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Final Research Paper

Introduction

The Urban Heat Island effect is a rapidly growing, widely spread, phenomenon sweeping and slowly destroying our nation. An urban heat island occurs when an urban area has microclimates that are hotter than the climates of their surrounding rural areas. Urban Heat Islands are contributing to climate change with the higher temperatures cities put out from vehicles, large buildings, factories, air conditioners, and dark building materials (i.e. concrete and asphalt) which absorb the energy from the sun and add warmth to their surroundings (Price, 2015).

This paper will discuss if the energy that college campuses retain, due to dark building materials such as concrete and asphalt as well as large amounts of electricity used, make an area more susceptible to having the characteristics of an Urban Heat Island in what is thought of as more rural areas.

Literary Synthesis

An urban heat island occurs when a metropolitan area which is significantly warmer than its more rural surroundings. Urban heat islands form in metropolitan areas as vegetation is replaced by dark building materials such as asphalt and concrete for roads, buildings, and other structures necessary to accommodate growing populations in an urban setting (UCAR, 2011).

The reason that metropolitan areas are more susceptible to the urban heat effect is that areas with more dense and taller buildings trap air between them causing the temperature to go up, this causes said areas to rapidly develop into heat islands (UCAR, 2011). However, the architecture described is needed to accommodate growing populations in cities, as well as places like college campuses, which house many people in a small area. This means that we must find other ways to mitigate the urban heat effect in metropolitan areas. Urban areas are a major contributor to climate change because although they currently cover less than 3% of the earth's surface, they are responsible for an estimated 71% of global energy-related carbon emissions causing the earth's surface temperature to increase (Battisti, A., et. al., 2018).

Although the heat island effect is more common in metropolitan areas over more rural areas, due to the high density of tall buildings made of heat absorbing materials, this information does not exclude more rural areas from the urban heat effect (UCAR, 2011). College campuses are an example of how more rural places, i.e. Farmville, can become susceptible to the Urban Heat effect than they might be without those campuses. Although Farmville is more rural than major cities such as Richmond and Washington D.C. it is still susceptible to the urban heat effect as it has many tall buildings in order to house and teach the students and faculty who attend and teach at Longwood University and Hampton Sydney University.

This phenomenon has caused researchers to study, research, and purpose a way to decrease and try to reverse the effect that have caused Urban Heat Islands through different Mitigation Technologies. One major mitigation technology that has been shown to reduce the heat effect is an adaption of roofs to be more eco friendly, and not just a giant slab of concrete collecting heat energy.

One roof adaptation used to decrease thermal temperatures is the use of cooling roofs. Cooling roofs are designed to be more reflective of sunlight and absorb less heat than a standard roof (US Department of Energy, 2019) An analysis done on cool roofs showed that the expected depression rate of the average urban ambient temperature varies between 0.1 and 0.33 K per 0.1 increase of the roofs albedo with a mean value close to 0.2 K (Santamouris, 2014). Another roof adaptation studied is the use of green roofs. Green roofs are a building's roof that has vegetation and a growing medium, planted over a waterproofing membrane. Green roofs are ideal for urban buildings with flat or shallow-pit roofs, and can include anything from basic plant cover to a garden (US Department of Energy, 2019). Green roofs are particularly effective in how they may reduce the average ambient temperature between 0.3 and 3 K (Santamouris, 2014).

The research done on both cooling roofs and green roofs show how they are very effective in the reduction of the urban heat effect, as they provide both direct and ambient cooling effects. In addition, it has been found that green roofs improve air quality by absorbing pollutants from the air cleaning it and increasing vegetation which provides more shade. Cooling roofs are particularly effective as they can be made of reflective materials, such as white vinyl, which would reflect the heat of the sun instead of absorbing it (Levinson, Ronnen M. et. al., 2017).

Although green and cool roofs are extremely effective methods of mitigation it seems that lighter colored building materials are the easiest to implement into the current urban setting as they seem to be less costly to impose into metropolitan areas and would change thermal temperatures drastically. Lighter colored building materials are green infrastructure improvements that are easier to implement into regular street upgrades and capital improvement projects to ensure continued investment in heat-reducing practices throughout your community (Rosenzweig, C., et al, 2006).

Simply by using a lighter color material to build streets and buildings we could reduce thermal energy levels by a large amount. Streets and sidewalks are constantly replaced with the same dark, energy absorbing asphalt and concrete when, solar reflective "cool pavements” stay cooler in the sun than traditional pavements. The reflectance of pavement can be enhanced by using reflective aggregate or a reflective surface coating which in turn would lower the thermal temperatures being absorbed (Levinson, Ronnen M. et. al., 2017).

Another simple mitigation technique would be the implementation of increased vegetation in Urban areas. Decreased vegetation is very important to the development of Urban Heat Islands as the displacement of trees and vegetation minimizes the natural cooling effects of shading and evaporation from the soil and leaves causing thermal temperatures to rise (UCAR, 2011). Vegetation is often heavily decreased and disposed of in metropolitan areas in order to increase the space to build more energy consuming buildings and streets. However, a previous study showed that vegetation patch size had a direct effect on reducing the land surface temperature of the green space in metropolitan areas. Green spaces with more vegetation tend to reduce the land surface temperature. The results of the study showed that the largest green spaces were between 1.5 and 2.8 °C cooler than the surrounding buildings (Gioia, et. al., 2014). These results help to prove that increased vegetation could only benefit urban settings as they help to reduce and reverse the effects of urban heat islands.

Urban heat islands have elevated temperatures due to structural design, lack of vegetation and water, and increasing human activity. This leads to pollution, climate change and disproportionate negative health impacts. Native, healthy tree covering can assist with the mitigation of high temperature environments and slow the spread of the urban heat island effect that is impacting metropolitan areas as well as college towns, such as Farmville.

Data & Methods

In order to determine whether or not the energy from the dark building materials and large amounts of electricity that college campuses retain make an area more susceptible to having the characteristics of an Urban Heat Island in a more rural area, we tested the effects of spatial variation on temperature of Longwood University's campus. Our goal was to understand how urban designs can affect small scale temperature patterns and how that can further lead to the urban heat effect. On September 3, 2019 we created a route throughout the campus of Longwood University which included a variety of different building heights and spatial variation. We followed the route while employing the use of a GPS unit and a thermocouple with a data logger enclosed in a PVC pipe in order to record temperature based data in relation to our location on campus at the time of the logged temperature. We repeated said route several times, but chose September third due to its high temperatures. We also used a FLIR C2 thermal imaging camera in order to capture both visible and thermal images of different locations throughout the campus in order to compare the surface temperature of different building materials.

Results

In our analysis of the data we found that there was significant spatial variation in temperature across campus. This analysis demonstrated that the presence of adequate vegetation is heavily associated with lower thermal temperatures, and consequently, surfaces composed of heat-absorbing materials, such as concrete or asphalt, that didn't have proper coverage were associated with higher thermal temperatures. In places with little to no vegetation and heavy building materials, such Madison Streetand the tennis courts (pictured bottom right on the poster), Longwood campus's surface temperature went up to 93.6 °F, in places of high vegetation, such as Stubbs lawn (pictured bottom left on the poster) , the surface temperature went as low as 78.6 °F. The range of 14.9 °F in our findings helped us to find that there was significant spatial variation in temperature across campus due to the difference in vegetation levels. We also found that manicured lawns, with inadequate soil moisture, are a poor substitute for healthy, native trees, and in regards to temperature, manicured lawns are similar to asphalt and concrete (pictured top left on the poster) . We found that campus designs that include adequate plant canopy coverage will assist with effective mitigation of high temperature environments reducing the urban heat effect.

Discussion & Conclusion

Due to the results of our data, it can be concluded that high vegetation can reduce the urban heat effect and lower the thermal temperature of the land that it covers, making areas less susceptible to becoming urban heat islands. For Longwood University, and the Farmville area, this means that we should continue, and increase, the high amount of vegetation planted throughout the campus in order for temperatures to remain or lower to habitable living conditions and not to contribute to climate change and global warming. The campus could also work to use more environmentally friendly building materials as well as adapting our current buildings with flat roofs to green or cooling roofs.

It has been shown through our research that the urban heat effect has a direct correlation to spatial variation as well as building materials and vegetation levels. Future research should be done on the vegetation levels and thermal temperatures of the Farmville community as a whole, as well as other college campuses, and their surrounding areas, in different climates and locations of many different sizes in order for our results to be validated. The increase in research should also include all times of year as well as all times of day. We could not accomplish this ourselves due to time restrictions of the course.

References

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