GIS Heat Mapping of Farmville, Virginia

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Abstract

Urban heat islands can pose a significant problem to our ecological environment. In the previous summer on July 15th, participants recorded heat data throughout nine specific paths in Farmville using heat sensors; this is the data I used for this project. CAPA Strategies, LLC modeled the data and provided a predictive raster surface model of temperature and heat index. The assumption for the heat data is that it would be more elevated in places with high levels of impervious surfaces such as the historic downtown area. Having elevated levels of heat in high populated places can be very detrimental for health, especially for older citizens. To display and analyze the data, I created multiple heat maps using ARCGISpro. Each map showed different data laid out in different formats. Multiple maps were created for the morning, afternoon, and evening temperatures using different scales to compare and contrast. Overall, the maps were very crucial in informing us how the heat island effect presents itself in Farmville. It was very important for us when we were narrowing down our locations for the fall tree planting. After all the spatial data was analyzed and presented to the local government officials including Jay Wilkerson, Farmville’s Arborist, and land stakeholders, final locations of tree plantings were determined.

Introduction

The heat island effect is a danger to our ecological environment. It can cause elevated temperatures during the day and night which can lead to overheating and heat stroke. Urban heat islands occur when cities replace natural land cover with dense concentrations of pavement, buildings, and other surfaces that absorb and retain heat. These kinds of surfaces can lead to higher daytime temperatures, reduced nighttime cooling, and higher air-pollution levels, (Climate Change and Heat Islands). Global warming is a topic that closely coincides with the heat island effect.

If temperatures continue to rise, heat islands will become more severe. Heat wave frequency and severity are expected to continue to increase as global temperatures continue to rise due to climate change. Areas already impacted by heat islands will likely bear the brunt of these heat waves and their associated harmful health and environmental effects, (Climate Change and Heat Islands). For example, carbon dioxide absorbs energy at a variety of wavelengths between 2,000 and 15,000 nanometers, a range that overlaps with infrared energy. As CO2 soaks up this infrared energy, it vibrates and re-emits the infrared energy back in all directions. About half of that energy goes out into space, and about half of it returns to Earth as heat, contributing to the greenhouse effect, (Fecht, 2021). With global warming on the rise, planting trees is one of the best ways to help combat the heat island effect. This is due to the tree coverage providing shade and absorbing heat that would have been absorbed by the ground otherwise. Heat Watch was a program that surveyed areas for heat data in 2021. Their goal was to help reduce heated areas in towns by introducing green ways to cool the area (such as tree planting)

My objectives for this research project are as follows:

1. Learn the basics of ArcGIS Pro to be able to map and analyze heat map data and determine the ideal area to plant trees.
2. Compile a literature review on urban heat islands and their effects on community tree plantings.
3. Compose a series of GIS heat maps that display different aspects of the data differently and informatively.
4. Analyze the heat map data to understand which areas of Farmville are in the most need.
5. Use the compiled heat maps to pick two overheated locations for a tree planting.

Methods

Data Collection:

The Virginia Foundation for Independent Colleges (VFIC) Heat Watch Campaign occurred on July 15, 2021. Specialized sensors were used to measure ambient temperature, humidity, longitude, latitude, speed and course in the morning, afternoon, and evening in 10 cities on the same day. The participating cities were Abingdon, Arlington, Farmville, Harrisonburg, Lynchburg, Petersburg, Richmond, Salem, Virginia beach, and Winchester in Virginia.

In Farmville, data was recorded along nine predetermined routes. Each of these routes were walked by the volunteers who were holding sensor devices and recorded in the morning at 8am, afternoon at 2pm, and evening at 7pm. The data was compiled by CAPA Strategies, LLC and used to create a raster data set. This was done by the point temperature data being extrapolated and modeled to create a raster layer dataset. Raster data is pixelated or gridded data

where each pixel is associated with a specific geographical location, (Introduction to Raster Data). A Raster layer was assigned a specific value based on the heat data. The resolution for our data set was 10 meters which is standard for LandSat data. The end result was a model heat map showing where the elevated temperatures are located in Farmville, VA.

Learning and Processing Maps in ArcGIS Pro:

I became acquainted with GIS through online tutorials and extensive literature review. This allowed me to become familiar with creating map layers and customizing them to be user friendly. Images were created for the data collection paths for each time of day (3 maps total). Next three base maps displaying temperature for the different times. Building these three heat maps allowed the opportunity to change symbology and to select map formatting and colors. The colors indicating the heat values helped to gain a deeper and quicker understanding of the data. Other maps were created that looked at: difference in morning to evening temperatures, humidity index, and humidity index minus regular temperatures. These maps were overlaid onto GIS maps of Farmville (collected via free sources—cite these and by contacting the Farmville GIS representative). These compiled maps allowed us to compare different aspects of the data to identify heated areas and aid in determining tree planting locations.

Results

The map where morning temperatures were subtracted from evening temperatures provided a visual on the difference in temperature from morning to evening. This showed clear areas that were experiencing high levels of heat. It also showed which areas were holding significant levels of heat overnight. These locations are likely to experience heat island effects. (Figure 1).

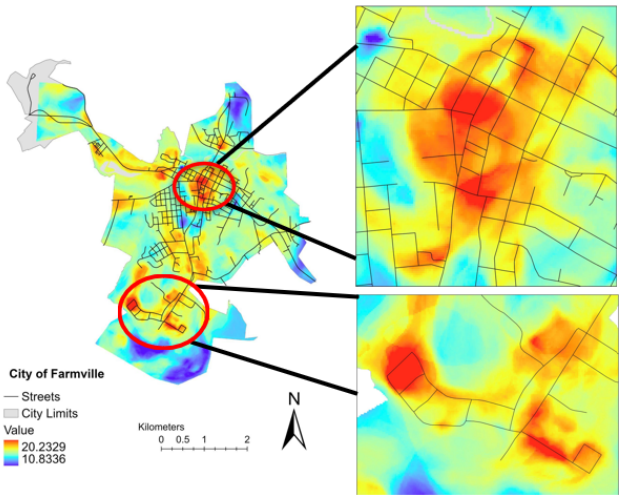

Figure 1: Two heat spots

The map on heat and humidity index data showed the temperatures for the heat index were higher than just the temperature. Apparent temperature, also known as the heat index, is what the temperature feels like to the human body when the air temperature is combined with the relative humidity, (What Is the Heat Index?). Specific colors were assigned to each temperature range and overlaid onto the Farmville map for each time of day (Figure 2). This allowed us to see not just the temperature but also the heat index across Farmville. This is how hot it actually feels in these areas, not just how hot the temperature is (Figure 2).

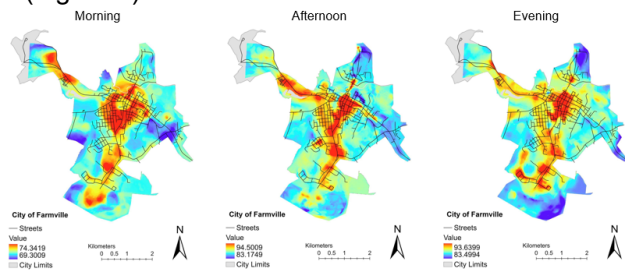

Figure 2: Heat distribution over time

To determine how humidity impacted heat islands as compared to regular temperature, the heat index data from a specific time of day was subtracted from the temperature data from the same time of day. From this, it was clear which areas were holding significant levels of heat. Also, it displayed how areas would feel to citizens versus what the forecast says the temperature was. These maps showed that humidity does, in fact, correlate to heat islands. The results of these maps showed multiple areas around Farmville with a significantly higher heat index compared to temperature. (Figure 3).

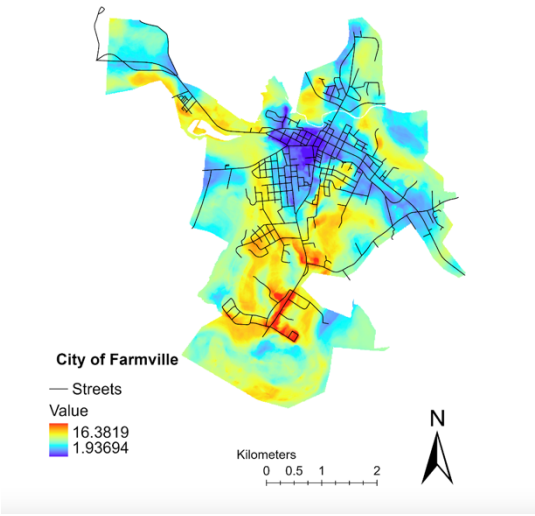

Figure 3: Evening heat index minus evening temperature

The last maps compared the temperatures and times of day. Some of the next maps created were classified maps instead of stretch which allows the assignment of temperature values to specific colors. This gave even more specific results. For these, a uniform scale was created where color indicated intervals of five degrees Fahrenheit with blue being the coldest and red being the hottest. Heated areas within Farmville were easily highlighted as red (Figure 4). Each time of day has a uniform map for the humidity and the temperature (Figure 5).

Using the different maps created, the three areas of highest temperature were identified as tree planting locations.

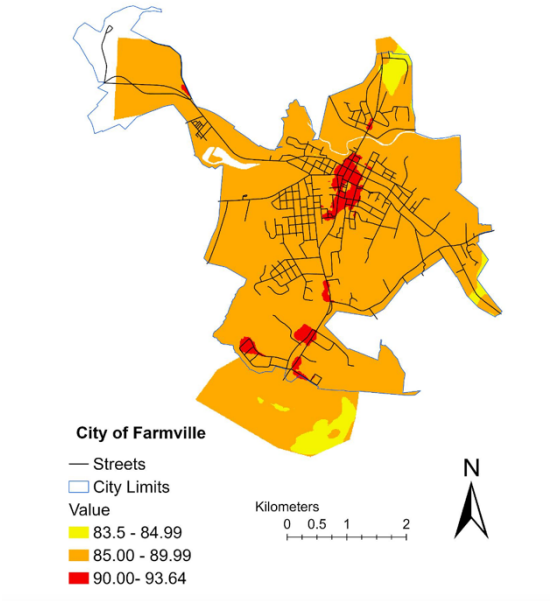

Figure 4: Evening temperature

These locations were also recommended by Jay Wilkerson. Since the same locations were identified by two different methods, this helped with 1) easier access to planting localities already recommended by the local government and 2) the hot spot could be cooled after trees were planted. We chose two ideal locations: the parking lot of the Fishin' Pig and the Andrew Drive public basketball court that were deemed hotspots and easily accessible.

Discussion

I was able to achieve my objectives of utilizing ArcGIS Pro to build maps to analyze heat map data and in using literature to understand heat island effect. My results showed the Fishin' Pig parking lot and the Andrew Drive public basketball court were two spots that were both hot zones for temperature and were around areas of highly impervious surfaces (concrete and asphalt). Both locations are considered public land and allow for easier access to plant trees.

Lower surface and air temperatures can be achieved by planting trees and vegetation which provide shade and evapotranspiration. Shaded surfaces may be 20–45°F cooler than the peak temperatures of unshaded materials. Evapotranspiration alone, or in combination with shading, can help reduce peak summer temperatures

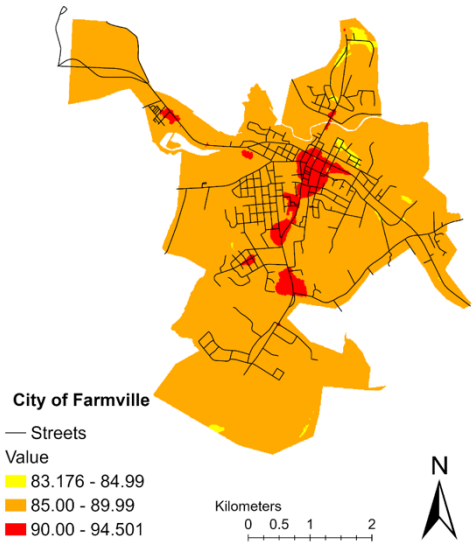

Figure 5: Afternoon temperature

by 2–9°F, (Using Trees and Vegetation to Reduce Heat Islands). The Fishin' Pig area averaged over 90 degrees Fahrenheit during day and evening times on all maps, while the basketball court averaged over 85 degrees Fahrenheit during day and night times on all maps. As predicted, areas that hold high levels of heat will stay warmer throughout the day and night.

With Farmville being such a small town, it was surprising to see these high levels of heat found in different locations around town. This shows that even small towns can experience large heat island effects around areas with high levels of impervious surfaces. These locations tended to overlap each other on the different map scales. With the tree planting this fall, the two locations chosen should experience significant temperature reductions. These were two areas with high levels of impervious surfaces which trap and retain heat. The new trees will provide shade for the area as well as absorb some of the heat. To check the progress of these areas after the planting; I would recommend that they be monitored at least once a year to compare the current and old temperature values. This way we can see if they are being cooled by the new trees and if so, by how much.

It was decided however, that it would not be just a tree planting; it will also be a seedling giveaway. This was an appealing idea because it gives an opportunity to citizens all throughout Farmville to plant

their own trees on their own land. This way, hopefully we will have impacted more than just the two chosen locations.

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