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The role of trees in reducing the urban heat island effect on the New Jersey Institute of Technology campus, Newark, NJ

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ABSTRACT

THE ROLE OF TREES IN REDUCING THE URBAN HEAT ISLAND EFFECT ON THE NJIT CAMPUS, NEWARK NJ

by

Dahlia Mansour

The Urban Heat Island Effect is a phenomenon where cities experience higher temperatures than the surrounding rural areas. This elevated air temperature occurs when cities replace the natural green cover with high-density infrastructure, resulting in increased absorbance of solar radiation and decreased cooling via evapotranspiration. The urban heat island effect can increase temperatures by 1 - 7 ºC during the day and 2 - 5 ºC during the night. The increased temperatures impact human health, increase energy use, and exacerbate air and water pollution.

In this study, the role of trees was investigated in mitigating the increased air temperature associated with the urban heat island effect, and specifically hypothesized that this effect is measured at the scale of individual trees. To test our hypothesis, the air temperature was measured at 2 meters and 10 meters away from the 28 individual trees on the NJIT campus. No significant differences were able to be detected in air temperature at this scale. Our results suggested that differences at this scale and time of the year are difficult to detect, and that further study is needed to carefully quantify the effects of individual trees.

THE ROLE OF TREES IN REDUCING THE URBAN HEAT ISLAND EFFECT ON THE NEW JERSEY INSTITUTE OF TECHNOLOGY CAMPUS, NEWARK NJ

by
Dahlia Mansour

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APPROVAL PAGE

THE ROLE OF TREES ON REDUCING THE URBAN HEAT ISLAND EFFECT ON THE NEW JERSEY INTITUTE OF TECHNOLOGY CAMPUS, NEWARK NJ

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DEDICATION

This thesis is dedicated to the memory of my mother, Vivian Abdulsalam, who always believed in my capacity to be successful not only in the academic arena, but also throughout my life. You are gone, but your belief in me has made this journey possible.

ACKNOWLEDGMENT

I am grateful to God for the good being necessary to complete this book. No one who achieves success does so without acknowledging the help and support of others. In this research, I encountered people who helped and traveled with me to achieve this life ambition. Therefore, for this achievement, I express my gratitude to those who unconditionally support and encourage me in all situations.

I am deeply indebted to my professor Dr. Daniel Bunker and my committee chair for their invaluable patience and feedback. I could not have undertaken this journey without my defense committee, including Dr. Philip Barden and Dr. Gareth Russell, who generously provided knowledge and expertise. This endeavor would not have been possible without the help of my cohort members, especially Cassandra, Isaiah, and Nada Ali, for their morning and afternoon help and moral support. I would like to extend my sincere thanks to Hanyu Wang for his decisive role in working on the campus survey. My deepest gratitude should also go to the librarian and facility members at NJIT, Mr. Ronald Martucci, Ms. LaTosha Wilson, Mr. Richard Martinez, William Araugo, and Mr. Omar Garcia, for their support and cooperation.

Lastly, I would be remiss in not mentioning my family, especially my father, spouse, and children, for their blessing and the constant support that they have been for me. Their belief in me has kept my spirits and motivation high during this journey.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER 1

INTRODUCTION

1.1 Urban Heat Island Effect

According to Mills (2006), Luke Howard (1833) was the first person to recognize the impact of the Urban Heat Island Effect (UHIE), which is an increase in air temperature in urban areas compared to rural areas (Bowler et al. 2010) (Oke 1982). Urban areas are some degrees higher in temperature compared to rural areas, which is “particularly problematic” (Bowler et al. 2010). In the United States, the UHIE increases the temperature in cities during the day by 0.9 - 7.2°F (1.0°-4.0°C) and during the night by 1.8° -4.5° F (1.0° -2.5° C) respectively. The greater disparity in weather is noticed in highly inhabited cities (Hibbard et al. 2017). Arnfield (2003) and Schatz and Kucharik (2014) revealed the impact of UHIE on climate by its occurrence during summer and possibly winter and spring as well. Moreover, Schatz and Kucharik (2015), reported that in July of 2012, the air temperature in Madison, Wisconsin, experienced a higher average in maximum temperature by 1.8 and a higher minimum temperature by 5.3, in addition to an increase by twice of the hours of air temperature ≥ 32.2 C.

According to a 2018 report by the United Nations, 55% of the global population lives in urban cities. This percentage is expected to reach 90% by 2025 due to urbanization in addition to global population increase (United Nations 2018). In the meanwhile, cities are growing. Based on data provided by the United Nations, cities with populations of about one million increased from 371 in 2000 to

548 in 2018 and are expected to reach 706 cities in 2030, while “megacities” with more than ten million residents will grow from 33 in 2018 to 43 cities in 2030 (United Nations 2016).

Uncovering ways to address the urban heat island effect is essential to improve public health, decrease environmental effects, reduce energy costs, and lower impacts on vulnerable populations is essential. Planting trees is one effective way to reduce the impact of urban heat island effects and decrease air temperatures.

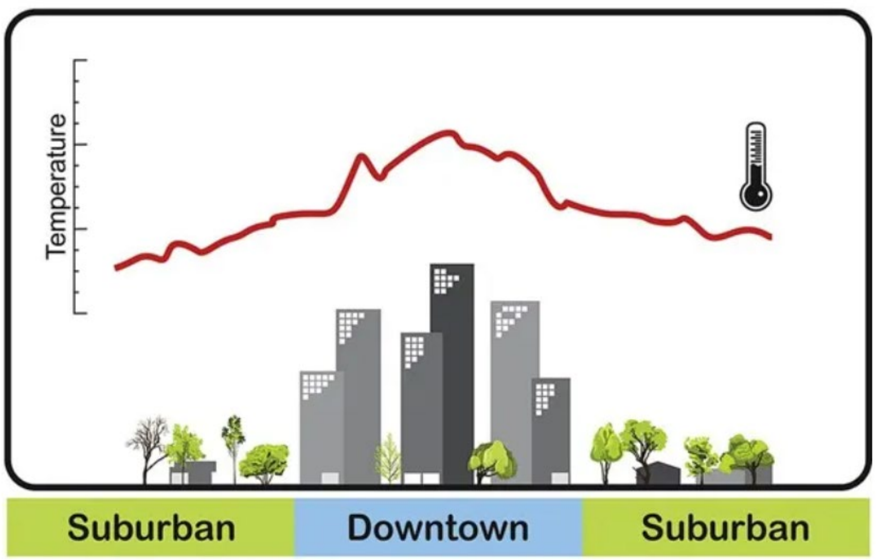

Figure 1.1 A characterization of urban cities and suburbs demonstrating the determination of soil surface temperature and urban heat islands from geostationary data for different land uses and covers.

Source: Silva, Janilci Serra, Richarde Marques da Silva, and Celso Augusto Guimarães Santos. 2018. “Spatiotemporal Impact of Land Use/Land Cover Changes on Urban Heat Islands: A Case Study of Paço Do Lumiar, Brazil.” *Building and Environment* 136: 279–92.

1.2 Adverse Impacts from Urban Heat Island Effect

The UHIE can have negative impacts on public health, impacting vulnerable populations negatively through higher mortality rates, air, and water pollution as a result of climate change, and increased energy use. Norton and colleagues (2015) stated that many studies found that human individuals' ability to recover from diurnal heat stress decreases due to the higher nocturnal temperatures, according to Clarke and Bach (1971).

Heat is a major "weather-related" killer in the US. When exposed to severe heat, individuals may experience life threatening diseases such as "heat exhaustion and heat stroke" (Crimmins et al. 2016). In addition, the urban heat island effect impacts mortality rates according to several statistics in the US and worldwide. Extreme heat in the United States caused more than 1300 deaths directly versus about 600 deaths per year occurring naturally due to other medical conditions or factors (Wuebbles et al. 2017). Figure 1.1 illustrates the annual death rates classified as "heat-related" according to the medical professionals in the fifty states and the District of Columbia between 1979 and 2018 (Wuebbles et al. 2017).

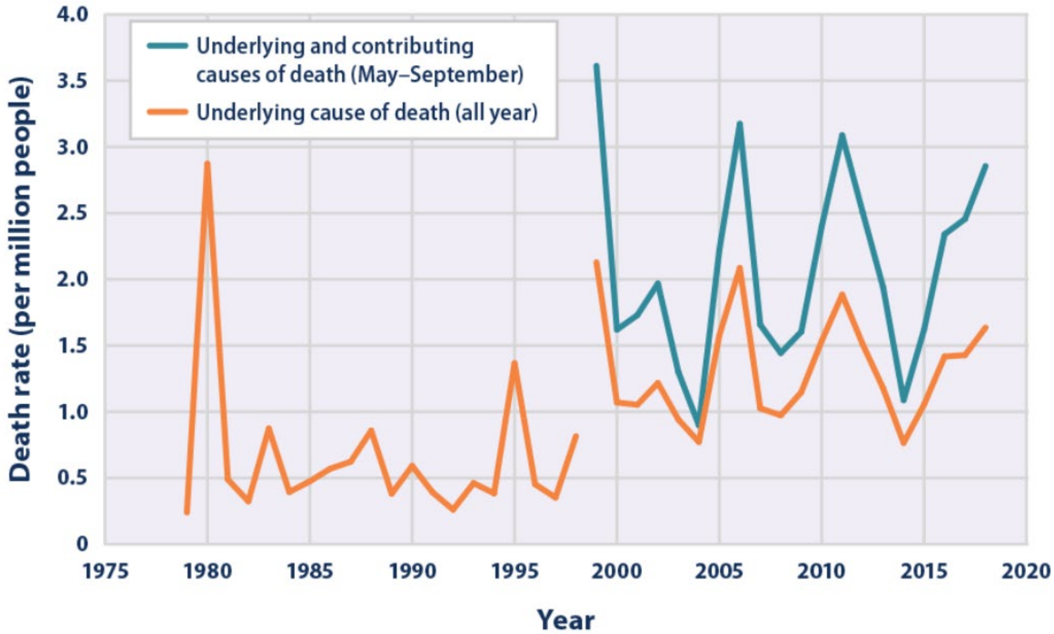

Figure 1.2 Deaths classified "heat-related "in the United States 1979-2018.

Source: Wuebbles, D.J. et al. 2017. *Climate Science Special Report: Fourth National Climate Assessment, Volume I*. U.S. Global Change Research Program. https://science2017.globalchange.gov/ (April 22, 2023).

Deaths due to the urban heat island effect were also recorded in Europe, where heat stress – a function of the body being able to cool itself – was the leading cause of weather-related deaths. Temperature extremes can also exacerbate chronic conditions, including cardiovascular, respiratory, and cerebrovascular diseases, and diabetes-related conditions. Based on readily available data, at least 15,000 people died specifically due to heat in 2022 in Europe. Among those, nearly 4000 deaths in Spain, more than 1,000 in Portugal, more than 3,200 in the United Kingdom, and around 4,500 deaths in Germany were reported by health authorities during the 3 months of summer. More information can be found here (World Health Organization: WHO, 2022) Investigating the relationship between the UHIE and air pollution is crucial, which can have the potential to impact human health, including energy loss. The combination of both shows a tendency for individuals to experience environmental stress and “increased physical discomfort” (Jiang et al. 2023).In addition, air pollution increases in the northern cities compared to the south, and during the summertime O_3 pollution increases as well (Jiang et al. 2023).

UHIE heats up the air, rivers, and water sources, and impacts the fish and aquatic life that are sensitive to temperature variation (Geilman 2020). Water is important for humans, animals, and plants. Some impurity is permitted in usable quality water, although water could be poisoned if there are high impurity levels as a result of human activities and urbanization (Zhu et al. 2023).

Higher urban temperatures increase energy bills and can add to air pollution, amplifying the impacts of excessive heat waves and exposing people to greater health risks (US EPA 2014). According to Li et al. (2019), the increase in the world’s energy use is around 31% (22-57% regionally). The increase in energy use has grown steadily because of rapid urbanization, environmental changes, and other drivers, including construction.

Trees are part of the process by which cities reduce UHIE. Therefore, plans are crucially needed to alleviate the impacts of UHIE and decrease the death rates associated with extreme heat by understanding the mechanisms and mitigating the effects by increasing vegetation in urban areas.

1.3 The UHIE Mechanism

To identify ways to decrease the UHIE and improve the quality of life in cities, it is crucial to understand the mechanisms that cause the UHIE. The explicit cause for UHIE is transforming the natural environment into an impervious built landscape, which alters "the thermal properties of the surface," and the atmosphere causes the urban heat island effect (Rashid and Al Junid 2014).

Studies confirm that the greater absorption, reduce cooling through lack of transpiration, and anthropogenically, which generates heat through transportation are the main causes of higher surface temperature in urban areas (Hibbard et al. 2017). Thus, pavement, buildings, and other surfaces absorb and retain more heat during the day than natural surfaces, and this energy is slowly released during the night, causing urban areas to be warmer than surrounding rural areas (Oke 1982).

The extent of the UHIE can differ according to various elements, such as the scale and density of the urban area and the duration of the day and the season. Norton and colleagues (2015) stated, the urban heat island is significantly hotter during the day. When the sun sets, the impermeable coverages in urban areas, which absorbed and retained the heat during the day, start to liberate it gradually, reflecting the actual influence of the urban heat island effect.

Extreme heat in cities globally as a result of manufacturing, noise, overpopulation, congestion, and poverty, can expose the inhabitants to various health issues and the contamination of water, air, and soil (Vardoulakis, Dear, and Wilkinson 2016).

Gill and Malamud (2017) defined the anthropogenic process as an "Intentional human activity that is non-malicious but that may have a negative impact on society through the triggering or catalyzing of other hazardous processes. Natural resources, ecosystems, and climate were significantly affected by this process. Examples of anthropogenic impacts include pollution, deforestation, loss of biodiversity, depletion of natural resources, urbanization," groundwater depletion, vegetation removal, quarrying and surface mining, and subsurface construction (tunneling) "(Gill and Malamud 2016). Understanding and mitigating the impacts of anthropogenic processes is essential to sustain the environment and conserve natural resources for the following generations.

Tree maintenance and planting in urban areas can help decrease the urban heat island impacts and create a more sustainable and enjoyable environment for all. Rahman and colleagues (2020) stated that the advantages of the cooling effect are the shade that the canopies give, which can decrease radiation and short waves, at the ground level (De Herd and Liébard, 2005), in addition to the evapotranspiration in which trees decrease the surrounding temperature, as a result of which the canopy of trees may reduce the air temperature considerably more than the shades from buildings (Charalampopoulos et al. 2013a).

1.4 The Effect of The Trees and Vegetation on UHIE

Trees and vegetation can be beneficial to reduce the urban heat island effect. The first of two major elements contributing to the cooling advantage of trees is, as De Herde and Liébard (2005) describe, the shade that was given by the tree canopies, which has a decrease of approximately 60-90% in short-wave radiation supply at the ground level. Shading can play an important role in the lower canopy boundary of parking lots (2 m and lower) by preventing solar radiation from encountering, and being absorbed by, engineered materials (Rahman et al. 2017). The second element is evapotranspiration, which is a mixture of two processes: water evaporation, which absorbs heat from the ambient air, lowering temperature. When leaves transpire, they release water vapor into the air, which is a cooling process. Moreover, the air temperature reduction inside or under the tree canopy cover ranges from 1°C to 8°C as an influence of evapotranspiration (Georgi and Zafiriadis 2006, Mohammad A. Rahman et al. 2017). In addition, when there is a proper tree deployment, the shade provided from the tree may decrease the building's air conditioning expenses by 20-50% (M. A. Rahman, Armson, and Ennos 2015).

Trees and vegetation can help to mitigate the urban heat island effect. A study conducted by Kong et al. (2016) explains that selecting the optimum species to grow is essential to have the most efficient cooling effect on the UHIE. This varies by the tree crown size, density, and the "optical properties of the leaves." Trees leverage many levels of impact on the microclimate underneath their canopies based on the species variation. Golden and colleagues (2017) stated, "A mature 40-ft tree with a crown of 30 ft can decrease air temperature by transpiring as much as 40 gallons of water per day", according to (Akbari et al., 1992). Therefore, in the presence of shade from trees, the temperatures are considerably lower compared to the shadows of buildings (Charalampopoulos et al. 2013b).

Overall, trees can be an efficient tool to reduce the impact of the urban heat island effect and create more comfortable and livable cities. In this study, we are investigating how trees can mitigate the urban heat island effect. Plants are crucially needed to alleviate the impacts of UHIE and decrease the death rates associated with the extreme heat by increasing vegetation in urban areas.

1.5 Measuring the UHIE

The urban heat island effect can be measured using a variety of methods, such as remote sensing for measuring air temperature, surface temperature measurements, and modeling techniques. Measuring air temperature is helpful in studying how to alleviate public health risks since those are the best indicators of how people are feeling (Jin 2012). Another common approach is measuring surface temperature using remote sensing techniques like thermal infrared imaging. Which represents the thermal energy released by the land, buildings and other surfaces. Also it would give better geographic coverage than measuring air temperatures (Jin 2012).

In this study we measured the air temperature at the local scale of the tree trying to detect the effect of individual trees on urban heat island effect, which was not done before to the best of our knowledge.

1.6 Hypothesis

We hypothesize that the impact of trees on reducing the UHIE is measurable at the scale of the individual tree.

CHAPTER 2

METHODOLOGY

2.1 Overview

To observe the role of the trees on reducing the air temperature on the New Jersey Institute of Technology (NJIT) campus, we conducted an experiment to measure the air temperature (°F) and relative humidity (RH) both near and far from individual tree canopies. The experiment was performed during the fall. The approach to this research was made in four phases. The first phase was choosing twenty-eight trees around the NJIT campus to use for measuring the air temperature. The second phase involved designing the humidity and air temperature monitoring apparatus. In the third phase we collected the data by placing the monitoring apparatus at two meters and ten meters away from each tree on the NJIT campus for a period of 3-4 days. This third phase was repeated twice. The fourth and final phase was analyzing the data using R statistical Software (v4.2.2, R Core Team 2022).

2.2 Study Location

Our study location is The New Jersey Institute of Technology (NJIT), Newark NJ. With more than 11,000 undergraduate and graduate students, NJIT is the largest technological university in the New York metropolitan region. The University has more than two million square feet of state-of-the-art facilities located on a forty-eight-acre campus in Newark, (New Jersey Institute of Technology |, n.d.) Newark is in Essex County in New Jersey and its populous city in the U.S. state of New Jersey and one the seat of the Essex County and one of the largest municipalities within the New York metropolitan area. The city’s population is 307,220 as of 2021 United States census. Newark density is 12,903.8/sq mi (4,982.2/km 2) ("Newark, New Jersey", 2023). Newark’s average temperatures based on the Newark International Airport Station during the month of January 24 -38 ºF, April 44-61 ºF, July 69-58 ºF, and October 48-65 ºF (Newark, New Jersey - City Information, Fast Facts, Schools, Colleges, and More n.d.) figure 2.1.

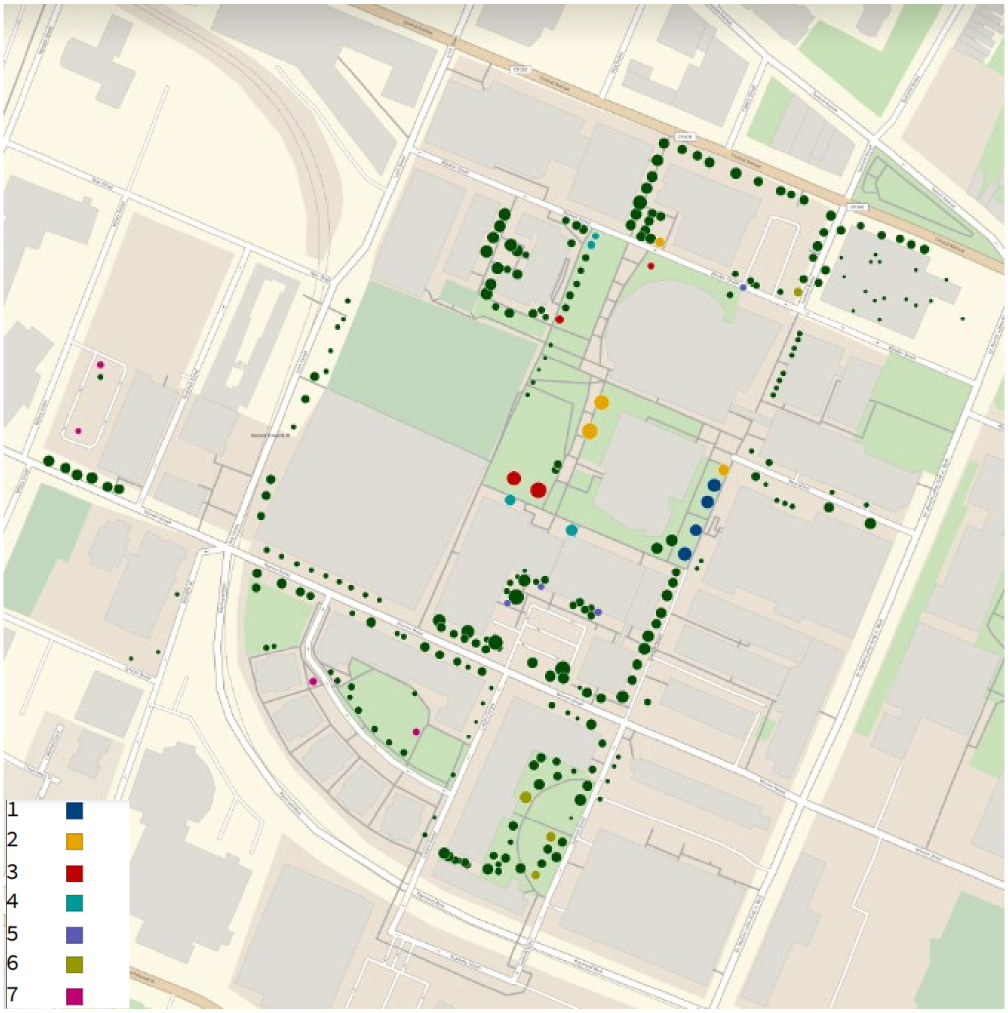

Figure 2.1 This figure illustrates all the green coverage on the NJIT campus. Trees, which are not included in the study are colored dark green, the colored dots represent our studied trees. Each dot is proportional to its DBH. Our 28 trees that were included in the study formed 7 cohorts showing in multiple colors, each cohort consists of 4 trees and represents a location. Each cohort was monitored for an average of 4 days starting on September 21st, 22, and this process was repeated twice and ended on November 11th, 2022.

2.3 Tree Selection and Characteristics

In conjunction with a related study, all trees (>10 cm DBH) were censused on the NJIT campus (Wang, 2019). Among these trees, we selected 28 for the present study. We selected a variety of trees, considering diversity of species, a variety of locations, and a mix of tree morphology including high- and low-density canopies to observe if there is a difference in reducing the air temperatures for the trees with greater leaf density versus trees with low leaf density.

Individual trees were chosen to maximize the distance from other trees and from surrounding buildings, to minimize interference of shade from other sources with the trees that we were studying. We created a numeric identification method for the trees by assigning a number to each of twenty-eight trees. Table 1 summarizes the trees, including tree number, species, height, and diameter at breast height (DBH). We also took a hemispherical photo for each tree and each monitoring apparatus at each distance (see below).

Table 2.1. Characteristics of Trees Included in the Study

Tree ID #	Scientific name (species name)	Height (m)	DBH (cm)	Cohort
1	*Zelkova serrata*	10	48.7	1
2	*Zelkova serrata*	10	38.2	1
3	*Zelkova serrata*	10	43.3	1
4	*Zelkova serrata*	10	48	1
5	*Zelkova serrata*	10	35	2
6	*Fraxinus pennsylvanica*	20	67	2
7	*Fraxinus pennsylvanica*	20	59.7	2
8	*Prunus sp.*	4	25	2
9	*Betula nigra*	8	13	3
10	*Ginkgo biloba*	8	20.1	3
11	*Gleditsia triacanthos*	12	67	3

12	*Gleditsia triacanthos*	12	51	3
13	*Prunus sp.*	4	30	4
14	*Quercus palustris*	12	37.5	4
15	*Ginkgo biloba*	8	20.1	4
16	*Ginkgo biloba*	8	13.7	4
17	*Cercis canadensis*	3	13	5
18	*Acer sp.*	7	12.5	5
19	*Cercis canadensis*	4	17	5
20	*Fagus sylvatica*	4	13	5
21	*Platanus acerifolia*	8	21.1	6
22	*Zelkova serrata*	7.3	20.2	6
23	*Zelkova serrata*	9.2	27.2	6
24	*Zelkova serrata*	8	38	6
25	*Prunus sp.*	3	15.5	7
26	*Acer rubrum*	6	16.2	7
27	*Ulmus thomasii*	6	10	7
28	*Platanus acerifolia*	10	14	7

2.4 Air Temperature Monitoring Apparatus

We designed and built wooden solar shields to host our temperature and humidity data loggers. The solar shields consisted of a 20 (w) by 18 (d) by 11 (t) cm spruce lattice within a 30 (w) cm by 28 (d) cm plywood roof and a 30 (w) by 24 (d) plywood floor.

The shields were painted white to increase their reflectivity and decrease the amount of heat absorbed by the surface as shown in Figure 2.2.

(A)

(B)

Figure 2.2 (A) Solar shield. (B) Solar shield roof painted in white.

According to the American Geosciences Institute (2016), for precise and relevant air temperature measurement, temperature and humidity sensors should be placed between 5 to 6 feet above the ground surface to minimize the effect of infrared radiation from the ground on air temperature. Therefore, we placed the solar shields on the top of five foot and four-inch-high wooden monitoring towers (Figure 2.3).

Figure 2.3 Humidity and air temperature monitoring apparatus including solar shield atop 5 foot and 4-inch-tall monitoring tower, placed height 2 meters away from focal tree.

Each monitoring tower and solar shield enclosed a weatherproof data logger with built-in temperature and relative humidity sensors (HOBO U23-001A Pro v2, Onset Computer Corp, Bourne, MA, USA). The data loggers feature a relative humidity sensor that can quickly recover from condensing conditions, which maximizes overall data accuracy. The logger can monitor and record temperature from -40°C to +70°C (-40°F to +158°F) and humidity from 0 to 100% RH. The sensor accuracy for the temperature is ± 0.21°C from 0°C to 50°C and ±0.38°F from 32°F to 122°F. The accuracy for relative humidity is ±2.5% from 10% to 90% RH. The Onset HOBO BASE-U-4 Optic UBS Base Station was used to transfer data from HOBO compatible data logger by way of an optical USB interface (Onset Computer Corp, Bourne, MA, USA).

2.5 Deployment of the Monitoring Apparatuses

To test our core hypothesis that individual trees have a measurable cooling effect on local air temperature, we deployed our temperature and monitoring apparatus at 2 and 10 m from each focal tree. We deployed the monitoring apparatus to collect temperature and humidity data over a period of seven weeks and two days on the NJIT campus, starting on September 21, 2022, and ending November 11, 2022. To minimize variation and standardize our sensor deployments, we placed our monitoring apparatus, at both 2 and 10 m, due north of the focal tree. Temperature and humidity were recorded every fifteen minutes. We deployed eight monitoring apparatuses in parallel, each with its own temperature and humidity censor, monitoring a cohort of four trees at a time. Each deployment lasted about 95 hours (Mansour 2023), after which time we moved the apparatuses to the next cohort of four trees. We repeated this a total of seven cohorts and a total of twenty-eight trees. After all, seven cohorts were monitored, we repeated this procedure for a second round of monitoring.

2.6 Statistical Analysis

My general hypothesis is that trees reduce air temperature and that this effect is detectable at the scale of the individual tree. We predict that over the duration of our experiment, our paired temperature sensors will show a lower temperature at 2 m from the tree trunk compared with the air temperature at 10 m from the tree trunk. To test this hypothesis, I first confirmed that the paired sensors recorded temperature during the exact same time during both rounds of monitoring. I then calculated the mean temperature for each sensor over this entire time. Finally, I used a paired t-test to determine if there is a significant difference in mean temperature at the two distances. Because the data are paired at each tree, a paired t-test was appropriate. I conducted the paired t-test using the Champely (2018). _Paired Data: Paired Data Analysis_. R package version 1.1.1, <https://CRAN.R-project.org/package=PairedData>, paired Data package in "R Core Team" (2022).

CHAPTER 3

RESULTS

We identified 28 trees and measured the temperature by deploying the air temperature monitoring apparatus at both two meters and ten meters from each tree every 15 minutes for an average of 170 hours and an average of 687 measurements for each tree from September 21, 2023, to November 11, 2023.

The mean air temperature for the sensors two meters away for the duration of the experiment (round 1, and round 2) was 58.00823, versus 58.08929 for the ten-meter sensor (Figure 3.1). The paired test showed no significant differences between temperatures near the tree and farther away from the tree ($t = 1.3493$, $df = 27$, p-value = 0.1885).

We also noticed that there were four trees with higher means during both rounds which are trees number twenty-one, twenty-two, twenty-three, and twenty-four, the average means for these trees, as shown in figure 3.1.

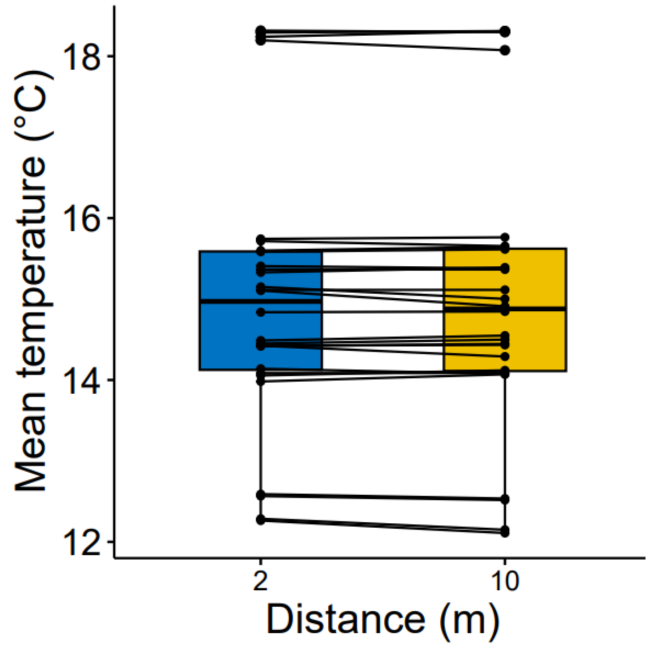

Figure 3.1 Paired t -test result (t = 1.3493, df = 27, p-value = 0.1885).

We visually inspected the temperature data and found that some trees appear to support our hypothesis, while others did not, suggesting a need for further studies. For instance, tree number 8 during round 1 showed higher temperatures at the 10-meter distance sensor than the 2-meter distance sensor, which supports our hypothesis Figure 3.2. On contrast tree number 17 during round 1 showed higher temperatures at the 2 meters distance sensor than the 10 meters distance sensor, which does not support our hypothesis Figure 3.3.

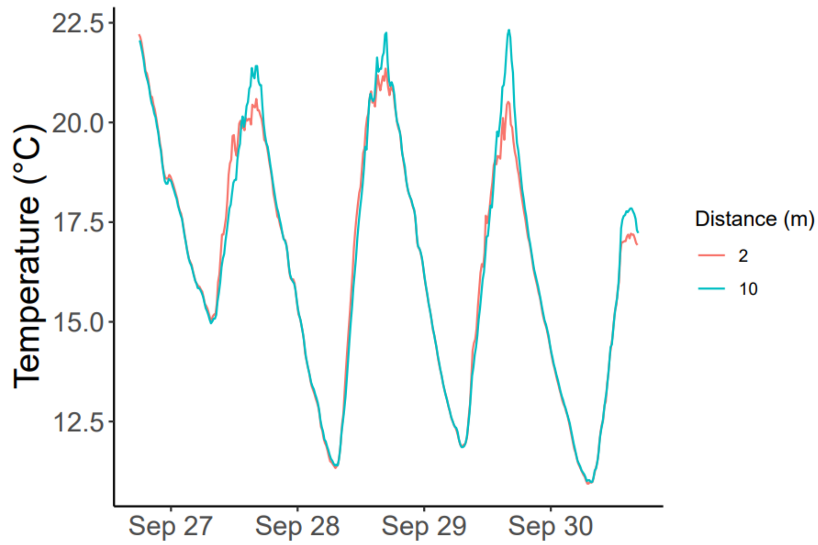

Figure 3.2 The air temperature for tree number 8 in the first round was higher at 10 meters than the 2 meters during the late afternoon, which supports our hypothesis.

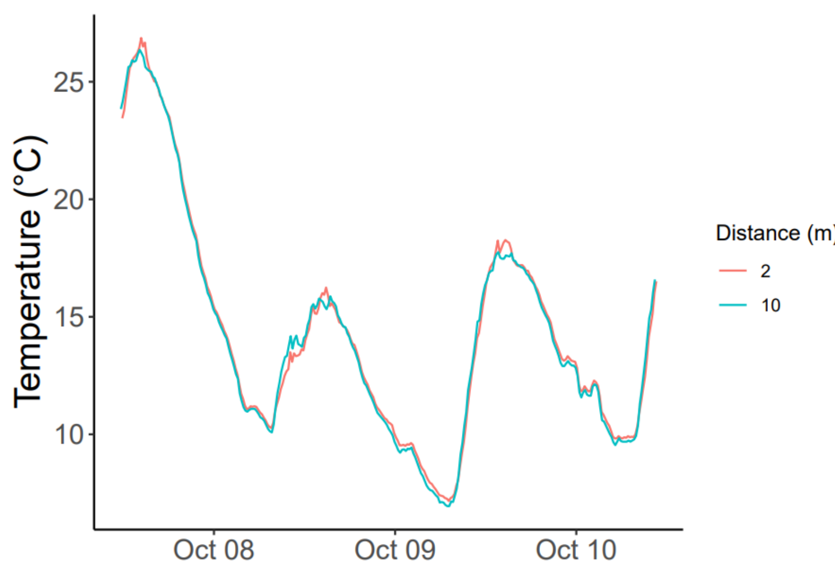

Figure 3.3 The air temperature for tree number 17 in the first round was higher at 2 meters away than the 10 meters away from the tree trunk, which does not support our hypothesis.

CHAPTER 4

4.1 DISCUSSION OF THE RESULTS

Our hypothesis was that trees have a cooling effect on the surrounding environment by reducing the air temperature and thus decreasing the urban heat island effect. Thus, we had predicted that when we placed paired air-temperatures sensors ten meters and two meters away from the trunks of the trees, we would find a detectable difference, and that the temperatures closer to the tree would be significantly lower than those recorded by the ten-meter sensor. The data collected did not support the hypothesis.

By analyzing our data, we found that there was not a detectable difference between the two sensors that recorded the air temperature at the two meters and ten meters from each tree. However, it is important to note that the results of this study by no means deny the validity of our hypothesis. There were certainly enough variables involved to warrant further studies exploring this issue, which is of extreme importance because of the potential health risks involved to the planet and its population.

This research has some limitations, which can be summarized as follows: We conducted this experiment during the fall, which is cooler than the summer. Therefore, fall is not the optimum season to determine the effect of the trees on reducing air temperature. During the fall, when the weather is cooler and daylight shorter, leaves start to fall off the trees. The stomata in the leaves contribute to the transpiration process, whose levels are impacted by the density of the leaves. The transpiration speed increases with the larger surface of the leaves, and vice versa. (Maylani, Yuniati, and Wardhana 2020). Therefore, leaves play a crucial role both in removing heat from the air and in producing a cooler atmosphere.

Another limitation factor is the variability in the evapotranspiration rate of the approximately twelve tree species we used in this study. Species differ in evapotranspiration rate. Evapotranspiration is a process that involves transpiration and evaporation, which is transferring the water from the soil to the roots and then the leaves and then to vapor form. The combination of these two processes utilizes local heat and cools the air (Akbari et al., 1992 , P32.). In a study conducted by Hui and Chu (2019), trees varied in their transpiration proportion in an exceptional way from one species to another. *A. confusa* had the highest degree of perspiration and it was marginally higher than double the native species that were used in the study. In addition, *M.rura, and A confusa,* both of which did not express remarkable disparity in their transpiration rate.

Variations in the tree sizes also might have limited the effects of the research. I used trees with DBH ranging from 10–76 76cm, and height ranging from three to twenty meters. These findings contrast with the role of green coverage in reducing air temperature. Canopy size has a positive effect on decreasing the air temperature either inside or underneath the canopy up to 8°C. through perspiration (Georgi and Zafiriadis 2006; Rahman et al. 2017), in addition to the effect on trees in reducing air temperature based on how much shade each tree would provide (Bowler et al. 2010).

Based on the data collected, my observations are that measuring the air temperature for the whole day instead of just a portion of the day may not been adequate. This may be due to the fact that the effect might be greatest during the day when it is hottest.

Even though trees can act as a trap for the heat underneath their canopy, the evapotranspiration process can help to counter this impact (Gómez-Baggethun and Barton 2013). Substituting standard trees and vegetation for heat-absorbing surfaces is a crucial and natural way to mitigate the adverse effect of the urban heat island (Al Junid, et al., 2020).

4.2 Conclusion

Urban areas are generally 7.2 ºF (1.0 - 4.0 ºC) and during the night 1.8 - 4.5 ºF (1.0 - 2.5 ºC) degrees hotter than rural areas. The UHIE is caused by a combination of factors that are related to constructed environment as well as human activities. One of the main factors is the presence of impermeable surfaces, such as pavements, and buildings, which absorb and retain heat during the day and release it gradually during the night, making urban areas warmer than surrounding rural areas. Another factor is lack of vegetation and green spaces also contribute to warmer urban areas. The vegetation helps absorb and dissipate heat through evapotranspiration and shade, which helps to keep the surrounding areas cooler. These factors can have a negative impact on human health, causing heart-related illness, depleting water supplies, debasing air quality, increasing energy use, and decreasing the quality of life.

We continue to believe that trees have a distinct role in reducing air temperature and producing a cooling effect. The effect of trees in reducing air temperature has been detected and measured through several research and studies. We are questioning at what scale we can measure this effect.

4.3 Future Directions

Future research is needed to quantify the effect of individual trees in reducing air temperature and cooling the surrounding atmosphere and subsequently in reducing urban heat island effect. The cooling effect of trees is amplified by them being close together. When trees are open (as they often are in urban settings), wind can easily bring warm air under the canopy. I would speculate that isolated trees might have a bigger impact on soil temperature than on air temperature.

Further analysis of the collected data should compare both round 1 finding with those from round two and daytime versus nighttime results. Further, follow up research should employ non paired analysis that looks at sensors across the landscape, correlating data with tree density. By using the hemispherical photos that have already been taken, researchers can collect enhanced measures of the impact of the trees versus the buildings by tracking the sun as it moves across the sites.

To address possible flaws in the original research, I would adopt several changes, including the selection of more isolated trees to avoid the interference of shadows from buildings or other trees,and the deployment of sensors at different locations, placing one closer to the trees than in the original study and the second at a greater distance away. I would measure the air temperature beneath the canopy and near the tree. I would also prioritize more diversity in the species of trees selected. Last, I would conduct the experiment during the warmer months of July through late September, rather than late September through mid-November, as in the original study.

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