EXPLORING THE RELATIONSHIP BETWEEN LAND COVER CLASSIFICATIONS AND URBAN HEAT ISLAND INTENSITY

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Abstract

The Urban heat island (UHI) effect refers to the phenomenon in which urban areas experience higher temperatures compared to their rural counterparts. This research aims to quantify and examine the UHI effect within three areas of interest (AOI) by utilizing LANDSAT imagery. In addition, this study seeks to explore the relationship between land cover classifications, which represent the most green (rural) and the most urban areas, and the intensity of the UHI effect. To achieve this, temperature data from local weather stations are analyzed, and statistical methods are employed to determine whether a correlation exists between the difference in land cover classifications and the intensity of the UHI effect, as determined by the average temperature difference between urban and rural areas. Google Earth Engine is used to visualize LANDSAT data from 2013 to 2022 in the months of July and August for each AOI. Subsequently, the data is compared with the land cover classifications from Collect Earth Online using statistical models in Microsoft Excel. These tools were used to take data from three pre-selected areas of interest in GLOBE Observer. The data findings from this analysis suggest that the more tree cover and rural an area is according to our classification method, the lower the UHI intensity. On the other hand, the higher the urban area, the higher the UHI intensity. By beginning this research, we have reinforced the validity of land cover classifications, and we now have the capability to generally predict the UHI intensity of locations based on their classifications. Overall, this investigation aims to contribute to a better understanding of the GLOBE land cover classifications and their potential indications of UHI intensity.

Introduction

During the 1800s, scientists began to observe a positive temperature differential between urban centers and their rural counterparts. Since then, scientists have classified such urban centers as urban heat islands (UHI), which is a heat accumulation phenomenon within an urban area due to construction and human activities (Yang et al., 2016). This phenomenon is recognized as the most evident characteristic of urban climate. The urban heat island effect is quantified using the average temperature difference between the hottest sector of the city and the non-urban space surrounding it (Martin-Vide et al., 2015). Scientists believe that despite their geographical proximity, urban areas become hotter as a result of human activity. The construction of urban buildings and infrastructure is one major contributing factor to why urban heat islands exist. As a result of the slow cooling properties of urbanized surfaces, it is difficult for heat to be dispelled in urban centers (Rodrigues de Almeida et al., 2021). Furthermore, materials such as concrete and asphalt have different thermal characteristics (thermal inertia/heat capacity) and surface radiative characteristics (albedo and emissivity) than materials typically used in rural construction. The temperature imbalance between urban and rural areas is worsened by the lack of vegetation in urban areas that would normally use evapotranspiration to cool the surface. Overall, as a result of human activity, land surface temperature data shows that variations between urban and rural areas are around 5 °C (Jabbar et al., 2023).

A major impact of urban heat islands is their effect on specific socioeconomic groups in urban areas. Within a large urban area, there are often smaller urban heat islands that unequally affect minority groups (Hsu et al., 2021). Areas in an urban city that lack the most vegetation are often inhabited by people of lower socioeconomic status. Urban heat islands are essential to understand and identify when addressing heatwaves and high temperature climate events. When a city undergoes a heat wave, those living in the most intense urban heat islands will undergo the most heat stress. This is important to understand when considering that vulnerable populations are often concentrated in urban heat islands (Suen, 2022). One measure that can be used to help reduce the risk of heat related illness for vulnerable populations living in urban heat islands is to create better heatwave alert systems (Tomlinson et al., 2011). Moreover, relieving the urban heat island effect is as simple as improving the green infrastructure in dense urban centers. By adding vegetation like trees and plants in parks or on the roofs on buildings, heat can be better managed (EPA, 2023). Overall, the urban heat island effect is a phenomenon that has been studied and will continue to be studied in an effort to minimize its effect.

Research Question

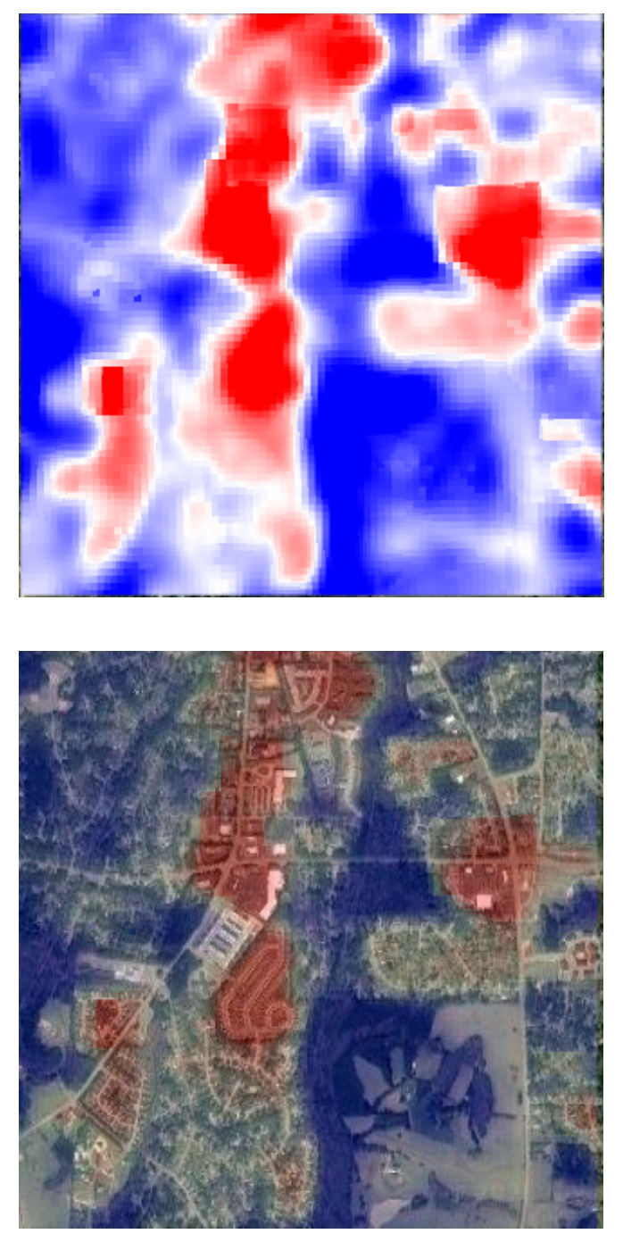
What is the relationship between the disparity in land cover classifications (most green vs. most urban) and the intensity of the urban heat island effect?

Methodology

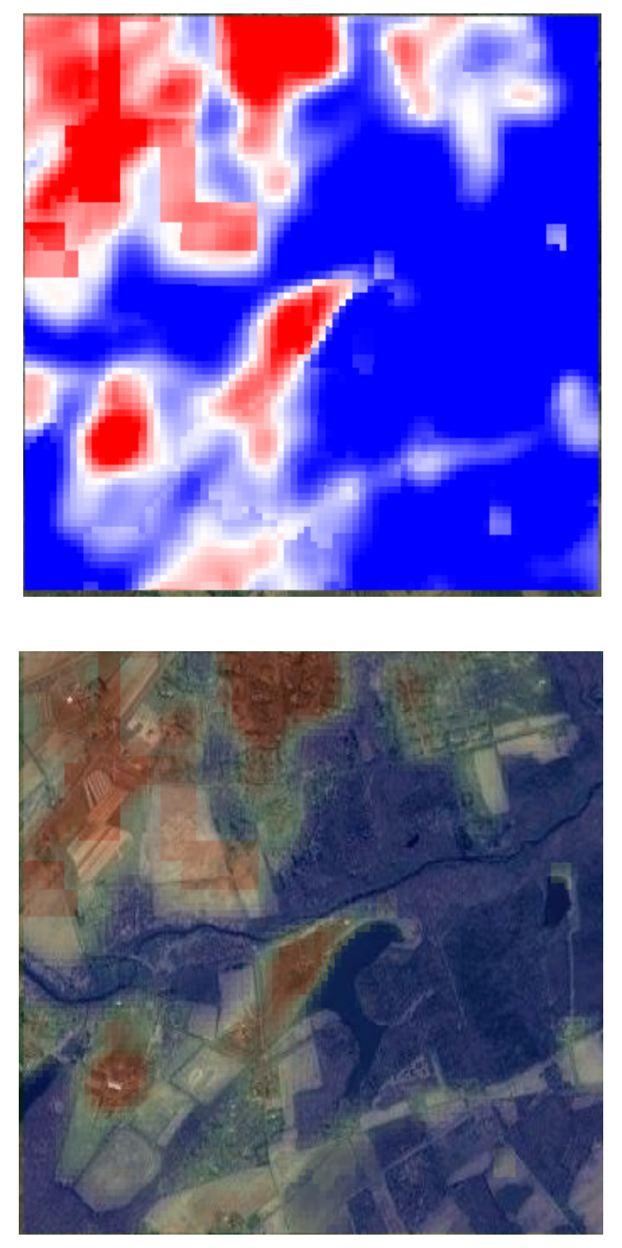
In order to answer this research question, we utilized LANDSAT satellite land surface temperature (LST) data that had been aggravated from 2013 to 2022. In each year, we selected the months of July and August as they represent the peak summer season when the urban heat island effect is most prominent. With this data, we utilized the Google Earth Engine in order to visualize 3 of our group members Area of Interest (AOI). With the help of the NASA Applied Remote Sensing Training (ARSET), we were able to create heatmaps of each AOI and calculate the Urban Heat Island Effect Intensity, which is represented by the average urban temperature minus the average rural temperature. After we calculated the intensity of the Urban Heat Island Effect in each AOI, we utilized Collect Earth Online data, a tool used to classify Google Earth Satellite images. Each AOI was split into 37 plots, each with 100 data points and multiple ways to classify each one. From this data, we used Python and the open source packages of Pandas, MatplotLib, and Numpy to analyze the CSV file that came with it. Lastly, we represented our findings using graphs.

Results

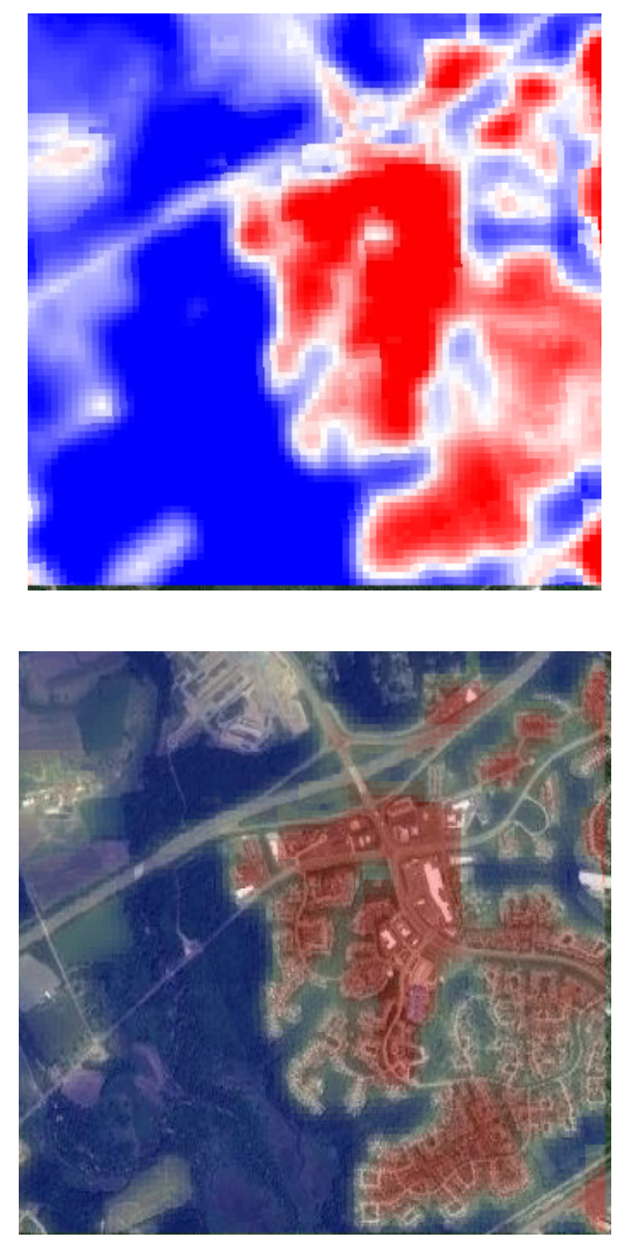
To create the images below, we used the Google Earth Engine, a platform used for analyzing geospatial data. These images represent the heatmaps in each of our AOI's which were derived from LANDSAT satellite land surface temperature (LST) data. Each image represents the aggregated LANDSAT LST data spanning from 2013 to 2022. To visualize the temperature distribution, we assigned a color palette to the images. The blue color represents lower temperatures, indicating cooler regions, while the red color represents higher temperatures, indicating warmer regions. Every image utilizes its own relative temperature scale, where the average rural temperature serves as the minimum value, and the average urban temperature serves as the maximum value. The UHI intensity is indicates how severe heat urban heat island is, which can be further analyzed through the percentage of land cover elements in each area of interest



AOI: 32
UHI Intensity:
8.99328374666382



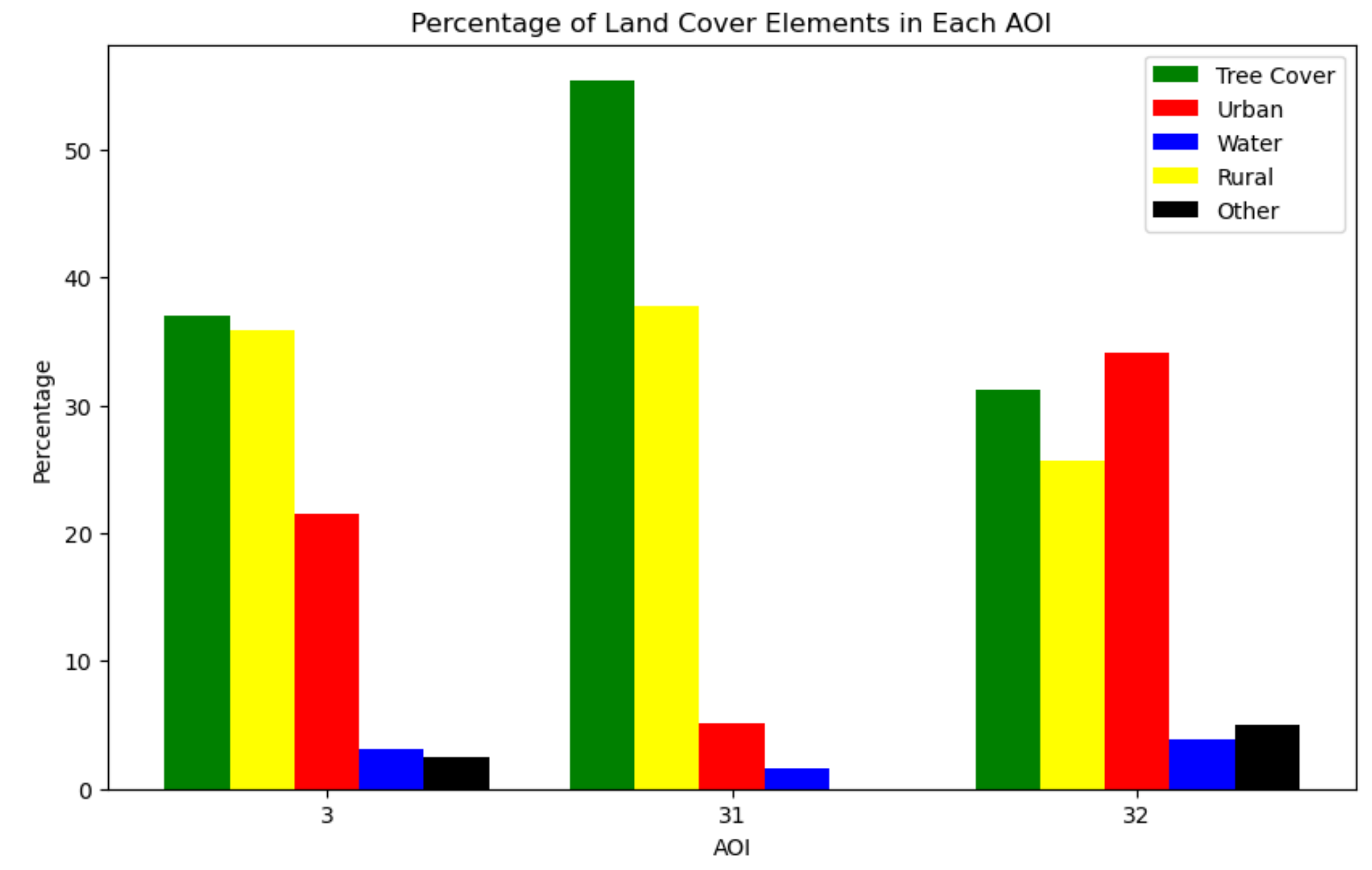
AOI: 31
UHI Intensity:
4.997688387007013



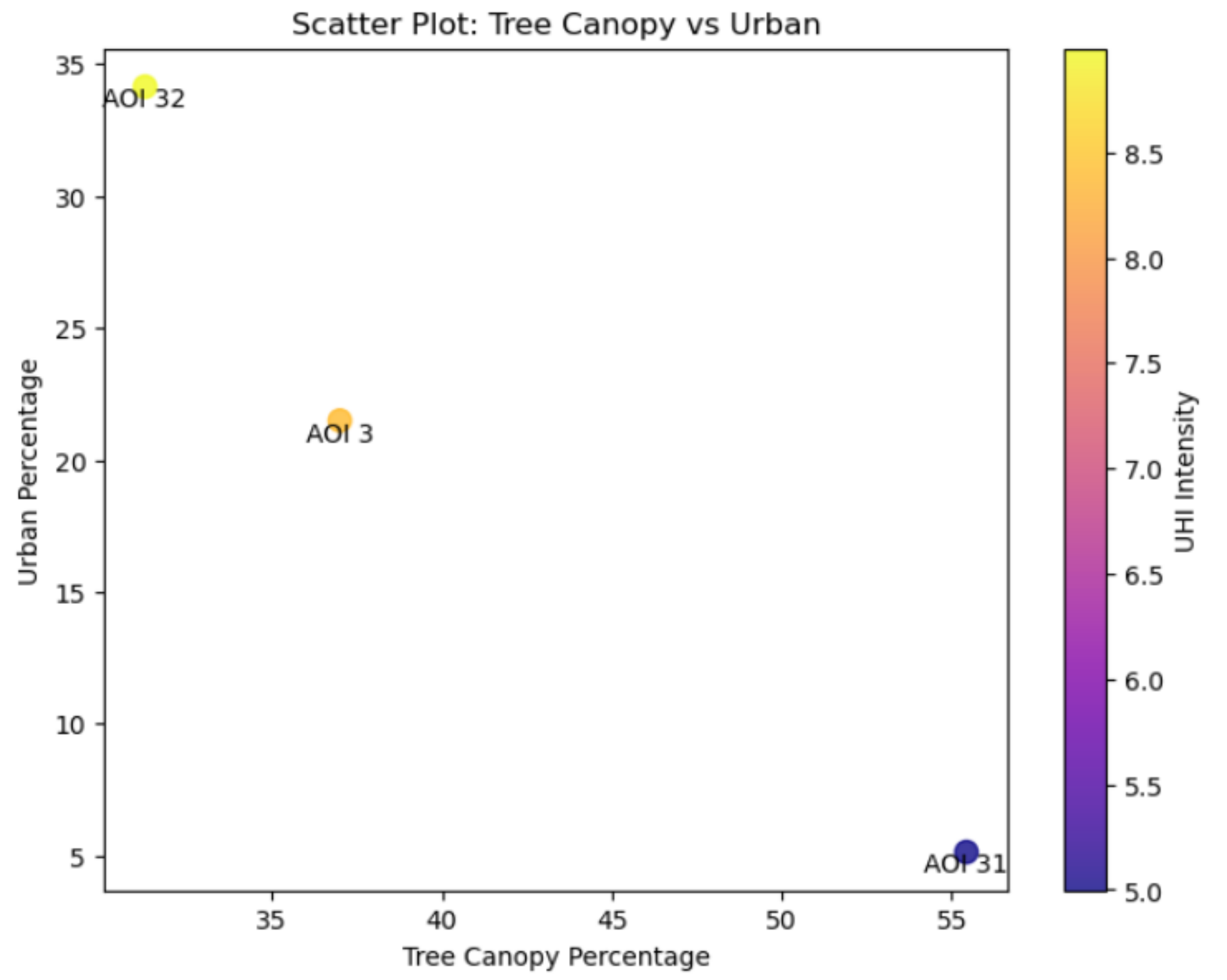
AOI: 3
UHI Intensity:
8.39727689237164

Results (continued)

In conjunction with the previous visualizations, the graph below was created using Python, and shows the percentage of tree cover (or rural area) in each AOI location we investigated. This data comes from GLOBE Observer AOIs that were ultimately classified in CEO. As shown, AOI 31 had the most tree cover, and was therefore the most rural out of the three AOIs. AOI numbers 3 and 32 were similar to each other in the percentages of land cover, and were more Urban compared to AOI 31.



Using the percentages of tree cover from CEO in each AOI, we created scatter plots to visualize our results. These plots compare the UHI intensity with the percentage of tree cover and urban land cover in each AOI. As shown in the plots, AOI 31, which was the most rural and had the most free cover, also has the lowest UHI intensity. In contrast, AOI 3 and AOI 32 were more urban, and had a much higher UHI intensity at almost 9.



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Conclusion

We ran into several obstacles during the course of this project that limited the quality of our investigation. Due to the project's scope, we were only able to dedicate enough time and resources to the analysis of a few Areas of Interest (AOI). Despite this, the knowledge gained from this constrained analysis is important and has opened the door for further advancements and research directions. This project can easily be improved by expanding the AOI data pool. By incorporating data from a larger number of GLOBE observers and analyzing a more extensive set of AOI locations, we can obtain more concrete findings about the correlation between land cover classifications and Urban Heat Island (UHI) intensity. Increasing the sample size will help us gain a deeper understanding of the relationship between land cover types and the UHI effect, thereby providing more robust conclusions and strengthening the validity of our research. Our research shows that GLOBE Observer classifications can be used to accurately anticipate where the Urban Heat Island would be strongest. Now that we are aware of this, we can use land cover data to anticipate the intensity of UHI in various urban and suburban locations, thereby assisting urban planners, lawmakers, and environmental scientists in making decisions that will lessen the impact of UHI. Moving forward, one potential way to enhance our research would be to create a mathematical prediction model. By creating a model that quantitatively relates land cover types to UHI intensity, we can establish a more precise and standardized approach to predicting the impact of urbanization on local temperatures. Such a model would allow for rapid comparison of the UHI effect across different regions, contributing to a better understanding of the distribution of UHI intensity. We could also investigate additional classification techniques and evaluate how well they compare to UHI intensity. We could better determine the most appropriate classification approach for particular geographic regions and land cover scenarios by comparing the accuracy of various classification systems in predicting the UHI effect. Through this comparative analysis, we would be able to better understand the challenges posed by UHI formation and identify opportunities to advance land cover classification methods. In conclusion, this research has laid a strong foundation for understanding the connection between land cover classifications and the Urban Heat Island effect. It serves as a stepping stone towards future investigations that could encompass a more comprehensive dataset, advanced mathematical modeling, and in-depth comparison of classification methods. By continuing to explore this topic, we can contribute significantly to the field of urban climate studies and support sustainable urban development for a cooler future.

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