Samantha King-Cash

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Christopher Labosier

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Longwood University - Hot or Not: Urban Heat Island Effect on Campus

I. Introduction

Population growth in the world over the past few decades has caused urbanization patterns to be on the rise. Due to this rising urbanization, the temperatures in cities have been increasing when compared to the surrounding rural areas. This effect is what is known as an urban heat island, or UHI. The main sources of these urban heat islands are the human population densities, city structures themselves, and human activity ("Urban Heat Islands," 2012). Urban areas have many negative impacts on the environment, including health problems for individuals as well as the ecosystem and an increase in the consumption of energy ("Heat Island Impacts," 2019).

We can begin our discussion on UHIs by asking if Longwood University's campus as a whole is an urban heat island or is it only certain areas that see UHI effects? Additionally, how do the warmest and coolest places on the campus compare in temperature, and how does the environment surrounding these locations affect the temperatures? It is important to understand the impact that urban heat islands have on the surrounding environment and community, because as urban environments expand, their effect on local warming becomes more drastic.

Recent studies, such as *Associated Determinants of Surface Urban Heat Islands across 1449 Cities in China* conducted by Li, Wang, Liu, Zhao, He, and Mao (2019), show that the populations of different urban heat islands suffer from the same effects at varying intensities. The buildings and city planning of more populated areas are distinct when compared to urban environments in less populated areas. As of now, not much research has been done on UHIs in rural locations because the focus has been primarily on major cities where the effects are more dramatic. The specific location chosen for our research on the effects of urban heat islands in rural towns is Longwood University in Farmville, Virginia.

Our research goal is to "identify spatial variations of temperature across campus" and the purpose of our research is to find out how urban architecture can alleviate small-scale temperature patterns. In this paper, the explanation of how urban heat islands are formed, what their impacts are, and mitigation strategies are discussed. Further, we examine how higher temperatures result from the architectural design of areas, lack of vegetation and moisture, and expanding human activity on Longwood University's campus - leading "to pollution, climate change and disproportionate negative health impacts" (Austin *et al.*, 2019).

II. Literature Synthesis

Urban heat islands are characterized by a significant increase in temperature due to the urban environment and increased population, which causes heat to be retained overnight and increases the pollution released into the environment. This is often the result of tall buildings trapping the heat that is being released from the ground and other surfaces with a low albedo ("Urban Heat Island," 2012). Low albedo means that a surface is able to retain more of the sun's energy, and is commonly associated with darker surfaces, such as streets and darker sidewalks. Low albedo surfaces also are not able to absorb water, so they do not cool down as quickly in the rain. Temperatures are rising in cities is a lack of vegetation, as vegetation is important in the absorption of rain water, and therefore, moisture is trapped in the air, which increases temperature (Voelkel and Shandas, 2017).

The temperature in urban heat islands during the day can be as much as 1.8 ºF to 5.4 ºF hotter than surrounding rural areas, while nighttime temperature differences can reach 22ºF (“Heat Island Effect,” 2019). The human population’s health is impacted by the rise in temperature, specifically side effects being dispersed among certain groups of people, increasing the possibilities of heat stroke, fatigue, and death (Anderson and McMinn, 2019). Those most affected by heatwaves are lower socioeconomic class individuals, infants, and the elderly. The main reason health risks are disproportionately felt throughout classes is due to the living conditions of each class. Lower socioeconomic classes are less likely to have access to air-conditioning and housing. They are also more likely to live in the city with limited access to transportation other than walking, subjecting these individuals to the higher temperatures felt throughout these areas (McCoy, 2019).

Aside from humans, entire ecosystems are susceptible to the negative impacts of urban heat islands. Water quality deteriorates when the hot runoff of stormwater reaches bodies of water, destroying the ecosystems found here (“Urban Heat Islands,” 2012). Sometimes this can help one species in the ecosystem, while weakening other species, forcing them to migrate, or even killing them off. Plants suffer through these environmental changes, also. Higher temperatures that are abnormal to a certain area can cause problems with the soil processes, such as leaf decomposition and the mineralization of nitrogen. This can in turn affect the plants in the ecosystem due to the lack of nitrogen in the soil (Yow, 2007).

The pollutants from human activity damages air quality in ecosystems as well. When it gets hotter out, energy consumption rises. People are less likely to bike or walk when the temperatures increase, meaning a higher use of cars. Cars are not the only causes of pollution; the use of air conditioners and other cooling systems becomes more prevalent, too. These cars and cooling systems release pollutants into the air, such as sulfur dioxide, carbon dioxide, and carbon monoxide. Contaminated air causes vital organs in animals and people to fail (Sharma, Jain, Khirwadkar, and Kulkarni, 2013).

Various strategies have been found to help mitigate the urban heat islands. Some of these include architectural and city planning, vegetation increase, changes to human lifestyles, and laws and policies put in place. These simple strategies have provided solutions that benefit the environment in multiple ways.

The planning of cities and the architectural structures of buildings can significantly reduce the heat in these urban locations. One change that can make a difference is replacing the darker asphalt and concrete to lighter tones. The lighter concrete and asphalt absorb water more easily as well as reflect the sun’s radiation, releasing more heat into the atmosphere rather than being trapped on Earth. A second structural idea is to change the architectural design of buildings. By adding open areas in the building structures, wind is able to flow through the openings, producing cooler temperatures (Salata *et al.*, 2015). Green roofs can also be added to buildings to reduce heat intake. Another change that can be made to city planning is putting in cooling zones. These are spots in which individuals can take a break and go inside somewhere where air-conditioning is provided in order to cool down for a little.

The increase in vegetation creates more ways to lower the temperatures in the urban heat islands. Putting more vegetation, such as trees, bushes, and grass, allows the process of evapotranspiration to take place. This process is when evaporation of water from the soil and transpiration of plants returns water back into the air. The vegetation provides shade for people and animals, along with lowering the overall temperature of the area (Salata *et al.*, 2015).

Lifestyle changes, like the decrease in energy consumption, can make a difference in the amount of pollutants released into the atmosphere. Not only do green roofs give a home to animals and allow for evapotranspiration to occur, they also insulate buildings, meaning less use of energy ("Reduce Urban Heat Island Effect," 2019). Cooling systems would not need to be used as much in buildings with the input of these green infrastructures. People could choose to walk or bike more, instead of using cars, which would reduce the pollutants put into the atmosphere, too.

The influence of the national and local governments through laws and policies is the last mitigation strategy of urban heat islands. The authorities are able to pass laws and policies promoting green infrastructures and restricting the amount of pollution into the atmosphere. Cars and air-conditioning units release gases that disrupt the environment, so the addition of laws limiting these objects can help reduce the energy consumption and pollutants.

III. Data and Methods

Our study area we decided to research is Longwood University in Farmville, Virginia. It is about 154 acres (0.62 km^2), roughly in the middle of Virginia. The climate in this area is hot, muggy summers and cold, wet winters (Average Weather in Farmville, n.d.). We are looking to answer the question of what causes the UHI effects on Longwood University's campus and how we can lessen the effects through mitigation strategies.

As a group, we began to answer the research question by finding previous studies that were similar to ours. The first study was focused in Portland, Oregon by Jackson Voelkel and Vivek Shandas. These researchers utilized scientific tools that were beneficial to our study, so we mirrored their data collection process and the techniques they used; however, they used a car to collect data while we were on foot (Voelkel and Shandas, 2017).

We started the data collection by gathering the necessary tools. The tools used were a GPS receiver and a data logger connected to a PVC pipe with a thermocouple sensor in the opening of the PVC pipe to allow airflow (Figure 1). The thermocouple was used to collect temperature in degrees Fahrenheit, while the GPS tracked the geographical location per second. Next, we chose a day with record-setting heat to record temperatures and followed a transect to collect the statistics on 3 September 2019, beginning at 2:25 pm EST and completing at 2:53 pm EST. Then, we went back out at a later date with a FLIR C2 thermal imaging camera, which took infrared pictures as well as regular pictures simultaneously. We collected pictures of structures or areas with varying temperatures. Specifically, we looked for areas on Longwood University's campus with noticeably low or high temperatures and correlating spatial variation of these areas (Austin *et al.*, 2019). The data collected was analyzed by creating an Excel spreadsheet listing the date of observation, the local time, latitude, longitude, and the temperature recorded in both Celsius and Fahrenheit.

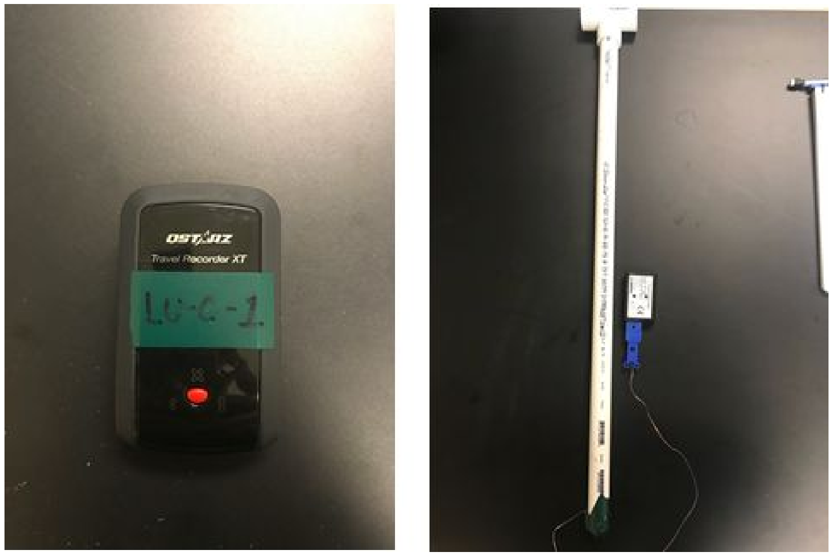


Figure 1. GPS tracking device (left) and thermocouple connected to data logger located inside a PVC pipe (right) (Austin *et al.*, 2019).

IV. Results

Figure 2 shows Longwood University's campus with the transect and correlating temperatures depicted as the color-coded dots from 3 September 2019. The temperatures we collected were between 78.6 °F and 93.6 °F with the mean of the data set equal to approximately 89.7 °F. The temperatures' range was approximately equal to 14.9 °F with a standard deviation of 1.8 °F (Table 1). The highest temperatures on Figure 2 are represented by the red dots. These areas typically are made up of asphalt or cement and have no tree coverage. The main reason there are a large amount of red dots on the upper right-hand side of Figure 2 is most likely due to the heating plant and recycling center located next to a wide street with very little shade. These all would cause a higher overall temperature in that small area when compared to other places on campus. On the other hand, the lowest temperatures mostly correlate with vegetation and/or canopy covered areas.

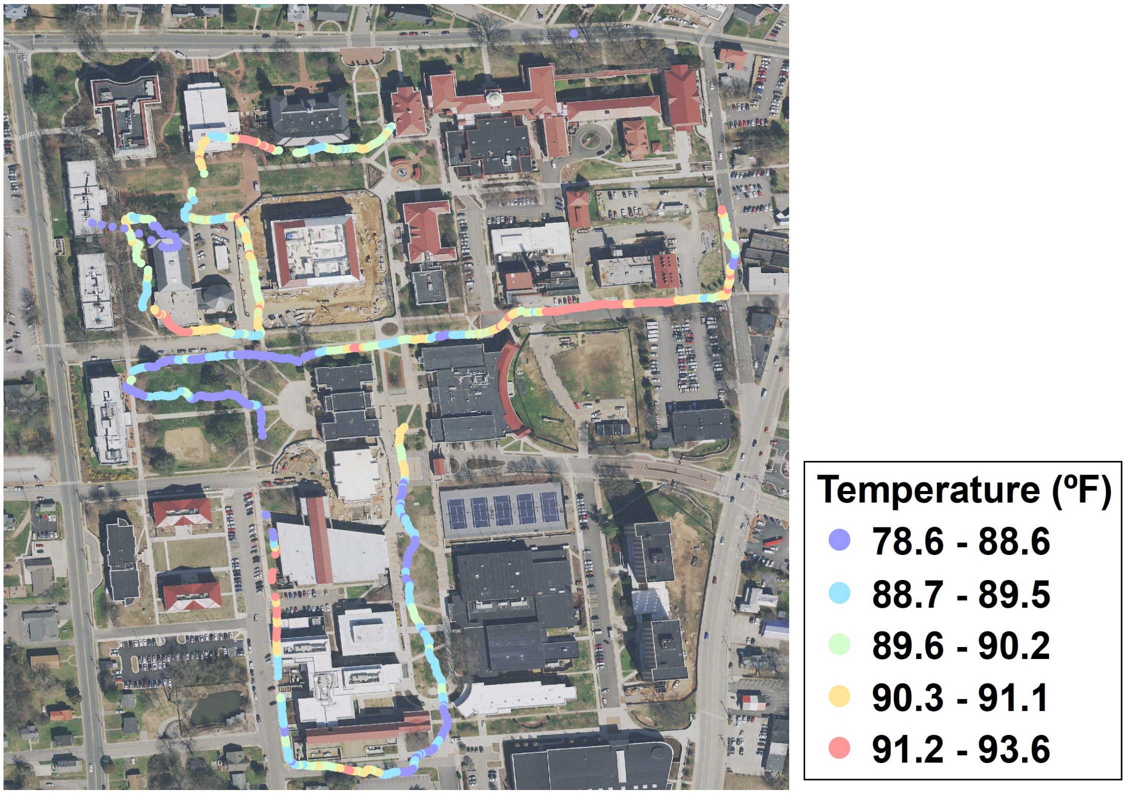


Figure 2. Imagery of Longwood University campus with multi-colored dots representing transect and the corresponding temperatures (Austin *et al.*, 2019).

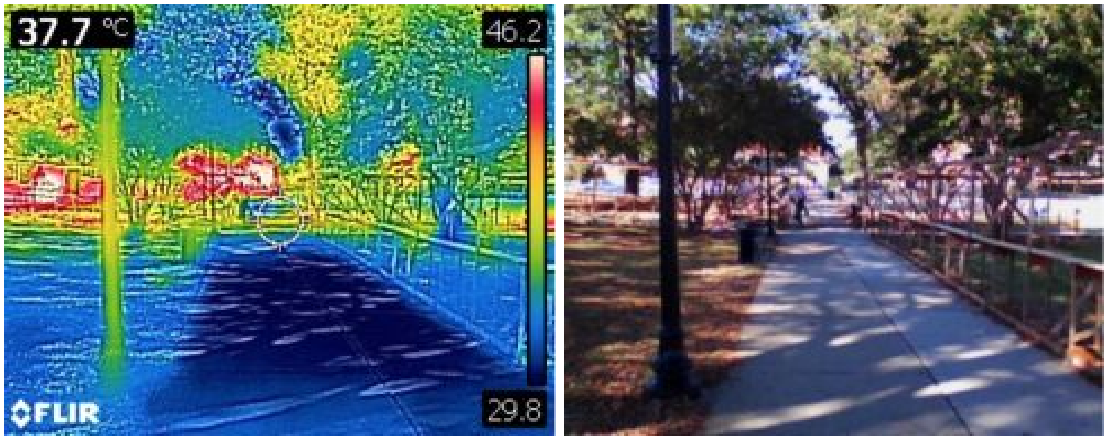
Metric	Value
Mean	**89.7ºF**
Standard Deviation	**1.8ºF**
Maximum	**93.6ºF**
Minimum	**78.6ºF**
Range	**14.9ºF**

Table 1. Statistical data from transect on 3 September 2019 (Austin *et al.*, 2019).

Figure 3 shows the infrared image of the temperature and heat of a parking lot in comparison to the grassy area next to it. Figure 4 is the same picture with color to show the difference in surface composition. The highest temperature of the scale is equal to 124.34 °F and the lowest is 49.64 °F. The grass and asphalt is in the red to white range on the scale, meaning the temperatures are approximately 96.08 °F to 124.34 °F. We found that the lack of moisture in the soil of the maintained lawns around campus cause these grassy areas to be just as hot as the asphalt, which is known to have a low albedo. This relationship can be seen in the figure below with the high amount of heat given off, even though both surfaces have different compositions (Figure 3).

Our studies show that the characteristics of a surface and the surrounding environment determines the temperature. Some of the qualities that tend to cause a surface to give off a large amount of heat would be a low albedo level and the inability to absorb water. No canopy coverage also causes higher temperatures. Likewise, a lower temperature will often result from a higher albedo level, the ability to absorb water, and sufficient canopy coverage (Figures 5 & 6).

Figures 3 & 4. Infrared image vs. color image captured with an infrared camera taken of parking lot and grass on 3 September 2019 (Austin et al., 2019).



Figures 5 & 6. Infrared image vs. color image captured with an infrared camera taken of the sidewalk and the canopy coverage on 3 September 2019 (Austin et al., 2019).

V. Discussion and Conclusion

Our findings demonstrate that there is a large spread of temperatures across the Longwood University campus correlating to varying locations. An analysis of the data collected shows that the presence of adequate vegetation and canopy coverage is correlated with lower temperatures. Therefore, temperatures are relatively higher for surfaces that are made up of heat-absorbing materials and/or limited-to-no canopy coverage (Austin *et al.*, 2019). The results from the previous section show how there can be small-scale UHI effects on a less-populated area than the studies that have previously been conducted in large cities by other researchers.

These results mean that the university campus does have some areas where UHI effects could cause negative effects for some people and the environment around these areas. In response to these issues, the campus landscaping or ground maintenance staff should think about mitigation strategies. They can add more trees and/or shrubbery, maintain the lawns to ensure appropriate moisture levels, and use infrastructure materials that have lower albedo levels, all of which would help lower average temperatures across campus. The use of certain technologies such as temperature and humidity sensors around campus can help mitigate the rising temperatures also by allowing the school to prevent negative UHI effects on the university's campus (Georgia Tech, n.d.).

There are a multitude of future research studies that should be conducted on the UHI effects on Longwood's campus. Further research on our studies could begin with choose a path that is followed consistently with the same tools we used, a GPS receiver and PVC containing a thermocouple connected to a data logger, and conduct the study over multiple weeks. Another idea for research could be to collect the temperatures throughout 24 hours to see how UHI affects nighttime temperatures in comparison to daytime temperatures. Studies could also be conducted over a full year during each season to see the seasonal effects on campus, especially how temperatures would change due to snowfall, since snow has a high albedo. This same study could provide us with a monthly UHI analysis to note when the highest and lowest temperatures tend to be, then find the reasoning behind the correlating UHI effects.

In conclusion, the temperature data we collected confirms there is a small UHI effect on Longwood University's campus in Farmville, Virginia due to structural designs, a lack of vegetation and soil moisture, and increased human activities. Our studies show that (1) tree canopy coverage is an effective way to mitigate higher temperatures, (2) lack of soil moisture in manicured lawns cannot be a replacement for flourishing trees and other vegetation, and (3) "in regards to temperature, manicured lawns are similar to asphalt and concrete." The data collected on our transect from 3 September 2019 span from 78.6 ºF and 93.6 ºF on a record-breaking day of heat (Austin *et al.*, 2019). The overall effects on our campus showed negative impacts on the environment. These effects are small in contrast to surrounding larger cities, such as a previous study done in Roanoke, Virginia by Parece, Li, Campbell, & Carroll (2016) with a significantly larger population size. The study conducted in Roanoke showed a larger impact on the area, especially in comparison to the small Longwood University campus.

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