings with Mathew Cahill and DCR field staff at Holyoke, Chelsea and Revere, to understand the tree planting programs in the three cities and make plans for our field work. We then organized two groups of students to conduct about one week of field in each of the city. (2) I managed the DCR tree planting databases in the tree Greening Gateway cities, and used them to query the tree planting geospatial data, design field survey maps and field survey data sheets. (3) I worked with Prof. Rogan and the HERO students to analyze tree survey data to assess tree health across the three cities by species, land use and site type, and the contribution and experience of residents and stakeholders. (4) I worked with Prof. Rogan to explore a three-dimensional computer model called ENVI-met that analyzes micro-scale thermal interactions within urban environments (Wang & Zacharias, 2015), and applied it in a selected block in Chelsea to understand the shading/air temperature and wind break benefits of the DCR's tree cohort.

Overall, I learned a lot from the internship and it was a great experience for me. During the internship, I learned how to better manage geospatial databases, create professional maps and apply GIS to solve practical problems in urban tree survey. The internship also improved my communication skills with people, which will be very important for my future career. Lastly, I had a great time in this summer with all the people who attended the project. We did not only succeed in conducting the project, but also shared our life stories and joys together.

CHAPTER 2: PROGRAM AND ORGANIZATION DESCRIPTIONS

2.1 Greening the Gateway Cities Program

Greening the Gateway Cities Program (GGCP) defined a goal of 10 percent in urban tree canopy in selected neighborhoods within gateway cities (Figure 1). The increase in tree cover is expected to reduce heating and cooling costs in the selected areas by approximately 10%, with an average homeowner saving approximately $230 a year, once the trees reach maturity (i.e., 20-30 years). Over their lifespan, the trees are expected to lead to $400 million in energy savings for residents and businesses in each gateway city (Executive Office of Energy and Environmental Affairs, 2017).

The program is also expected to reduce the Urban Heat Island (UHI) effect. UHI has impacts on ecological and human communities, which is largely determined by the amount of tree cover versus impervious surface in a city. The UHI effect causes urban areas to experience temperatures approximately 1-3° warmer than surrounding rural areas in the daytime, and as much as 22° warmer at night. Under the stress of global climate change, UHI mitigation will become increasingly important due the increased energy costs and health impacts (Rizwan et al., 2008). Trees reduce UHI through solar shading and increased evaporative cooling, and therefore it is critical to maintain a health urban forest. This relies on effectively planting and maintaining urban trees, which is critically important to Massachusetts' Gateway Cities, as those cities are more susceptible to the climate change impacts than the cities with well-established and mature tree cover.

The program can also provide other benefits beyond energy savings. For example, healthy urban trees decrease water runoff. Research in other cities (Dwyer and Miller, 1999; Armson et al., 2013) show that areas with high tree cover have much lower runoff values than the areas with low tree cover. Urban tree canopy also provides other economic, social, health and aesthetic benefits (Roy et al., 2012).

There are two key components in this program including routine monitoring of ecosystem benefits and the establishment of new tree planting programs in new Gateway Cities. For the first component, in situ tree and energy measurement are conducted in the gateway cities. Thermal sensors were placed in the gateway cities including Chelsea, Fall River and Holyoke. Those sensors record the air temperature near the surface every hour in both the sites with and without tree canopy, so that the effects of tree canopy could be assessed in terms of temperature variations. Tree cover and health are monitored through field survey. Additionally, airborne LiDAR (Light Detection and Ranging) and satellite thermal sensor data are utilized to assist the monitoring. For the second component, it is reported that GGCP has been expanded to include the cities of Brockton, Haverhill, Lawrence, Lynn, Leominster, New Bedford, Pittsfield and Quincy since April 2016 (EEA, 2016). The expansion of the GGCP will bring benefits to the new neighborhoods throughout Massachusetts in the long term.

2.2 Human Environment Regional Observatory (HERO) Program

The HERO program is a unique undergraduate-graduate faculty experience that engages in research on human-environment relationships in Massachusetts. The mission of HERO program is to analyze the causes and consequences of global environmental changes at local scales. Past research involved the impact of the invasive species of Asian Longhorn Beetle, initial tree planting assessment, and resident experience with the beetle and tree planting. In the 2017 summer, the study area was expanded to three greening gateway cities in MA, including Holyoke, Chelsea and Revere, to understand the factors related to tree health and survivorship and the experience of residents and stakeholders.

HERO is an eight-week curriculum program sponsored by Clark University O'Connor Fund currently. Each year a group of Clark University undergraduate and/or graduate students are selected to join the program. The students are paired with a Clark faculty mentor and other researchers on the HERO team. They will learn how to use various research methods such as GIS, remote sensing, geostatistical modeling, interviews and focus groups.

The theme of HERO program in 2017 is Greening the Gateway Cities, which expanded the HERO program’s previous analysis of juvenile tree health and stewardship from Worcester to three Massachusetts Gateway Cities: Chelsea, Revere and Holyoke. The research focus will be a multiyear project. Additionally, the tree inventory and stakeholder assessment complements the previous several years of research conducted in Worcester in collaboration with the DCR and the Worcester Tree Initiative (WTI).

2.3 Department of Conservation and Recreation (DCR)

DCR manages state parks and oversees more than 450,000 acres throughout Massachusetts. It protects, promotes, and enhances the state's natural, cultural, and recreational resources (DCR, 2017). Under the GGCP, DCR is in partnership with local municipalities and grassroots organizations to plant up to a combined of 15,000 trees in Chelsea, Holyoke, and Fall River (EEA, 2015). DCR have developed a successful approach to plant the number of trees required to have an energy impact and focus on high-density urban neighborhoods.

The program began in Holyoke in late spring of 2014 with a goal of planting 800 combined street and yard trees per year (400 per season). They have planted 921 yard trees and 650 street trees. In 2014, the DCR initiated the tree planting program with the formal support of community partner Nuestras Raices (2017), a nonprofit focused on grassroots urban agriculture. Nuestras Raices was involved in canvassing initiatives in the first year of the program.

The Chelsea- Revere tree planting program began in 2014 with a goal of planting 800 combined street and yard trees per year (400 per season or about 10 trees per a week). They have planted 871 yard trees and 416 street trees in Chelsea. They also planted 190 street trees and 422 yard trees in Revere. The program employs community members in Chelsea who have traditionally been underemployed or who are living in unstable situations. Around three quarters of the staff is locally hired. In the past, Chelsea Collaborative (2017), an organization that works to enhance the social, economic and environmental health in the community, partnered with the DCR, largely to aid outreach to the immediate community.

CHAPTER 3: INTERNSHIP RESPONSIBILITIES

3.1 Tree Survey Field Work

The urban tree survey field work lasted for four weeks from May 22 to June 16, 2017. I worked with Prof. Rogan, Prof. Martin, two PhD students, two graduate students, and six undergraduate students conduct tree survey training, site visit and field work in Worcester, Holyoke, Chelsea and Revere, MA.

In the first week we organized opening reception, on campus training and site visits in Holyoke, Chelsea and Revere. In the opening reception, we invited people from local and state agencies including DCR, U.S. Forest Service and WTI, and faculty and students at Clark University and University of Massachusetts, Amherst. Lara Roman from U.S. Forest Service gave us a presentation on the tree survey work she has done in California, and gave the HERO students training on how to measure trees and assess tree health at Clark University campus (Figure 2 and 3).

We also organized site visits in the three gateway cities to discuss with Mathew Cahill and DCR field staff about their tree plantation programs. On May 23rd the HERO program traveled to Holyoke and met with DCR urban foresters, Rachel DeMatte and Ahron Lerman at the Westfield DCR office (Figure 4(a)). The DCR employees two foresters, two of which are employed long term and the other two being short term seasonal employees that work during the tree planting season in both Holyoke and the neighboring city of Chicopee. The program in Holyoke has had a number of successes, one of the most prominent being the DCR’s utilization of its employees to canvas and address resident questions as they plant and maintain street trees. These personal conversations with residents have increased stewardship participation in the yard tree program. On May 24th the HERO program visited Chelsea and Revere to meet with forester Hilary Dimino (Figure 4(b)). HERO was introduced to Chelsea’s program in the Mary O’Malley Park, located next to the Tobin Memorial Bridge and the Mystic River. This public site, with ample room, allowed for substantial tree planting by the DCR. This park faces unique challenges in its close proximity to Boston and Logan Airport, both of which worsen air quality and increase noise pollution according to Hilary Dimino. Continued tree planting efforts on this site not only help diversification of this ecosystem, but should also offer tangible benefits in water and air filtration as well as noise reduction from nearby transportation. The DCR’s outreach into the community to promote the yard tree program has consisted of door to door canvassing with bilingual informational material in Spanish and English. This useful because many residents in both Chelsea and Revere speak English as a second language. Public schools in the area have also served as a reliable nucleus to distribute information to eligible neighborhoods. In general, the effectiveness of local projects are heavily influenced by the capabilities and willingness to participate of local Departments of Public Works (DPWs). Chelsea’s program was more effective in meeting planting goals with DPW assistance, while Revere lagged behind without substantive assistance from their local DPW. Chelsea offers a model of success with its large community and local government participation in the program.

3.2 Tree Planting Database Management and Map Design

We obtained the tree planting geodatabase of the three Gateway cities from DCR. In total there are 2000 tree location points in the database. There is information about tree planting location, species, planting date, street address, city, owner, and other information. What I did include querying the data, updating the attribute table, verifying the accuracy of locations, adding new points and removing redundant points. Firstly, I queried the public vs. private trees in the three cities. Because private trees were usually planted in the yards of private owners, we need to gain permission to access their yards beforehand. For public trees that are planted in streets, since we cooperate with DCR, we are permitted to measure these public trees. Thus, we need to know the information of public vs. private trees and use the information to make our tree survey plans. Secondly, after we collected the survey data, we need to enter the data in Microsoft Excel datasheets. Then I used Microsoft Access and ArcGIS to update the attribute information of surveyed trees. Thirdly, as there could be errors in the database, I also worked with the HERO students to verify whether a tree location is correct, the species information is correct, and remove the redundant tree points that are in the same location. Lastly, I used Microsoft Access and ArcGIS to query the tree points in each survey sector we designed, and used to it to create survey maps and data sheets (Figure 5).

For the field survey maps, we used ArcGIS Data Driven Pages to create the maps for the survey sectors in each city. Firstly, I worked with the two program managers to divide the survey area in each city into sectors based on the clustering of tree points and proximity to roads. Then we used Minimum Bounding Geometry tool in ArcGIS to calculate the minimum bounding box that covers each sector. Using the sector layers in each city, and we were able to design field survey map series for all the sectors in each city automatically. The ArcGIS Data Driven Pages was a very powerful tool for us to create survey maps (Figure 6).

3.3 Tree Survey Data Analysis

After finishing the survey, then we conducted tree health assessment analysis. The questions we answered include three aspects: How does tree health compare across the three cities (1) by species? (2) by land use? (3) by site type? Firstly, we calculated the survivorship of each tree species in each city, and determined the top and bottom five species for survivorship (Figure 7 and 8). Secondly, we calculated the survivorship and vigor for the street trees in each land use class (Figure 9). The results show that single-family and multi-family residential land uses have better street tree survivorship and vigor, while the institutional has the worst tree survivorship and vigor. One of the reasons could be that several institutions lacked good tree stewardship. Thus, for the future tree planting program more efforts need to be spent in improving the tree stewardship in institutions. Thirdly, we calculated the survivorship and vigor for the street trees in each site type (Figure 10). The results show that sidewalk planting strip and other maintained have better tree survivorship and vigor, while maintained park has the worst tree survivorship and vigor. One of the reasons could be in maintained park, there are many people visiting these areas and it is more likely that vandalism happens to the young trees. Better stewardship is also needed in maintained parks.

3.4 Urban Tree Plantation Benefits Simulation

In order to better understand the benefits of urban tree plantation, I also worked with Prof. Rogan to use a tool named ENVI-met to simulate the air temperature and wind speed for different landscape scenarios in a 180 m by 180 m block selected in Watts Street in Chelsea (Figure 11).

ENVI-met is a three-dimensional micro-scale model based on computational fluid dynamics approach, which simulates surface-plant-air interactions in urban environment (Zölch et al., 2016). The model operates at the micro-scale with spatial resolutions of 0.5-10 m and time frames of 24-48 h. Firstly, a base map is needed to establish the 3D model in the block. I used ArcGIS base map and then used the “SPACES” module in ENVI-met to digitize trees, buildings, roads and grassland (Figure 12). In order to determine the building and tree height, I also used Google Earth 3D model to measure the heights (Figure 13). I constructed two model scenarios (before and after plantation) for comparison.

Secondly, initial meteorological parameters were used to establish the simulation project. The parameters include initial air temperature, wind speed, direction and relative humidity. For the temperature data, I used both the weather station data in Boston Logan International Airport and the thermal data logger placed in the selected block. Using the data, I conducted sensitivity analysis to compare the simulated temperate with the actual temperature data in both the winter and summer seasons in 2015 (Figure 14 and 15). The comparisons show that the simulated temperatures basically share similar trends with the weather station and thermal data logger data. The biggest difference happens during the afternoon from 12 – 3 pm. In average, the difference between simulated and data logger temperature is 0.59 °C in winter and 0.65 °C in summer, and the difference between simulated and weather station data is 3.14 °C in winter and 0.95 °C in summer.

Lastly, I simulated the air temperature and wind speeds for the two scenarios in both the winter and summer seasons using ENVI-met. Then I exported the simulated results and used ArcGIS to create difference maps to show the differences of the two scenarios. Table 1 and Figure 16-19 show the comparison results for the two scenarios. The comparisons indicate that in winter temperature increases and wind speed decreases on average in the 5 m buffers surrounding tree locations, while in summer temperature decreases and wind speed increases on average in the buffers. Further analysis on the other planting scenarios and dates will be conducted to further examine the effects of urban tree plantation.

CHAPTER 4: INTERNSHIP ASSESSMENT

My internship with the HERO program and DCR was an extremely valuable and beneficial experience for me. From the work I had done in the internship, I was able to better understand the importance of teamwork, learn how GIS could be applied in urban forestry, learn new geospatial database management skills, and learn new skills of microclimate simulation using ENVI-met.

Firstly, this internship needs collaboration among the professors and students and the staff from DCR, WTI and DCR. We need to commute between Worcester and Holyoke, Chelsea and Revere, to conduct field work, interviews, data analysis and presentations. Collaboration is one of the key factors for the success of the tree health assessment project. I was very fortunate to work with Prof. Rogan, Prof. Martin and two PhD students together to make plans and lead field surveys from the beginning to the end of the project. We were able to collaboratively make plans ahead of time and also very quickly adapt to changes such as bad weather. Meanwhile, each of us was clear of our own role in terms of project management. When one person was not able to attend, others usually would be able to take charge of the person’s role. Because of all these mechanisms, we were able to run the project smoothly and adaptively, and successfully achieved our project goals.

Secondly, I gained practical experience of GIS applications in urban forestry. Mapping was one of the important aspects of my internship. We need to map the tree location for field survey plan and navigation. Without the various maps we made, it would be impossible to finish the field survey work. Although I learnt how to make map series from the GIS class I learnt, this summer internship gave me lots of opportunities to practice this skill in urban forestry applications. And in the final presentation and data analysis, mapping is also a very useful tool for us to visualize results and convey information. I applied my GIS skills to help the HERO students to solve various GIS problems they had, such as how to edit GIS layers, how to join two tables in ArcGIS, et al.

Thirdly, I learned many new skills of managing geodatabases using both Microsoft Access and ArcGIS. Although I learnt various geodatabase formats in my GIS classes, I usually use folder to organize my GIS data. Thus, I did not have many experiences of managing a real geodatabase. In this internship, I had opportunity to manage the tree planting databases in the three Gateway cities. I learnt how to use Microsoft Access to build SQL queries, edit/delete and append records, and design datasheets. I had a better understanding of the ArcGIS personal geodatabase, and how to organize features in this database format.

Fourthly, I was able to learn a new tool ENVI-met with the help of Prof. Rogan. ENVI-met is a very new tool that was developed to model microclimate in urban environment. But there was no people in the HERO program who had learnt the tool before. Thus, I had to learn by myself through reading online tutorials, reading papers, and watching videos. At the beginning it was challenging, because the model is complex and there weren't many materials available. But through conducting experiments and talking with Prof. Rogan, I was able to figure out how to effectively apply this tool to evaluate the benefits of urban tree plantation. This experience was valuable to me because I realized that learning new skills and tools is important in a new job. Thus, I need to keep improving my learning abilities.

The coursework and experience at Clark University prepared me well for this internship. Firstly, Clark University has a strong GISDE program, in which students learn a lot of geospatial analysis, mapping and database management skills. For example, from the Advanced Remote Sensing, Advanced Vector GIS and Advanced Raster GIS classes, I had a much deeper and more comprehensive understanding of GIS data analysis, and was able to solve the technical questions I had in the internship. Secondly, the students have chances to take classes that cover broader topics, such as Landscape Ecology, Wildlife Conservation GIS and Species Distribution Modeling. These classes broadened my knowledge in ecology, urban forestry and conservation, which was very useful for me understand the context of my internship projects and better communicate with the students from different backgrounds, the DCR staff and journalists. Lastly, many of the course projects I conducted at Clark University are team projects. These projects helped me improve my communication skills and become better at collaborating with others. In this internship project, I collaborated with professors, students, DCR staff and journalists, and the collaboration was very important for the success of the projects.

I would highly recommend this internship to other GISDE students. The HERO program and DCR provide students with the opportunity to apply their GIS knowledge in urban forestry, learn how to conduct field work and scientific research, learn how to effectively communicate and collaborate with people. Thus the internship is a very rewarding experience to the students who are interested in GIS and urban forestry.

CHAPTER 5: CONCLUSION

I think the internship experience with the HERO program and DCR is one of the most important and valuable experiences I had while studying at Clark University. I believe what I have learnt from the internship prepared me for my future career. I did not only learn new skills and knowledge about GIS, urban forestry and microclimate modelling, but also learnt how to collaborate among people of different background and conduct scientific research. I was able to successfully apply my GIS expertise and my knowledge in landscape ecology in my internship, and helped the professors and students accomplish their project tasks. I will bring the knowledge and skills learnt in this internship to my future jobs, and further improve my GIS knowledge and skills of collaborating with other people.

FIGURES

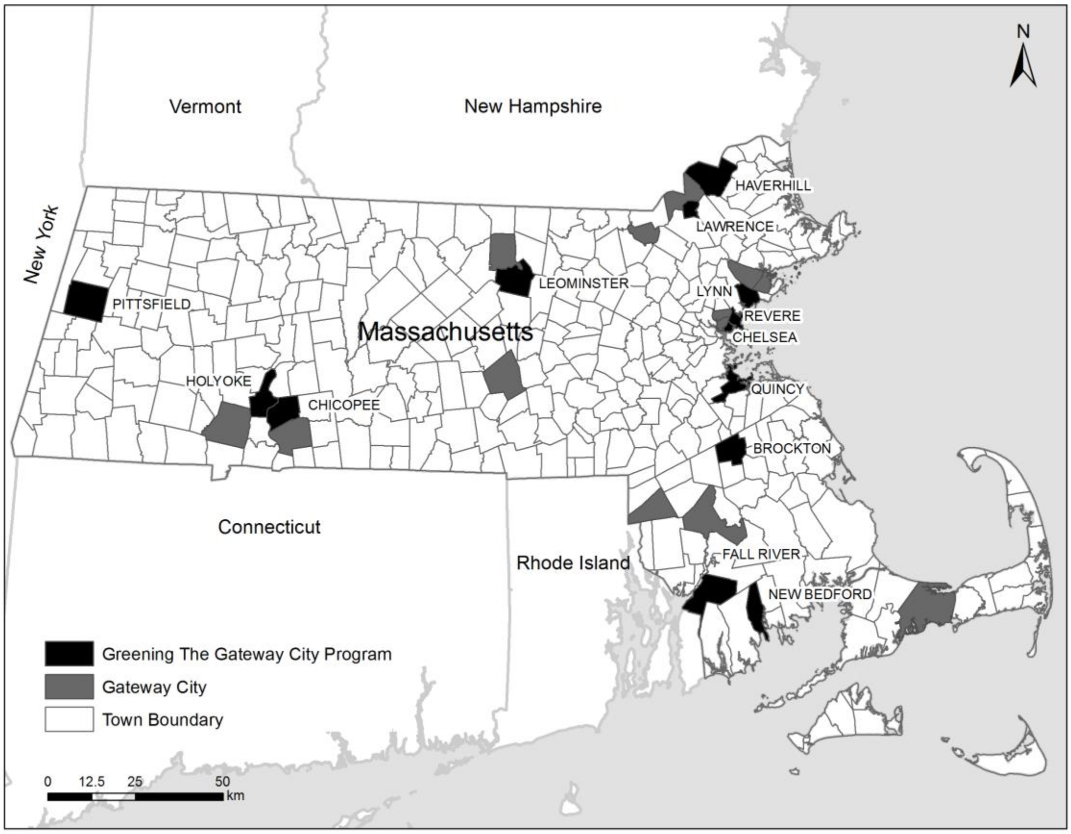


Figure 1. The location of MA Greening the Gateway City Program

Figure 2. HERO students were measuring trees on Clark University campus

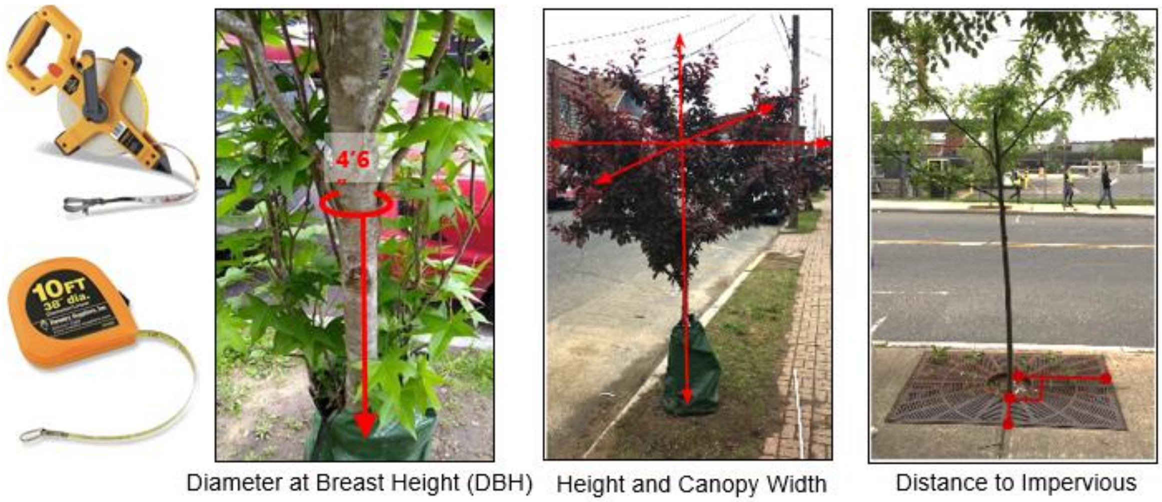
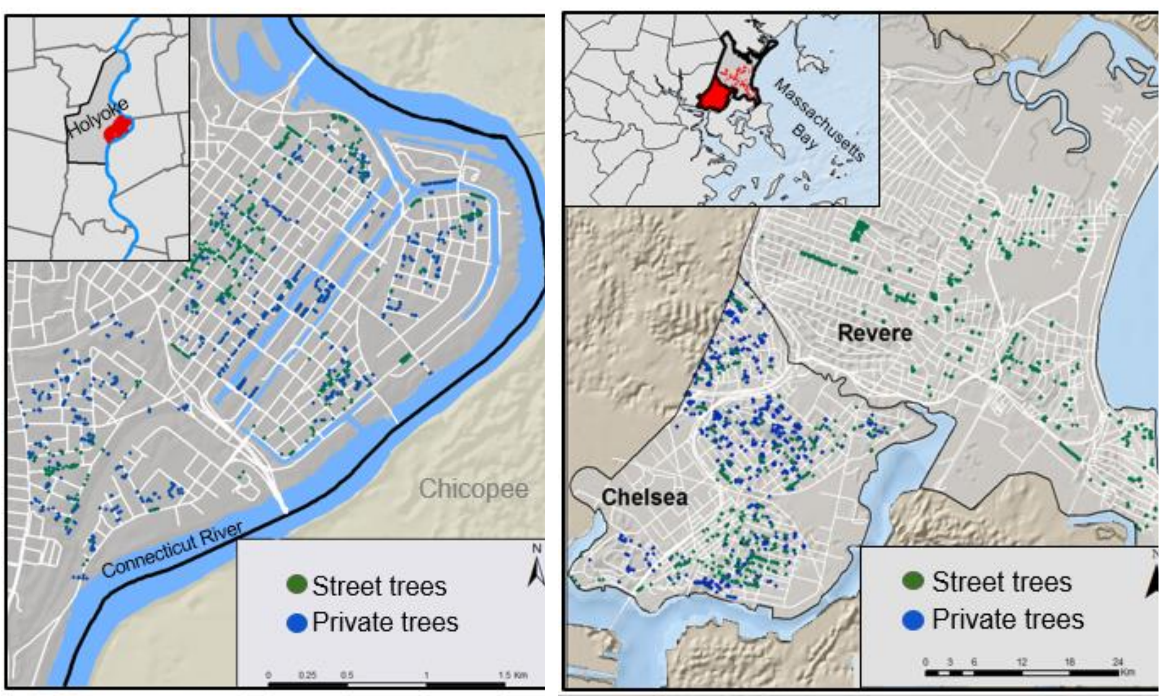
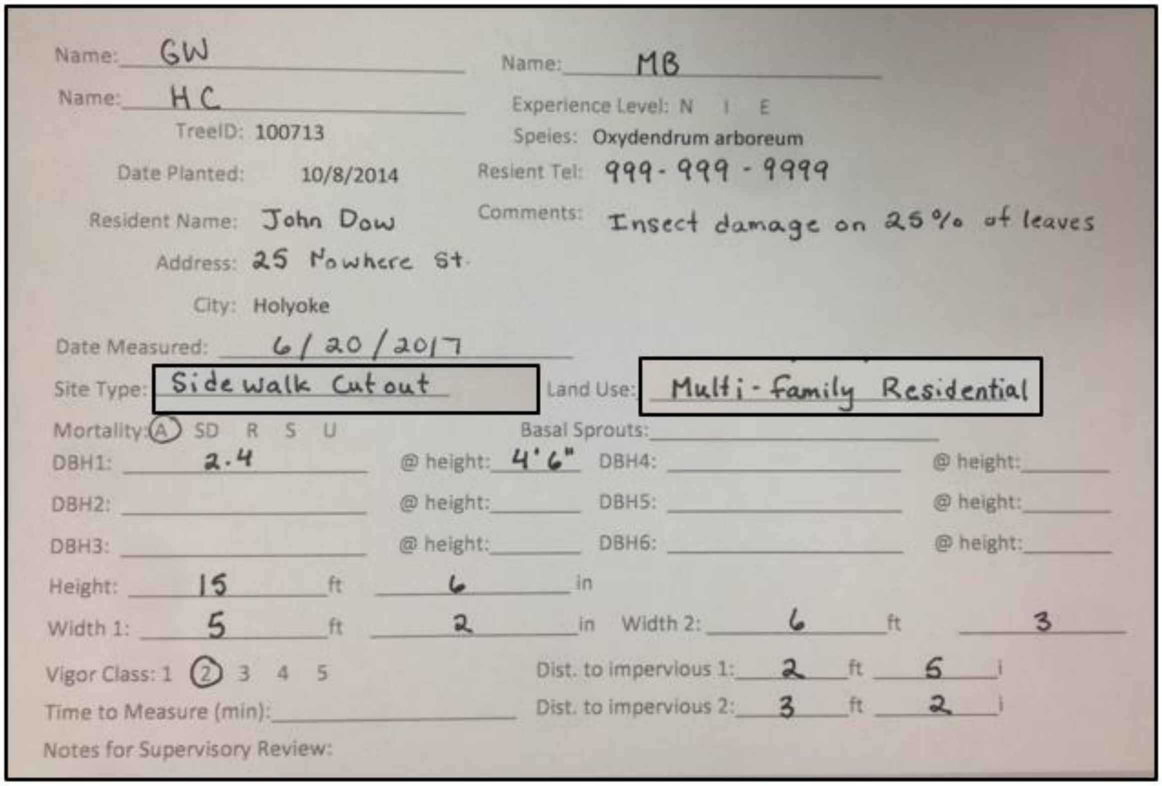


Figure 3. Size metrics of tree assessment



(a) Tree plantation location in Holyoke **(a) Tree plantation location in Chelsea and Revere**

Figure 4. Tree plantation location in Holyoke, Chelsea and Revere



Name: GW
Name: HC
TreeID: 100713
Date Planted: 10/8/2014
Resident Name: John Dow
Address: 25 Nowhere St.
City: Holyoke
Date Measured: 6/20/2017
Site Type: Sidewalk Cutout
Mortality: (A) SD R S U
DBH1: 2.4 @ height: 4'6"
DBH2: @ height:
DBH3: @ height:
Height: 15 ft 6 in
Width 1: 5 ft 2 in
Vigor Class: 1 (2) 3 4 5
Time to Measure (min):
Notes for Supervisory Review:

Name: MB
Experience Level: N I E
Speies: Oxydendrum arboreum
Resient Tel: 999-999-9999
Comments: Insect damage on 25% of leaves
Land Use: Multi-family Residential
Basal Sprouts:
DBH4: @ height:
DBH5: @ height:
DBH6: @ height:
Width 2: 6 ft 3
Dist. to impervious 1: 2 ft 6 i
Dist. to impervious 2: 3 ft 2 i

Figure 5. Tree survey data sheet

Figure 6. Residential tree survey map in Holyoke

The black dots are the tree locations, the labels are tree IDs, and the black box depicts the boundary of all the trees that belong to the resident house.

Figure 7. Top five species for survivorship in the three Gateway cities

Figure 8. Bottom five species for survivorship in the three Gateway cities

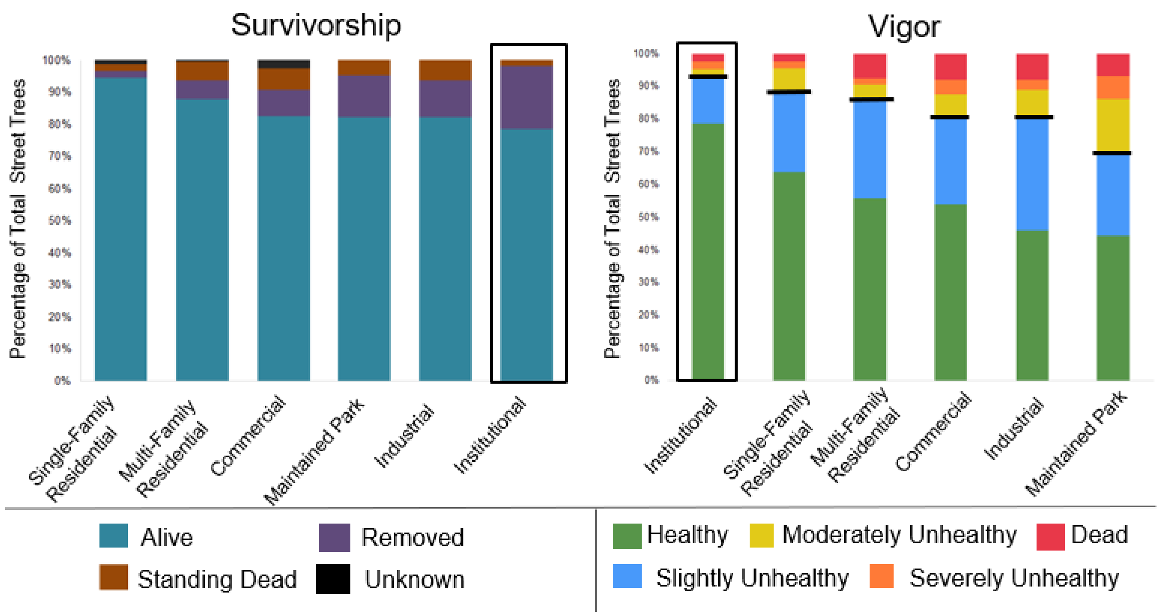


Figure 9. The survivorship and vigor of street trees for each land use class

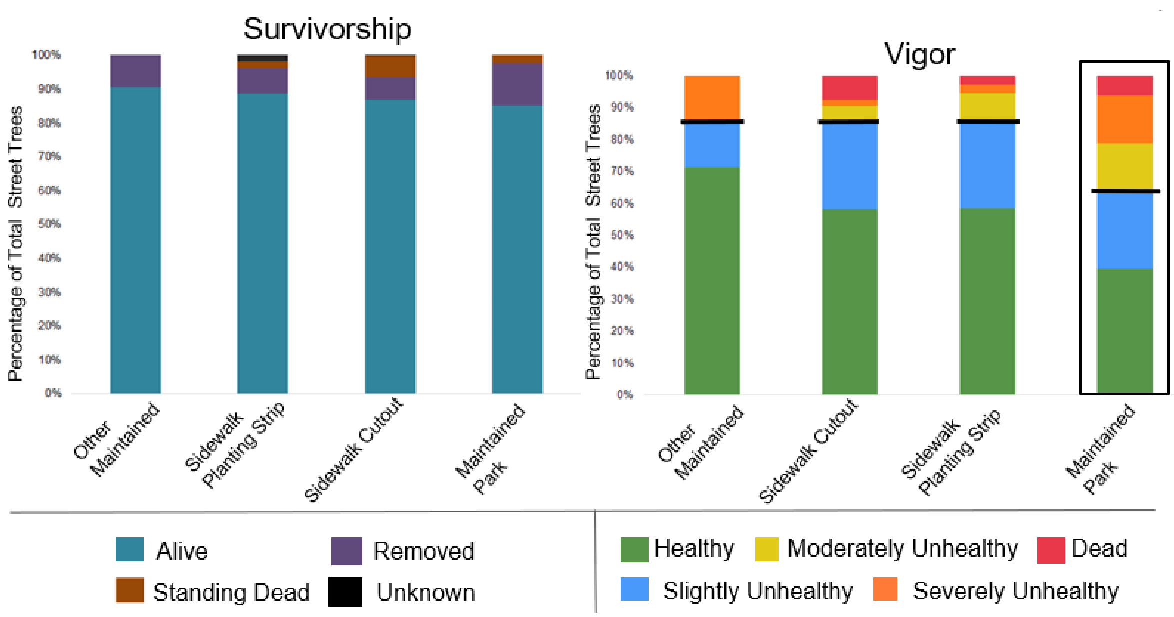


Figure 10. The survivorship and vigor of street trees for each site type

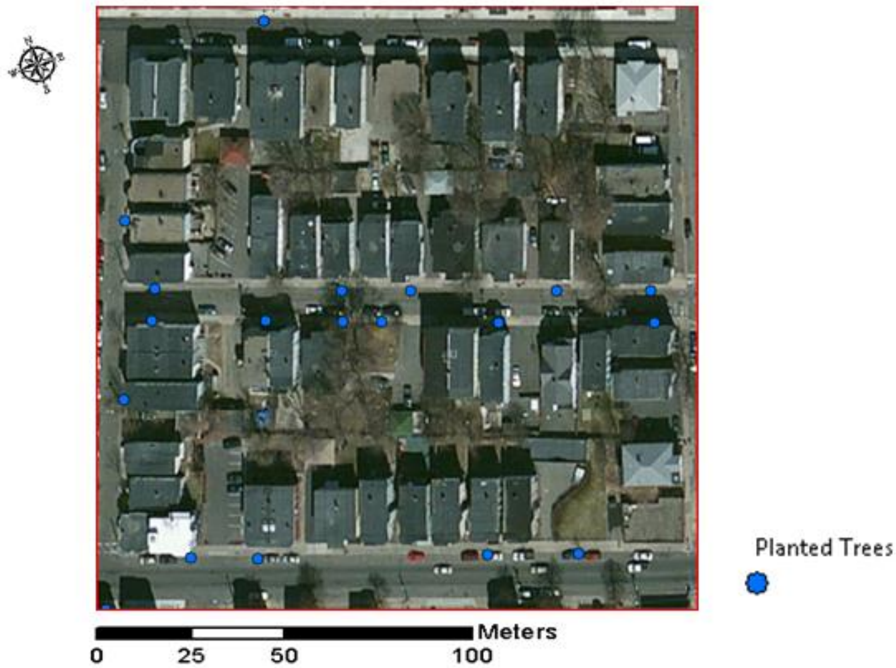


Figure 11. The selected 180 m by 180 m block in Watts Street in Chelsea

Figure 12. 2D models of the selected block in Watts Street in Chelsea

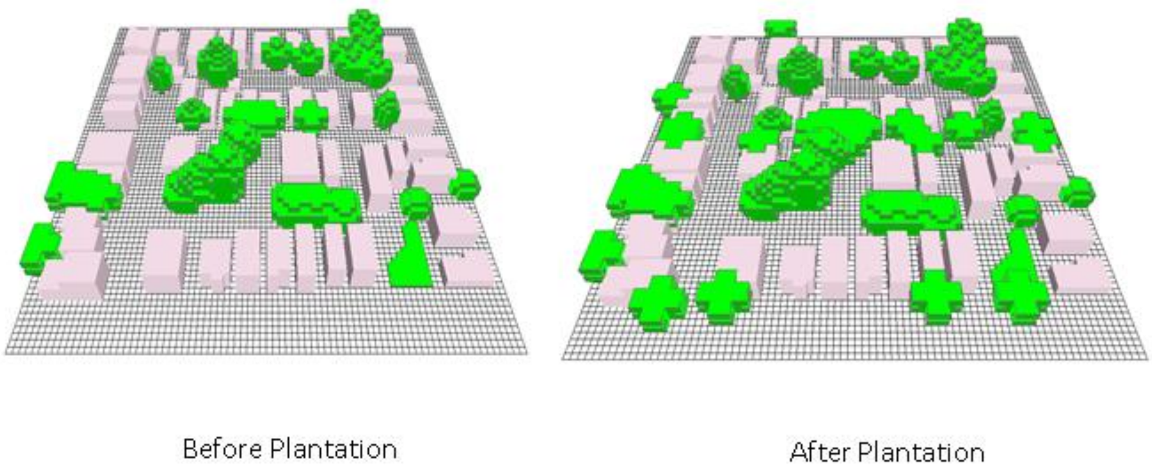


Figure 13. 3D models of the selected block in Watts Street in Chelsea

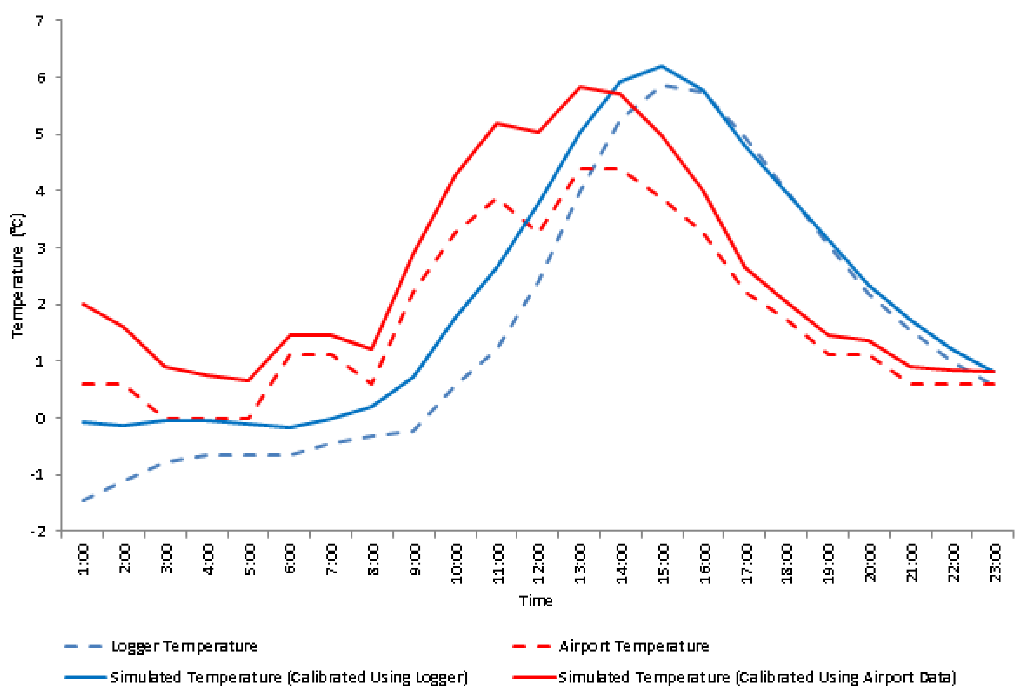


Figure 14. The thermal data logger, airport vs. simulated temperature on Jan 2, 2015

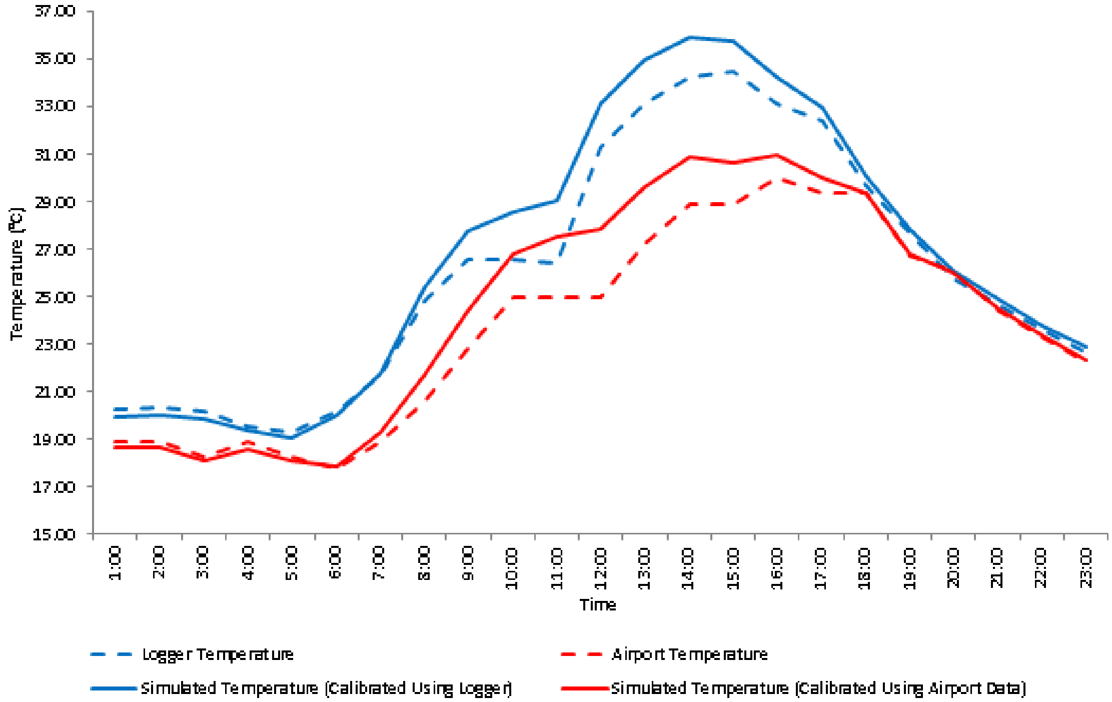


Figure 15. The thermal data logger, airport vs. simulated temperature on May 26, 2015

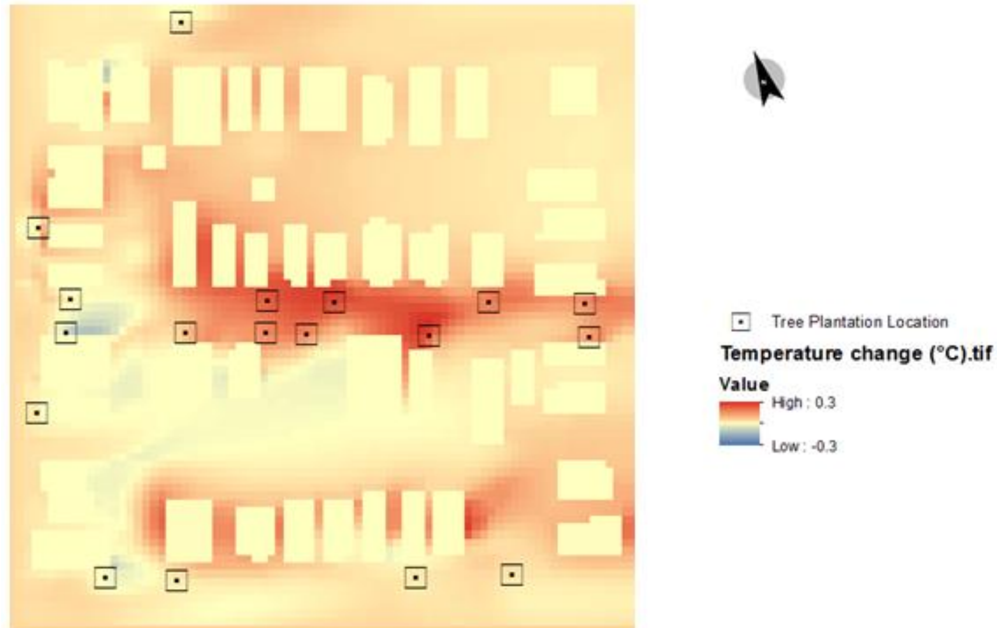


Figure 16. Air temperature change after tree plantation in at 8 am on Jan 2, 2015

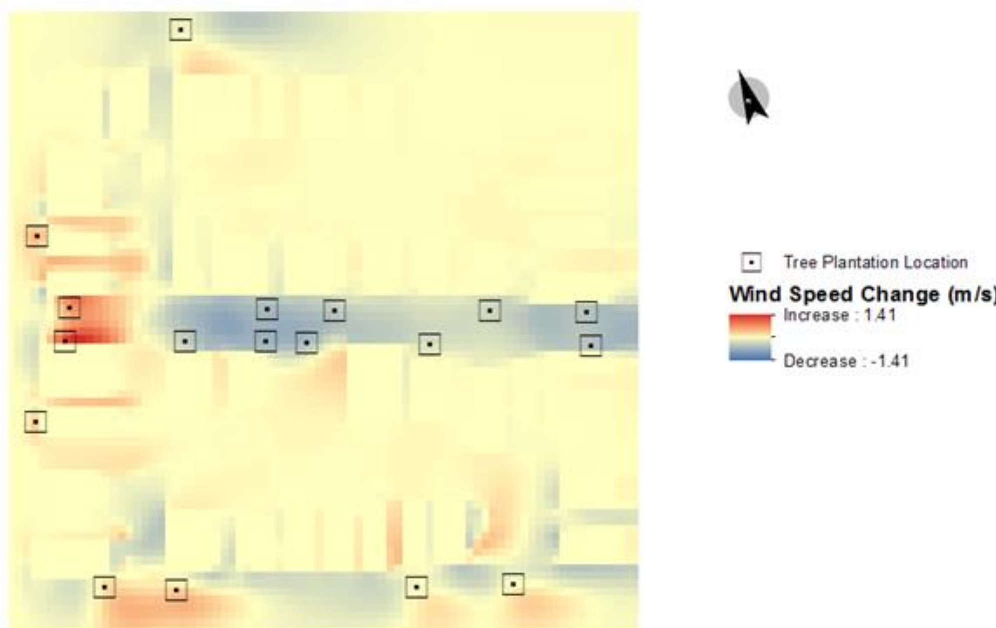


Figure 17. Wind speed change after tree plantation in at 8 am on Jan 2, 2015

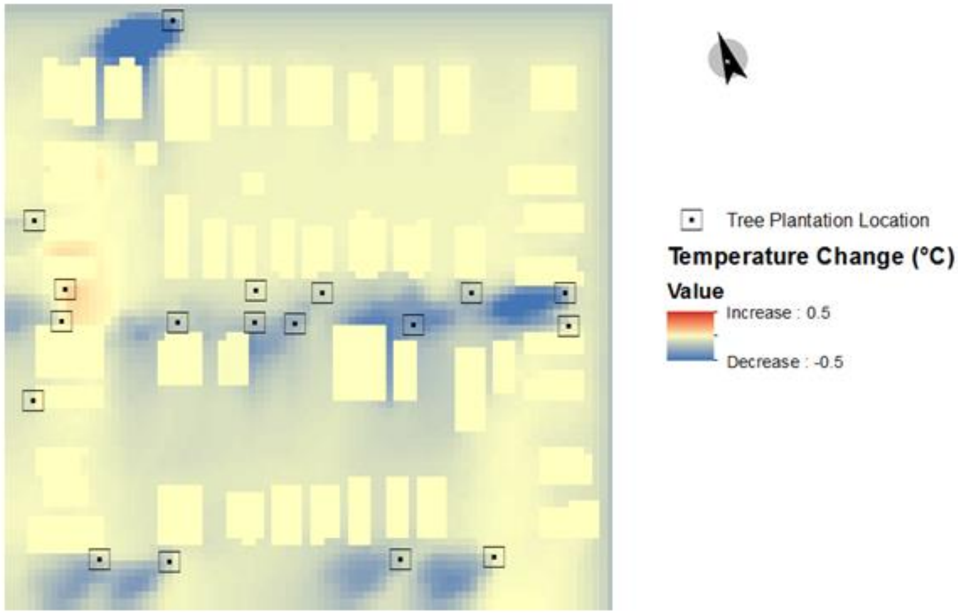


Figure 18. Air temperature change after tree plantation in at 8am on May 27, 2015

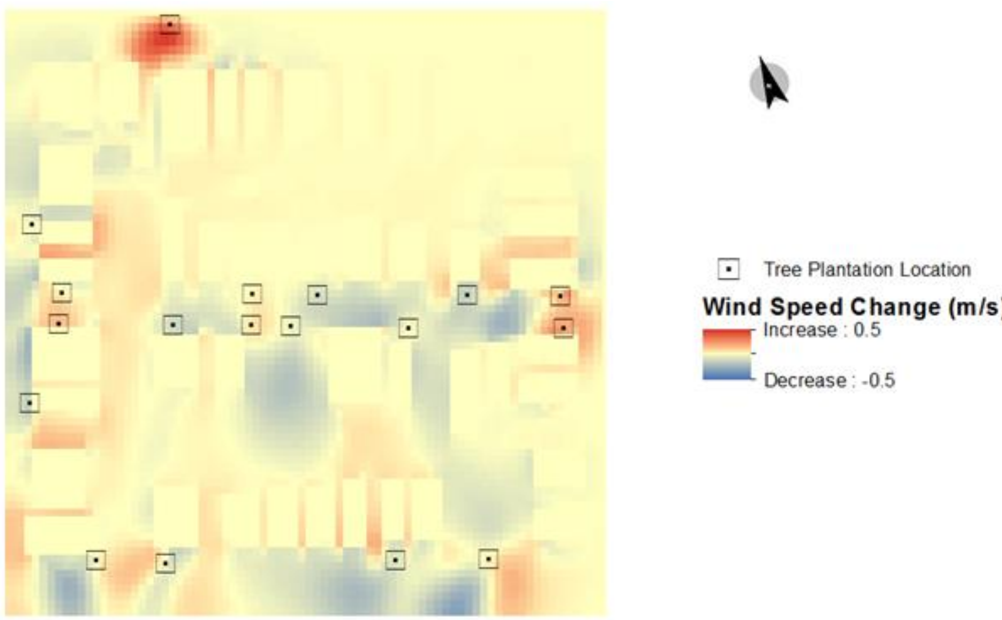


Figure 19. Wind speed change after tree plantation in at 8 am on May 27, 2015

TABLES

Table 1. Temperature and wind speed comparisons in summer and winter (in 5m radius buffer zones surrounding planted trees)

Season	Measurement	Before Plantation	After Plantation	Change	Change in Percentages
Winter	Temperature(°C)	3.230	3.315	0.085	2.632%
	Wind speed(m/s)	2.202	2.060	-0.142	-6.449%
Summer	Temperature(°C)	25.182	25.039	-0.143	-0.568%
	Wind speed(m/s)	0.892	0.896	0.004	0.448%

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