Methods for Reducing Urban Heat Islands: A Comparison of Seattle, El Paso, Jackson, and Norfolk

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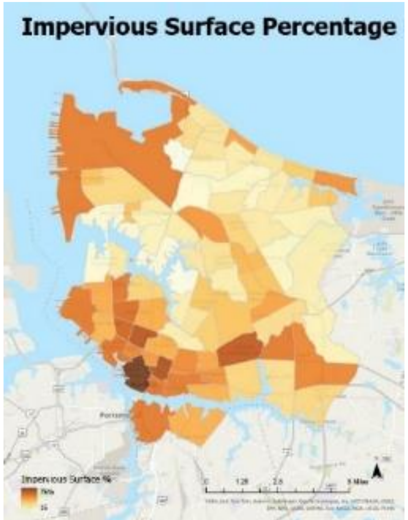
Purpose Statement: A metropolitan region that is significantly warmer than the rural areas surrounding it is known as an urban heat island (UHI). These UHIs are dense in places with lots of activity and people. My research focused on Seattle, Washinton; El Paso, Texas; Jackson, Mississippi; and Norfolk, Virginia. I chose these cities because two of them are landlocked and two of them are not. There are different processes these cities can do to help minimize the urban heat island effect. Previous studies have shown that simply making the area more tree dense and reducing impervious service can help significantly. (*High summer land surface temperatures in a temperate city are mitigated by tree canopy cover* 2023, *On the influence of density and morphology on the urban heat island intensity* 2020) This project aims to explore these relationships further, along with the population of each census area shown.

Four Questions and Hypothesis that I Tested on these Cities Include:

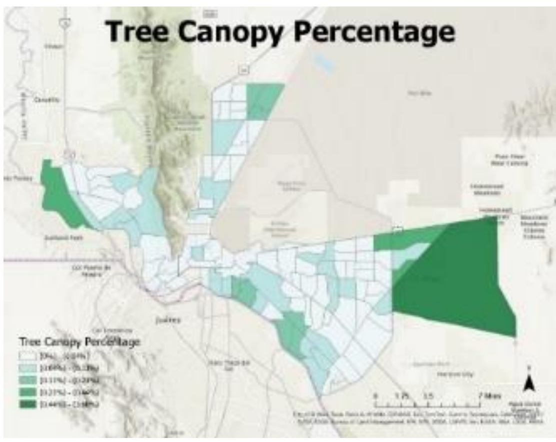
1. **How does tree canopy percentage affect UHIs?**
   a. H1: Tree Canopy Percentage decreases UHIs.
   b. H0: Tree Canopy Percentage does not affect UHIs.
2. **How much do impervious surfaces affect the UHIs?**
   a. H1: Impervious surfaces increase UHIs.
   b. H0: Impervious surfaces do not affect UHIs.
3. **How much does the population affect the UHIs?**
   a. H1: Population increases UHIs.
   b. H0: Population does not affect UHIs.
4. **Does the R-score of the hypothesis above change depending on if the city is landlocked or on an ocean?**
   a. H1: Landlocked cities will have a higher R-score for the hypothesis than cities that are not landlocked.
   b. H0: Landlocked cities will not have a higher R-score for the hypothesis above in cities than cities on the ocean.

Explanations of Maps:

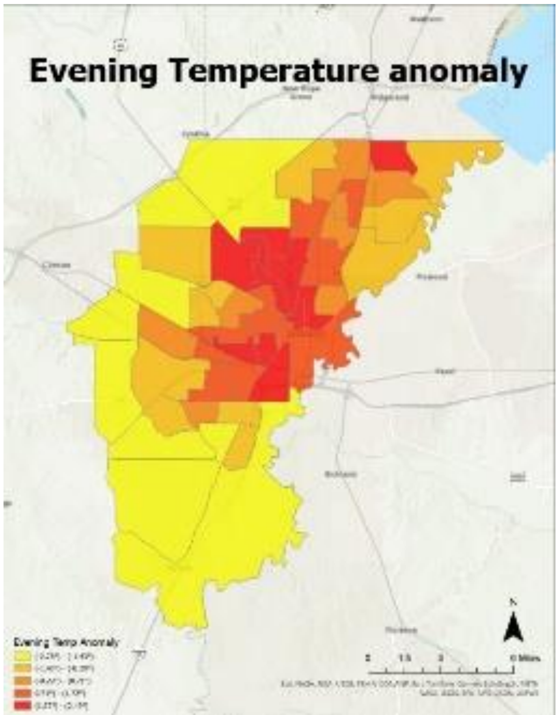
Impervious Surface Percentage Maps: These maps represent the impervious surface percentage in each census block. They are represented by tan/brown symbology.



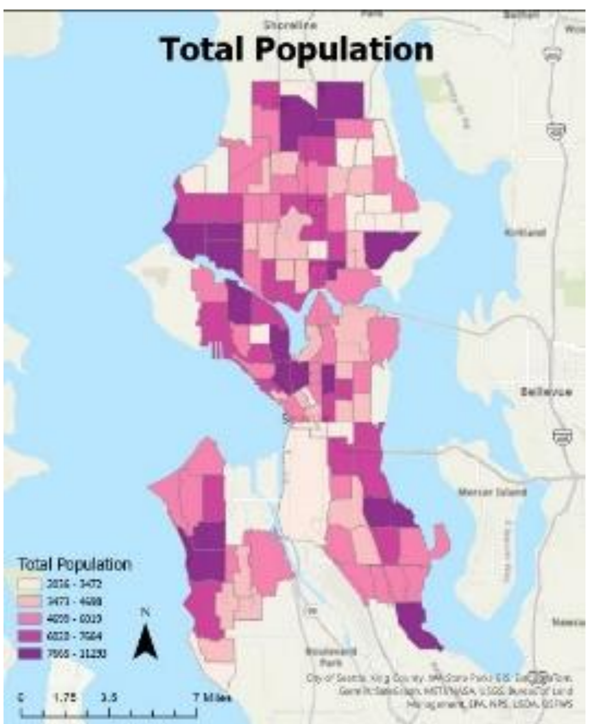
Tree Canopy Percentage Maps: These maps represent the Tree Canopy percentage in each census block. They are represented by white/green symbology.



Evening Temperature Anomaly Maps: These maps represent the evening temperature anomalies by degree. They are represented by yellow/red symbology.



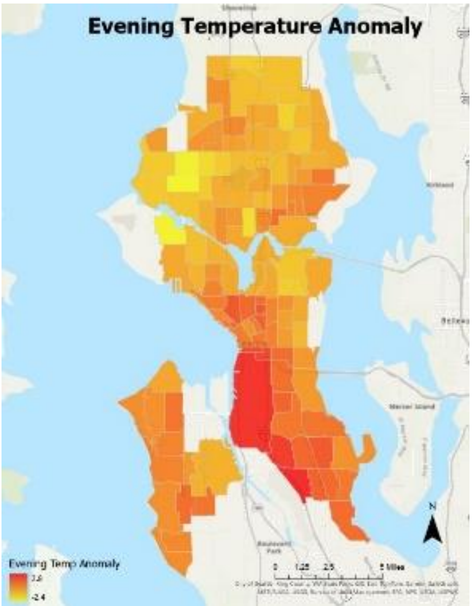
Total Population Maps: These maps represent the total population in each census block. They are represented by pink/purple symbology.



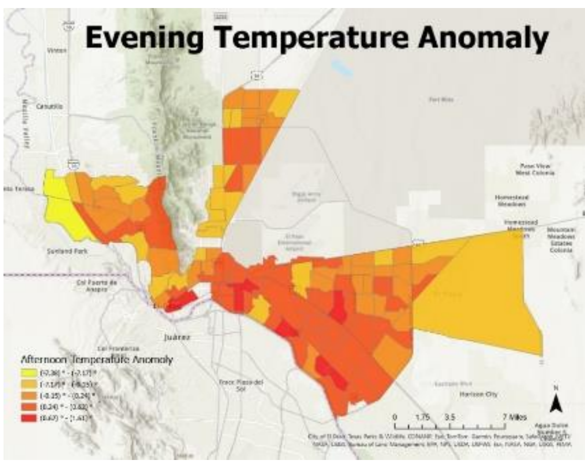
<u>Map of Temperature Anomalies in Each City:</u>

In these maps you can see where the temperature gets darker the temperature anomalies get higher. I used these and visually compared them to the three variables I cover throughout this, (population, tree canopy percentage and impervious surface percentage.)

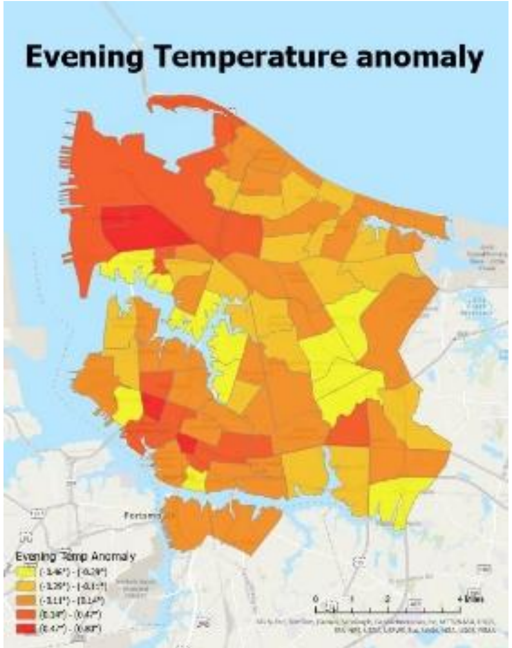
Seattle Temperature Anomalies:



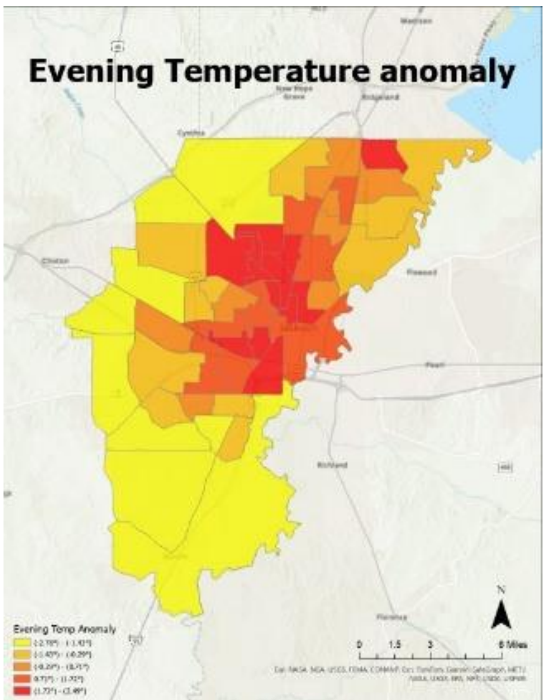
El Paso Temperature Anomalies:



Norfolk Temperature Anomalies:



Jackson Temperature Anomalies:

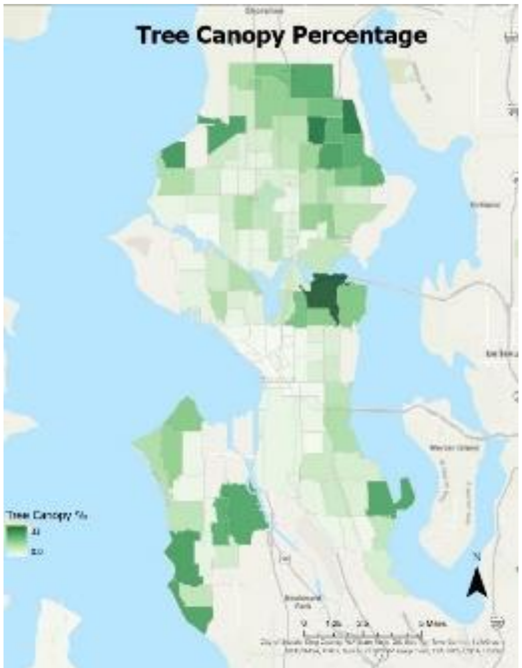


Results of First Hypothesis:

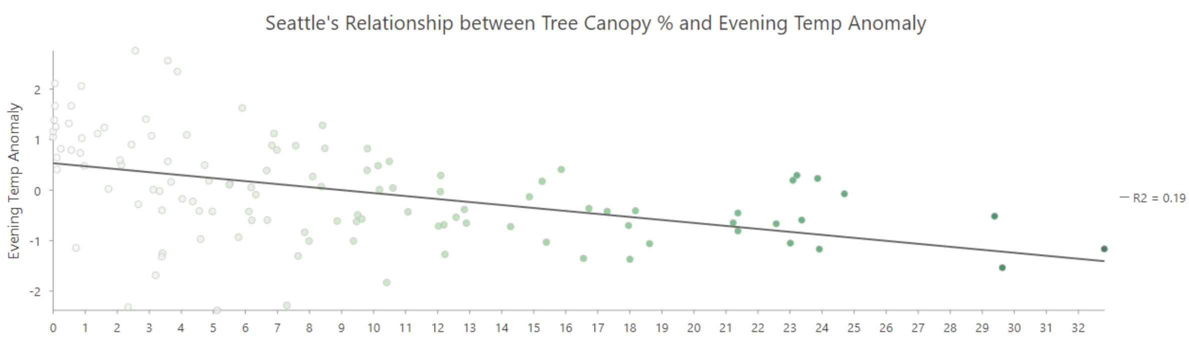
Question: How does tree canopy percentage affect UHIs?

I found that between all four cities the relationship between temperature anomalies and tree canopy percentage was an average R-score of *0.21*. (square root of R^2 score shown in scatterplots). Confirming my hypothesis that tree canopy percentage decreases UHIs. Here are the maps and the scatterplots that represent this relationship:

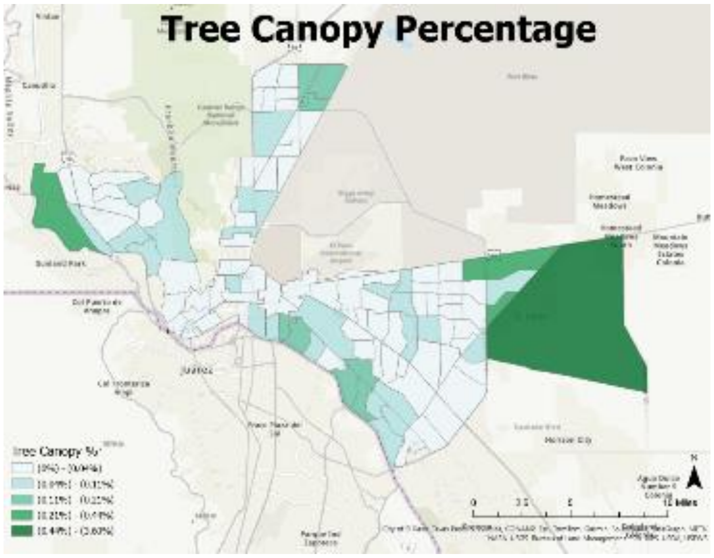
Map of Seattle's Tree Canopy Percentage:



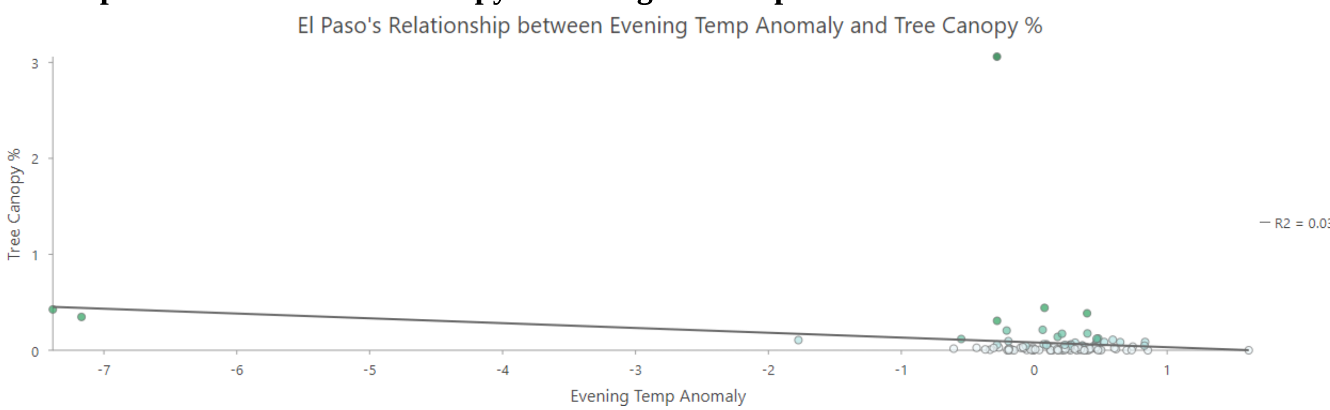
Scatterplot of Seattle's Tree Canopy Percentage vs Temperature Anomalies:



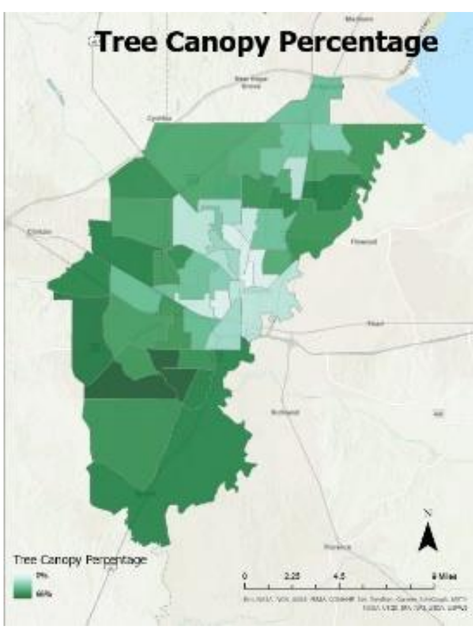
Map of El Paso's Tree Canopy Percentage:



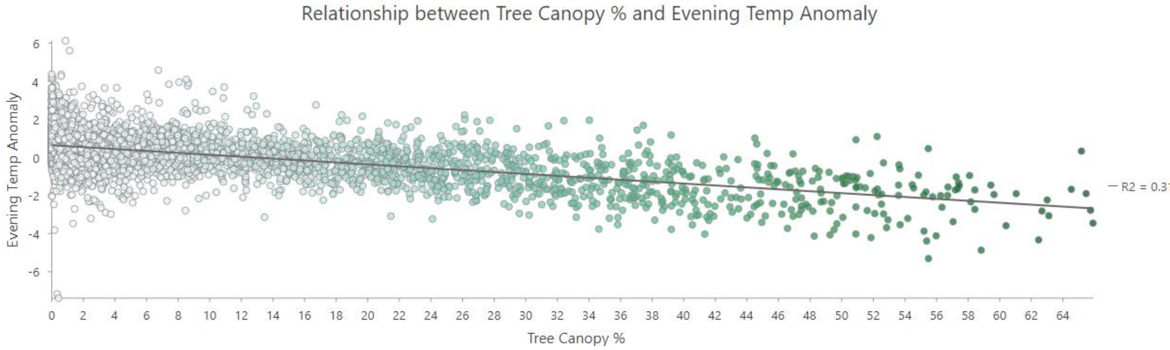
Scatterplot of El Paso's Tree Canopy Percentage vs Temperature Anomalies:



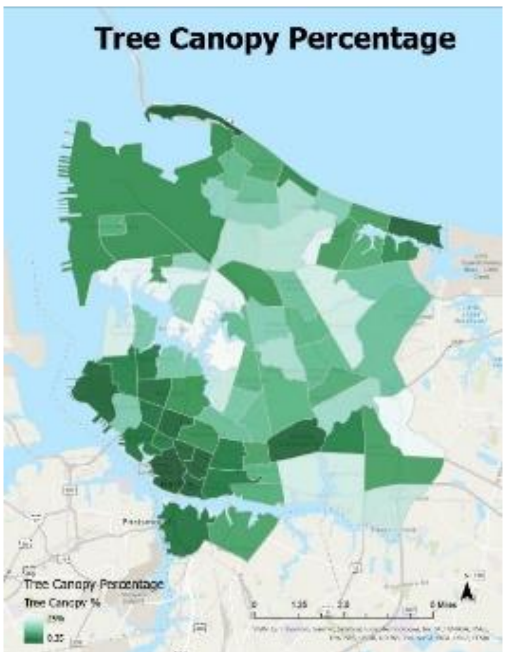
Map of Jackson's Tree Canopy Percentage:



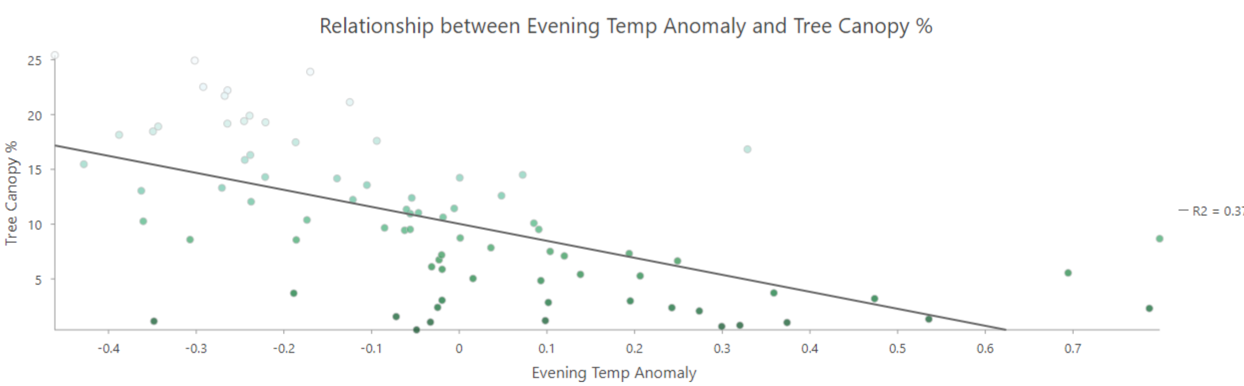
Scatterplot of Jackson's Tree Canopy Percentage:



Map of Norfolk's Tree Canopy Percentage:



Scatterplot of Norfolk's Tree Canopy Percentage:

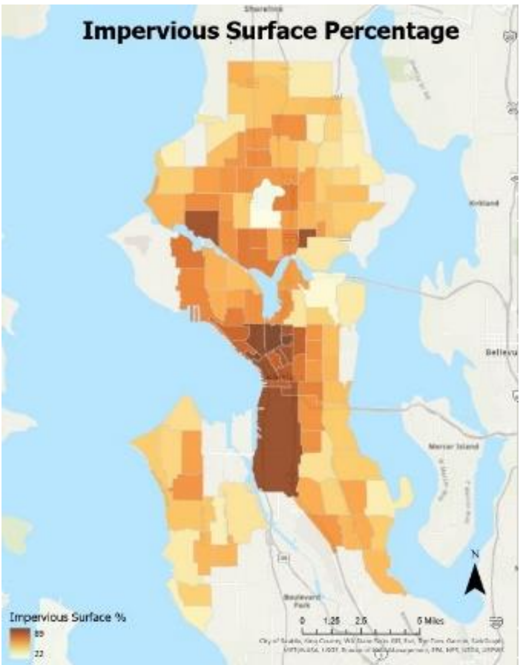


Results of Second Hypothesis:

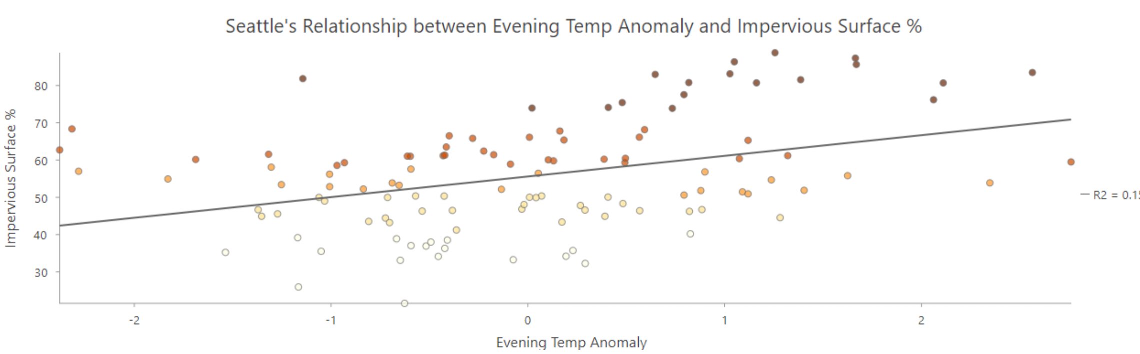
Question: How much do impervious surfaces affect the UHIs?

I found that between all four cities the relationship between temperature anomalies and impervious surface percentage was an average R-score of *0.23*. (square root of R^2 score shown in scatterplots). Confirming my hypothesis that impervious surfaces percentage increases UHIs. Here are the maps and the scatterplots that represent this relationship:

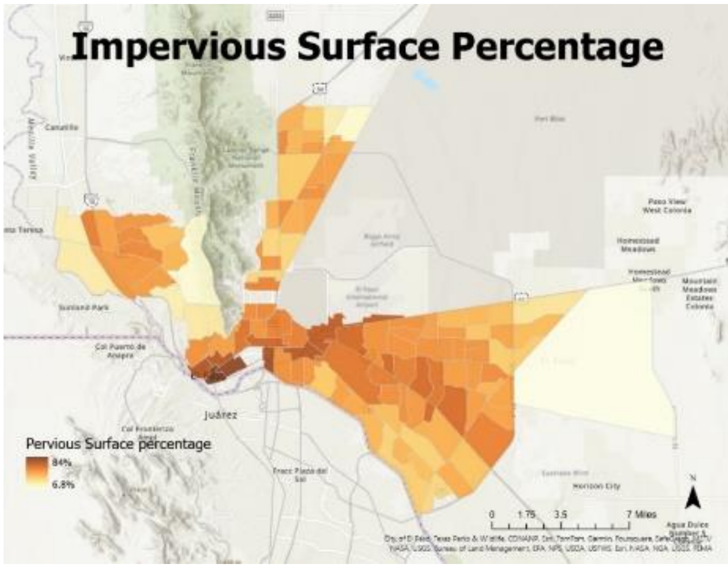
Map of Seattle's Impervious Surfaces percentage:



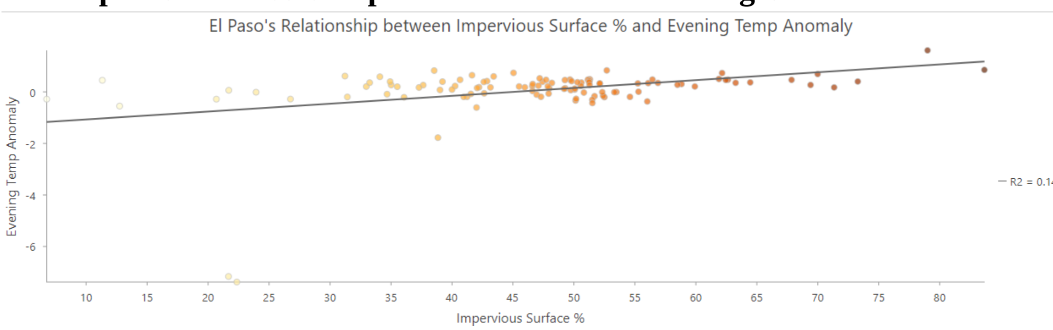
Scatterplot of Seattle's Impervious Surfaces Percentage vs Temperature Anomaly:



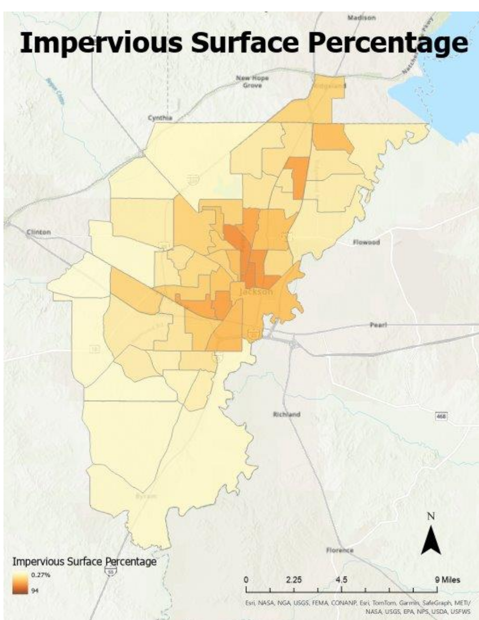
Map of El Paso's Impervious Surfaces Percentage:



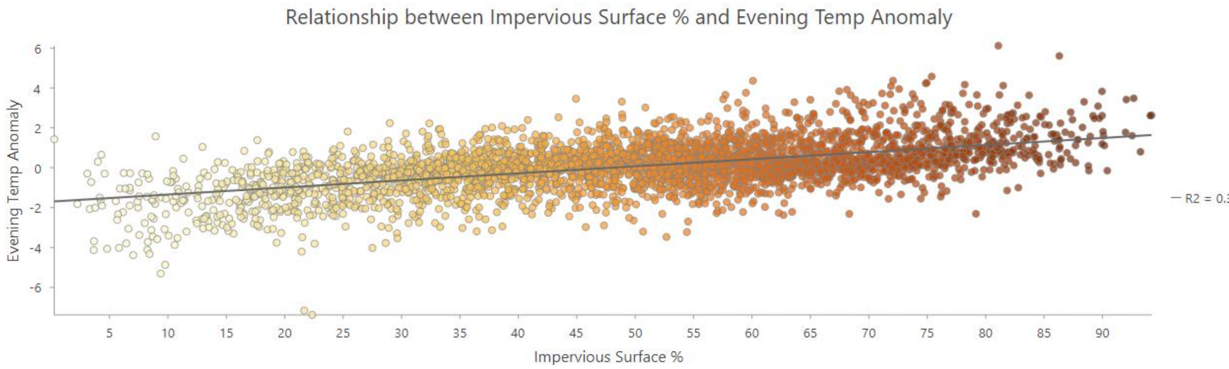
Scatterplot of El Paso's Impervious Surfaces Percentage:



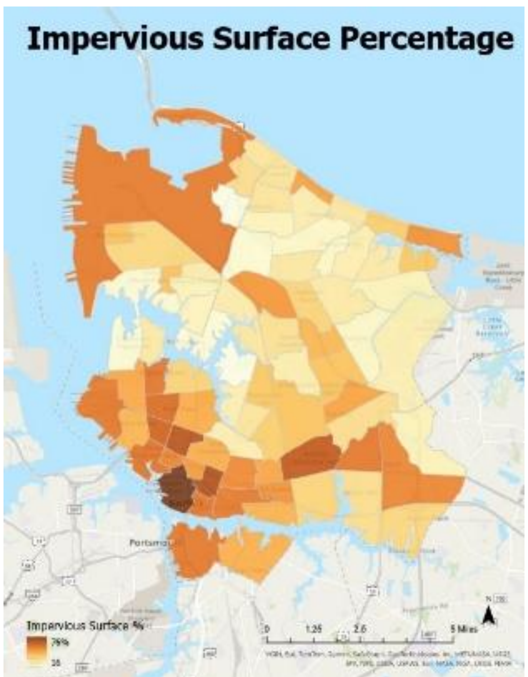
Map of Jackson's Impervious Surfaces Percentage vs Temperature Anomaly:



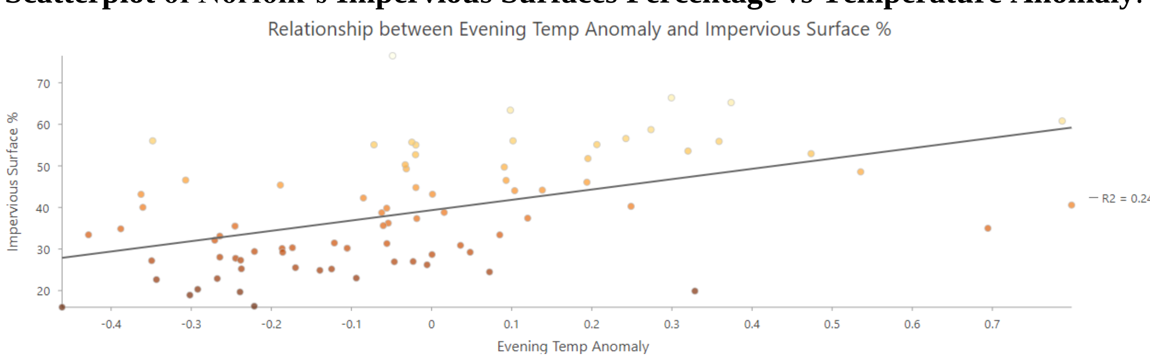
Scatterplot of Jackson's Impervious Surfaces Percentage vs Temperature Anomaly:



Map of Norfolk's Impervious Surfaces Percentage:



Scatterplot of Norfolk's Impervious Surfaces Percentage vs Temperature Anomaly:

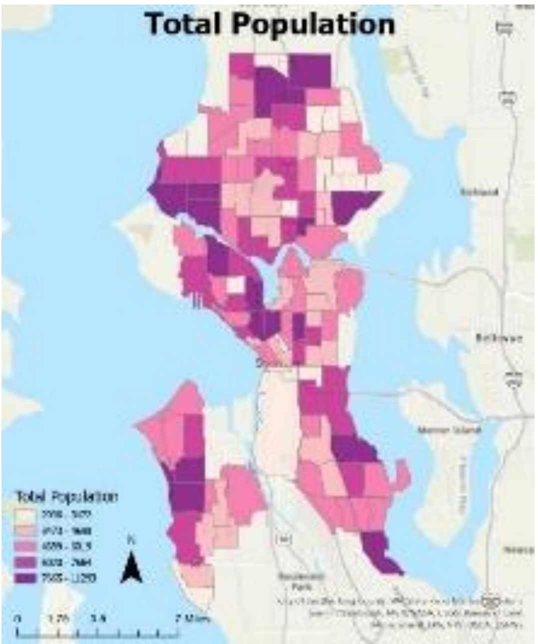


<u>Results of Third Hypothesis:</u>

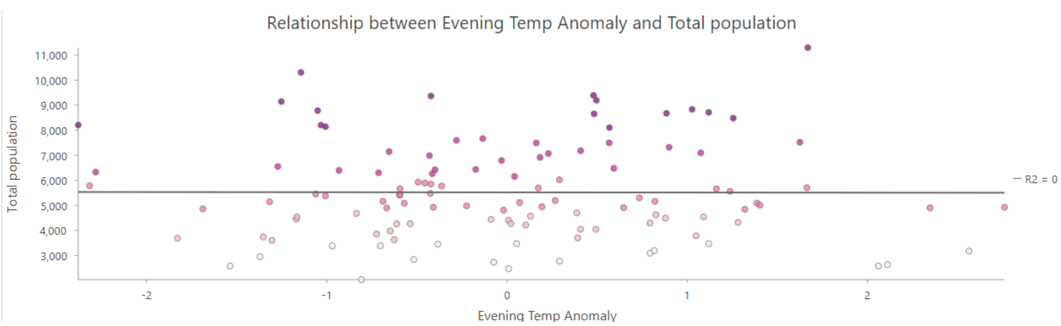
Question: How much does the population affect the UHIs?

I found that between all four cities the relationship between temperature anomalies and population was an average R-score (square root of R^2 score shown in scatterplots) of *0.07*. This is such a low correlation that I would say that there isn't one. Confirming a null hypothesis. Here are the maps and the scatterplots that represent this relationship:

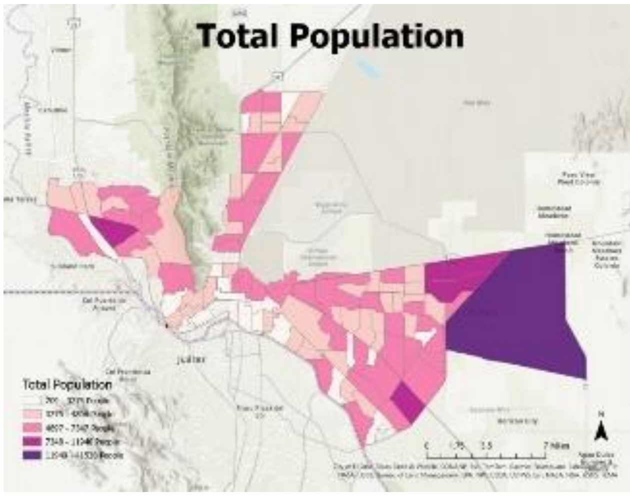
Map of Seattle's Population:



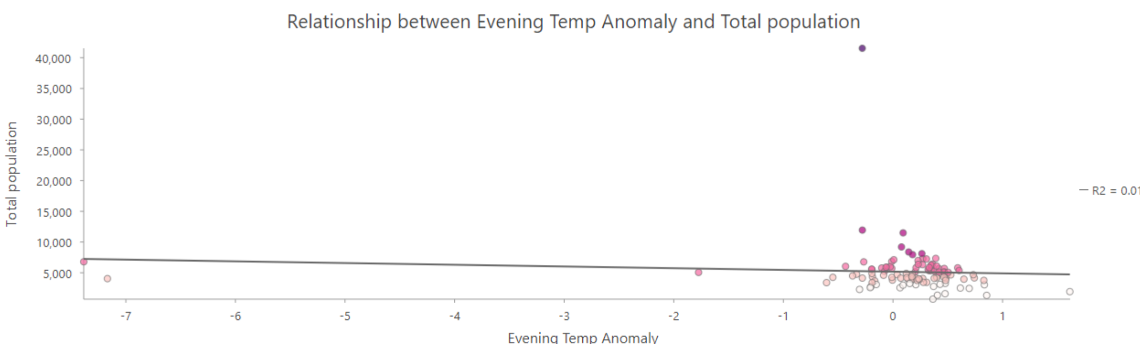
Scatterplot of Seattle's Population vs Temperature Anomaly:



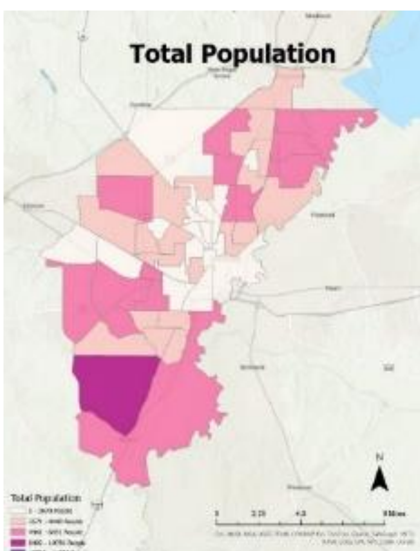
Map of El Paso's Population vs Temperature Anomaly:



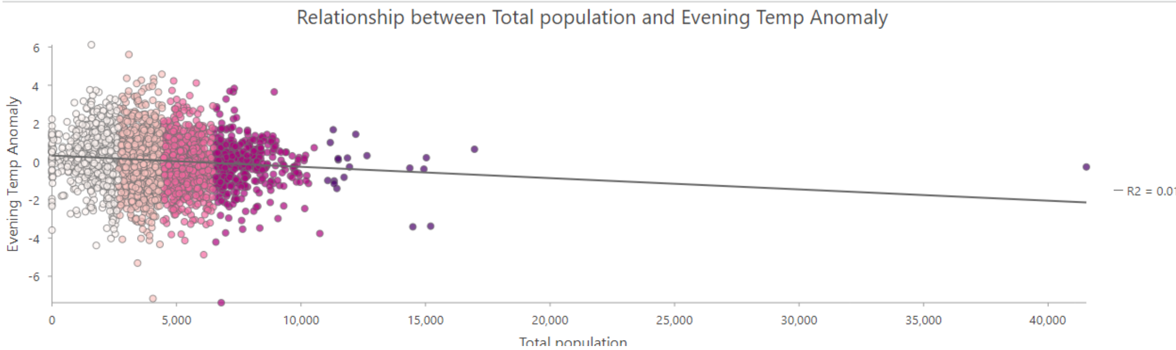
Scatterplot of El Paso’s Population vs Temperature Anomaly:



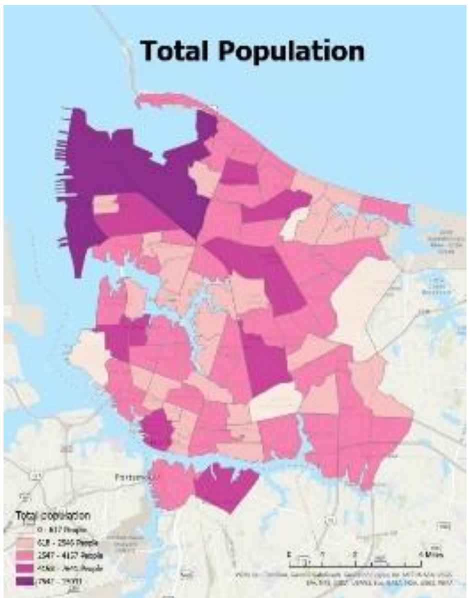
Map of Jackson’s Population:



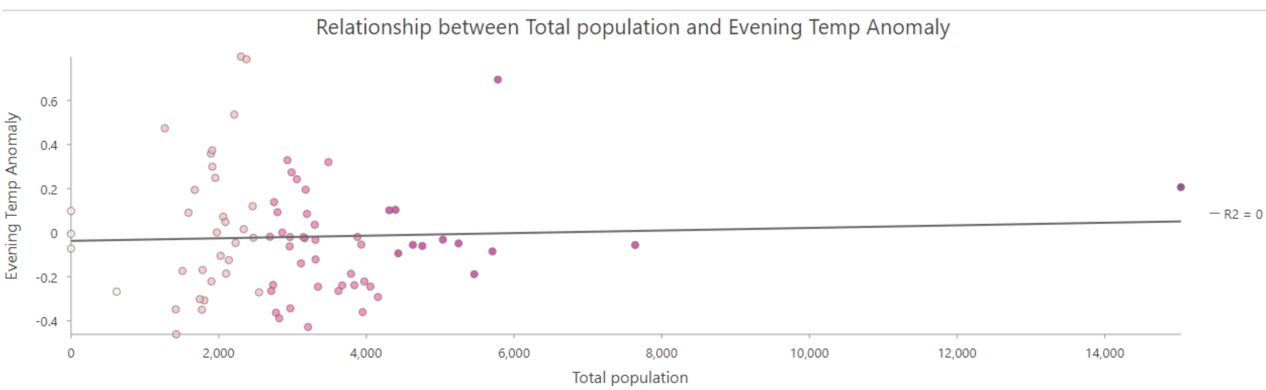
Scatterplot of Jackson’s Population vs Temperature Anomaly:



Map of Norfolk's Population:



Scatterplot of Norfolk's Population vs Temperature Anomaly:



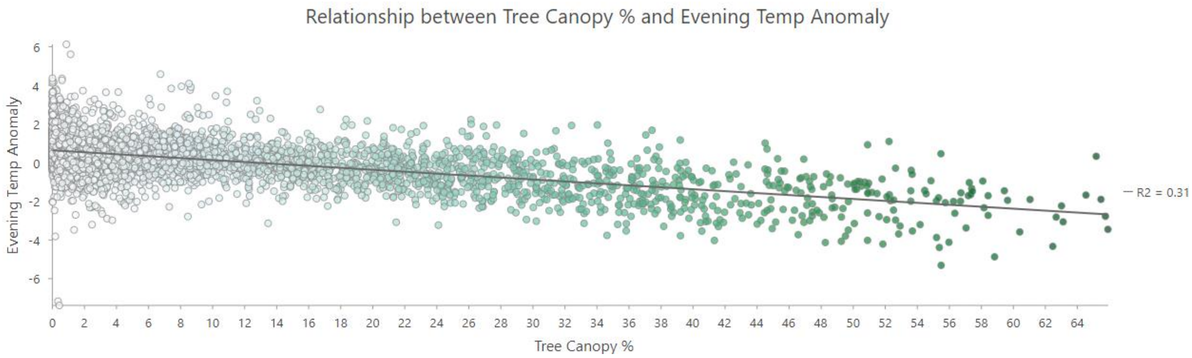
<u>Results of Fourth Hypothesis:</u>

Question: Does the R-score of the hypothesis above change depending on if the city is landlocked or on an ocean?

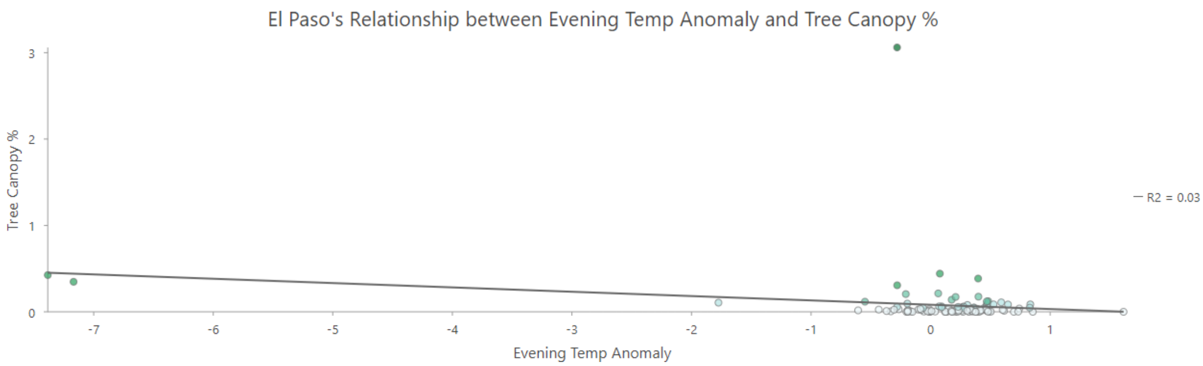
My Hypothesis is that landlocked cities will have a higher R-score for the hypothesis than cities than are not landlocked. I took these two categories of cities (landlocked, not landlocked) and averaged both R-scores for each variable I tested above (population, tree canopy percentage and impervious percentage). I then compared the two averages of both categories which confirmed a null hypothesis.

Scatterplot and average R-score of both landlocked cities for tree canopy percentage vs temperature anomalies (El Paso/Jackson):

Jackson:



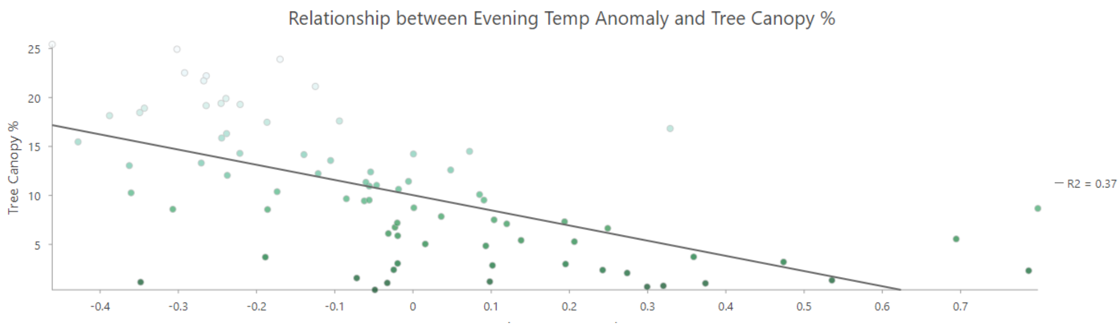
El Paso:



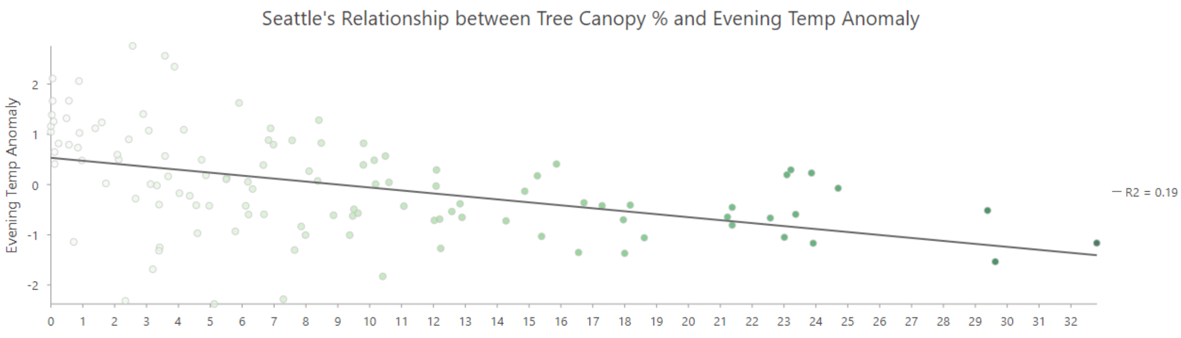
Average R-score: *0.41*

Scatterplot and average R score of both non-landlocked cities for tree canopy percentage vs temperature anomalies (Norfolk, Seattle):

Norfolk:



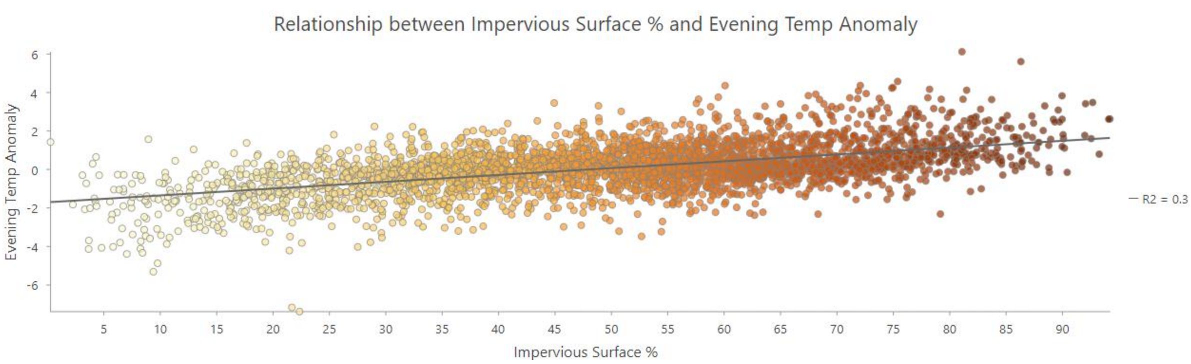
Seattle:



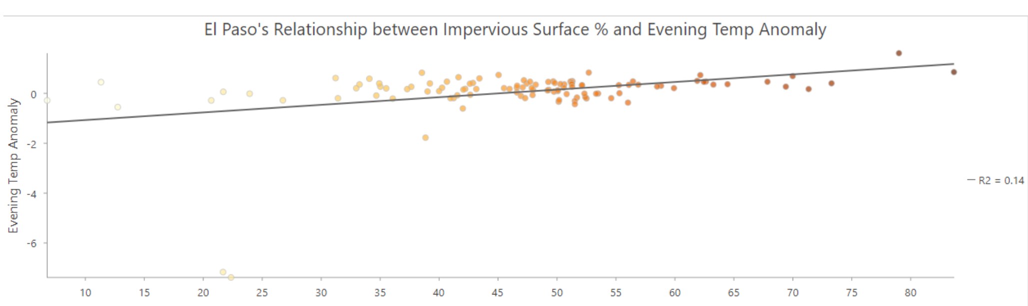
Average R-score: 0.53

Scatterplot and Average R-Score of Both Landlocked Cities for Impervious Surfaces Percentage vs Temperature Anomalies (El Paso/Jackson):

Jackson:



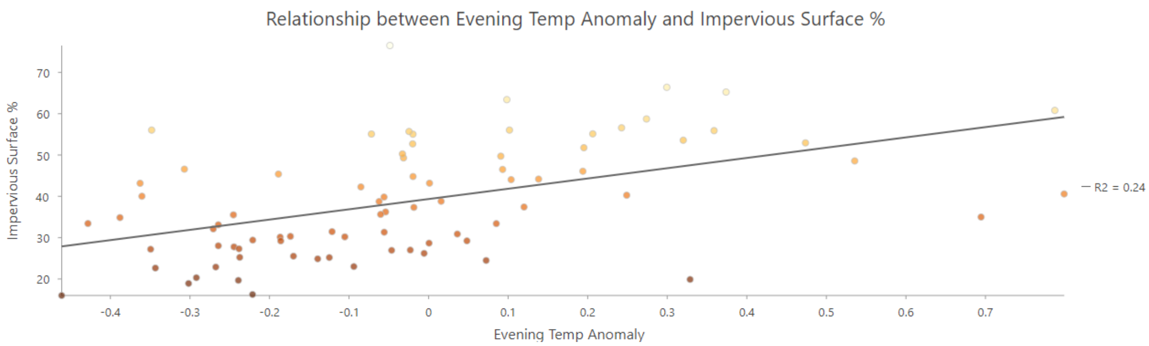
El Paso:



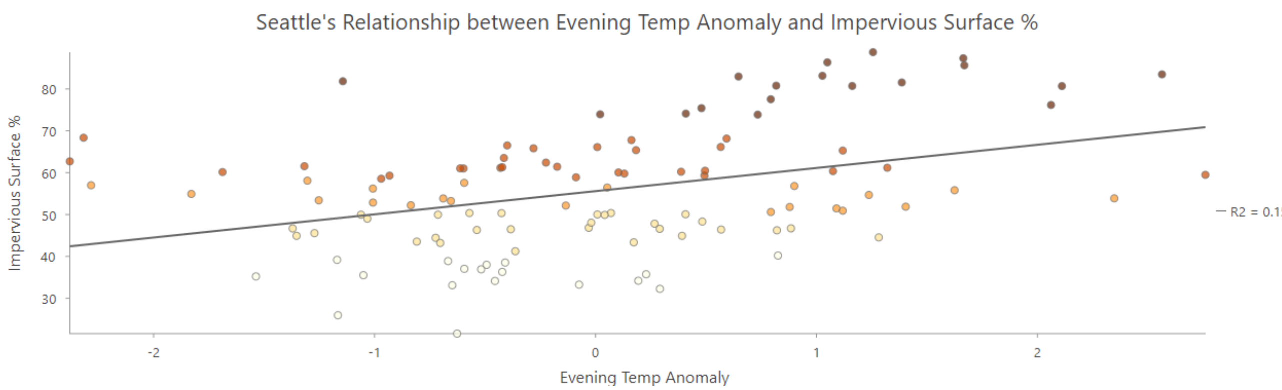
Average R-score: *0.469041576*

Scatterplot and average R-Score of both non-landlocked cities for impervious surfaces percentage vs temperature anomalies (Norfolk, Seattle):

Norfolk:

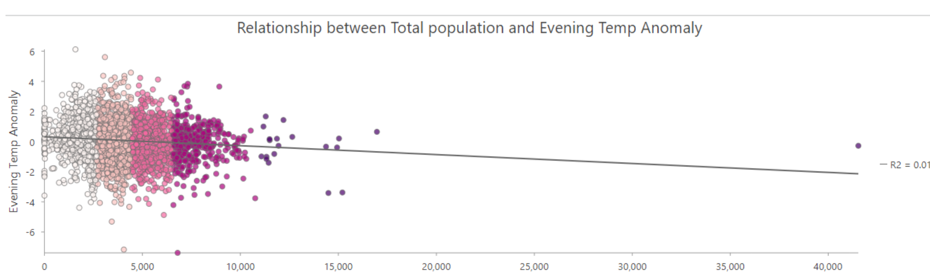


Seattle:

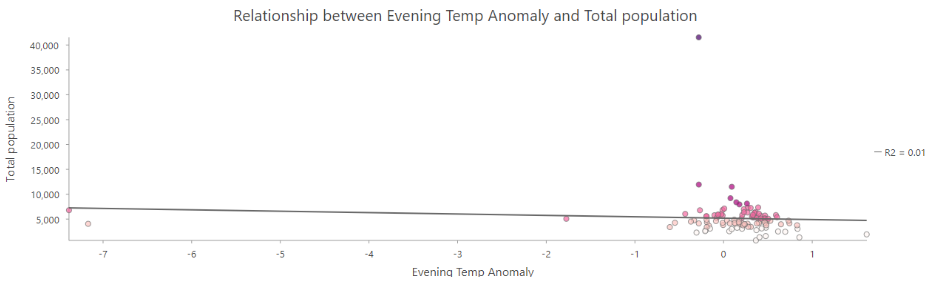


Average R-score: *0.4415880433*

Scatterplot and average R-score of both landlocked cities for population **vs temperature anomalies (El Paso/Jackson):**

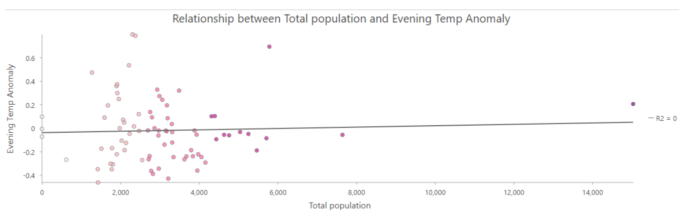


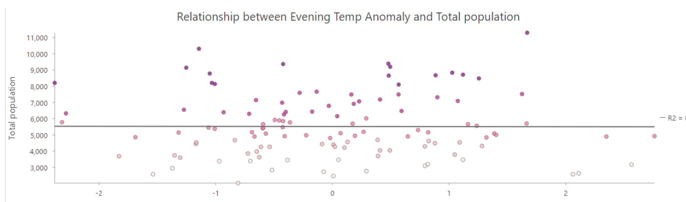
Jackson:

El Paso: 

Average R-score: *0.1*

Scatterplot and average R-score of both non-landlocked cities for population vs temperature anomalies (Norfolk, Seattle):

Norfolk: 

Seattle: 

Average R-score: *0*

<u>**Methodology:**</u>

Impervious Surface Percentage Maps: This map represents the impervious surface percentage in each census block. I created this map with the data I collected from (*NOAA Mapping campaigns*); I chose the symbology that I thought would represent impervious surfaces and then compared it to the evening temperature data, creating a scatterplot.

Tree Canopy Percentage Maps: These maps represent the Tree Canopy percentage in each census block. I created this map with the data I collected from (*NOAA Mapping campaigns*). I chose the symbology that I best thought would represent the Tree Canopy Percentage. I then compared it to the evening temperature data, creating a scatterplot.

Total Population Maps: This map represents the total population in each census block. I created this map with the data I collected from the (*NOAA Mapping campaigns*). I chose the symbology that I best thought would represent the Tree Canopy Percentage. I then compared it to the evening temperature data, creating a scatterplot.

Evening Temperature Anomaly Map: This data was provided by (*NOAA Mapping campaigns*). I chose which symbology I thought would best represent the evening temperature anomalies.

Process:

I initially started in just Seattle and wanted to compare different factors to determine how to decrease urban heat islands in that area. A dense population causes urban heat islands. I started with that variable to confirm a significant correlation between higher temperatures and a higher population. I then moved on to compare temperature anomalies to tree canopy percentage and impervious percentage. As soon as I started making these correlations, I ran into the issue that urban heat anomalies correlated to these three variables, which were not that correlated during afternoon or morning temperature anomalies but were highly correlated in the evening, which I found very confusing. I've done some research since then; according to (*High Summer, land surface temperatures in a temperate city are mitigated by tree canopy cover* 2023); it *may be because during the day, impervious surfaces and tree canopy cover have minimal impact on temperature but in the evening, impervious surfaces retain heat while tree canopy cover cools the area more, intensifying the urban heat island effect.* I also noticed that on the west side of Washinton, the temperature anomalies were less even where the population was higher, so that led me to want to research different cities around the country where NOAA also has the UHI project. Two were landlocked, and two were not (including Seattle). I suspected the correlation between all three variables would be higher in the landlocked cities than in those that were not.

Results/Conclusion:

Overall, I was correct when it came to three out of four of my hypotheses. Canopy and impervious surface percentages influence the urban heat islands and I believe that if we reduced impervious surface percentages and increased canopy percentages, we would see a decrease in these temperature anomalies. My hypothesis from population to temperature anomalies did not show as much of a correlation as I suspected it to, I would like to do more research comparing that variable in the future. My final hypothesis being incorrect, a city next to the ocean didn't differ in correlation to landlocked cities, in these cases.

Bibliography:

Mapping campaigns. HEAT.gov - National Integrated Heat Health Information System. (n.d.). https://www.heat.gov/pages/mapping-campaigns

I collected this data and based my research on the NOAA Urban Heat Island Mapping Campaign. NOAA has provided funding for CAPA Heat Watch to aid over 60 communities in the United States in mapping their urban heat islands (UHI). CAPA Strategies has devised a process to assist cities in planning and executing a field campaign based on volunteer community science. Local partnerships are established in the process, which involves community residents in a scientific study to understand the distribution of heat in their area. The process generates high-quality outputs that have been useful in urban forestry, city sustainability plans, public health practices, research projects, and other engagement activities. It was an invaluable resource for my research.

Elsevier. (2023, September 11). *High summer land surface temperatures in a temperate city are mitigated by tree canopy cover*. Urban Climate. https://www.sciencedirect.com/science/article/pii/S2212095523002006

This was a similar study to mine. Comparing how impervious surfaces to tree canopy coverage affects Urban heat islands. They found a similar result to mine. Tree canopy coverage decreases urban heat islands and impervious surfaces increases them. They go into detail about the statistical evidence behind this, which I find very interesting.

Heinecke, R. (2021, September 28). *What are urban heat islands?*. Breeze Technologies. https://www.breeze-technologies.de/blog/what-are-urban-heat-islands/

This article is a very brief article that I used when I initially was trying to gather an idea for this project. It goes over what urban heat islands are, why they are problematic and how they can be reduced. Very interesting but also very easy read for people just starting to learn about urban heat islands.

Li, Y., Schubert, S., Kropp, J. P., & Rybski, D. (2020, May 27). *On the influence of density and morphology on the urban heat island intensity*. Nature News. https://www.nature.com/articles/s41467-020-16461-9

This was another study about how impervious surfaces and tree canopy affects urban heat islands, with the same findings as me and to science directs' study. I think they go into detail about the statistics of these comparisons and prove the significance of them well.

Urban heat islands. MIT Climate Portal. (n.d.-a). https://climate.mit.edu/explainers/urban-heat-islands

I used this source to learn about green roofs. I would like to expand my knoweldge on green roofs and compare cities who have implemented them to cities who haven't. Also goes into detail with impervious surfaces and how they are negative.

Education, U. C. for S. (n.d.). *Center for Science Education*. Urban Heat Islands | Center for Science Education. https://scied.ucar.edu/learning-zone/climate-change-impacts/urban-heat-islands

This resource goes in detail to how these urban heat islands are formed. It also gave me a few ideas of things I would like to research more in the future. It brought up the fact that the humidity of these urban heat islands is affecting the populations day-to-day life a lot more than the couple of degrees of temperature anomalies.