Improving Microclimates in Los Angeles' Heat-Vulnerable Communities

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TreePeople

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Abstract

Climate change is at the forefront of pressing issues threatening planetary and human health and well-being today. Every year, heat kills more people in the United States than all other weather-related causes combined.[1] Due to anthropogenic climate change, heat events are becoming increasingly more common year-round. While some communities are more resilient against rising temperatures due to affluence and differences in topography, under-resourced communities often have fewer coping mechanisms for this additional stress. This heat stress has resulted in a steady rise in the number of heat related health incidents reported over time. The study client, TreePeople, is actively seeking out the best courses of action to increase climate resiliency within Southern California. By researching the differences in temperature and humidity of various land cover classes, the study team sought to identify opportunities to improve the pedestrian experience in heat-vulnerable neighborhoods. This report analyzes the disparities in temperature between a variety of different land cover classes in three under-resourced communities of Los Angeles County. Results indicate drastic variations in temperature and humidity between different types of land cover classes. Tree shade and building shade created the coolest areas along the study routes whereas asphalt-covered areas proved to be the hottest. Further research can be done on the types of land cover classes that would be most effective in reducing temperatures given the parameters dictated by community needs and preferences, as well as those dictated by codes, regulations and funding availability.

[1] Centers for Disease and Control Prevention. (2014). *Climate Change and Extreme Heat Events*

Introduction

Over the last century, climate change has steadily increased average global temperatures with no indication of slowing down. Global climate change directly influences the growing number of extreme heat days, particularly in areas that already face higher temperatures. With a rapidly growing population and current greenhouse gas emissions, Los Angeles is projected to have approximately 54 days above 95°F by the end of this century. It is imperative that Los Angeles County adopt and implement proper climate adaptation and mitigation strategies to ensure the health and safety of its residents.[2]

Los Angeles is a heat-vulnerable region due to myriad factors including a large population size, varied topography, diverse demographics and socioeconomic characteristics, and varied land-use patterns, including those with a large preponderance of heat-retaining surfaces. These factors, combined with anthropogenic greenhouse gas emissions and specific materials used for urban construction, exacerbate the effects of a phenomenon known as the Urban Heat Island Effect.[3] The Urban Heat Island Effect leads to higher temperatures in cities compared to surrounding areas due to lower reflectivity, fewer sources of shade, lower rates of evapotranspiration, and increased availability of heat sinks.[4] This study assessed and evaluated the effects various land cover classes on temperature and humidity and their effects on microclimates in Los Angeles. This information will be used for climate-mitigation strategies to alleviate heat stress in heat-vulnerable neighborhoods.

This study focused on pedestrian exposure to heat events in three under-resourced Los Angeles neighborhoods: San Fernando, Sun Valley and Huntington Park. Documenting and reporting the pedestrian experience during heat events is important in developing the narrative of heat-vulnerable populations and how such communities cope with heat stress. Temperature and humidity data were collected using portable sensors and supplemented with infrared images. Neighborhood selection was informed by the client's programmatic and policy presence and the likelihood of the results leading to practical application in those neighborhoods. Study routes were chosen based on high degrees of land cover variation and pedestrian traffic.

The methodology, data, and analyses from this study will be used to fill in gaps for Los Angeles-specific microclimate data and set the framework for further documentation of the pedestrian experience. The information gathered from these results has implications for public health, policy, and environmental justice.

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[2] F Sun , DB Walton , A Hall . A hybrid dynamical–statistical downscaling technique. Part II: end-of-century warming projections predict a new climate state in the Los Angeles region. *J Climate*. 2015;28(12):4618-4636.

[3] U.S. Environmental Protection Agency (EPA). (2008). Reducing Urban Heat Islands: Compendium of Strategies. Washington, DC: Climate Protection Partnership Division.

[4] UCAR Center for Science. (2011). Urban Heat Islands.

Methodology

1. Determine the Study Sites

With the client's recommendation, this study focused on Huntington Park, San Fernando, and Sun Valley as study sites on the basis of topography and heat-vulnerability. In determining heat-vulnerability, we examined socioeconomic and demographic factors as they play a large role in heat resiliency.

Geographically, Sun Valley and San Fernando are in closer proximity to each other, whereas Huntington Park is located further south east. Although the topographical differences between these areas added complications in standardizing data collection, an emphasis was placed on comparing data points between different land cover classes rather than comparing data points between the three study sites.

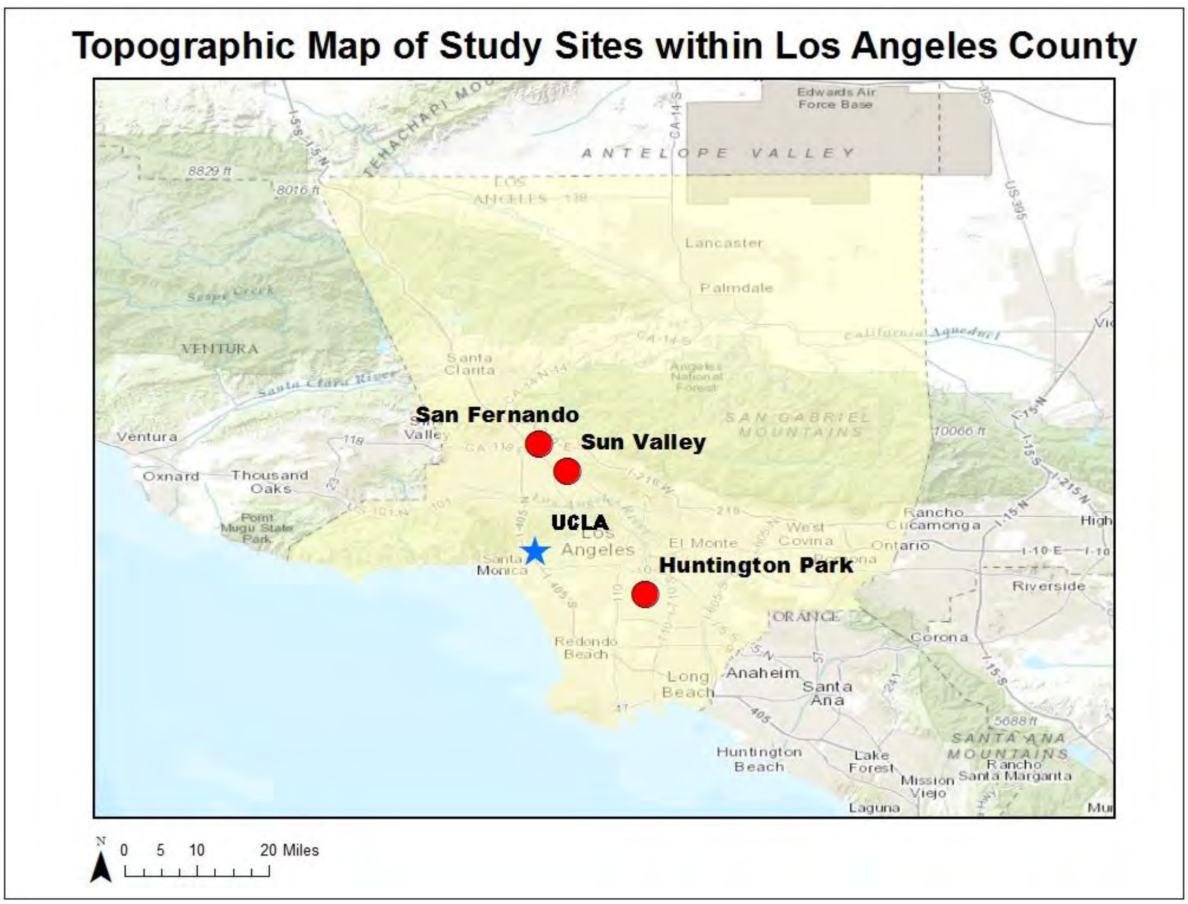


Figure 1: *Map of Los Angeles County with the study sites in relation to UCLA. Los Angeles County layer courtesy of the Los Angeles County GIS Data Portal.*

2. Specify the Pedestrian Experience Routes

Within each neighborhood, routes were chosen specifically with the pedestrian experience in mind. As such, points of high pedestrian activity that included destinations such as grocery stores, schools, churches, bus stops, parking lots, and restaurants were selected. All routes were 0.5 miles long and covered as many high-pedestrian traffic points as possible. Google Earth and Google Street View were referenced preliminarily to screen for potential data collection routes. Following that, each neighborhood was scouted to determine the exact data collection paths and points. This was then followed by a trial run to finalize the paths and adjust that data collection methodology.

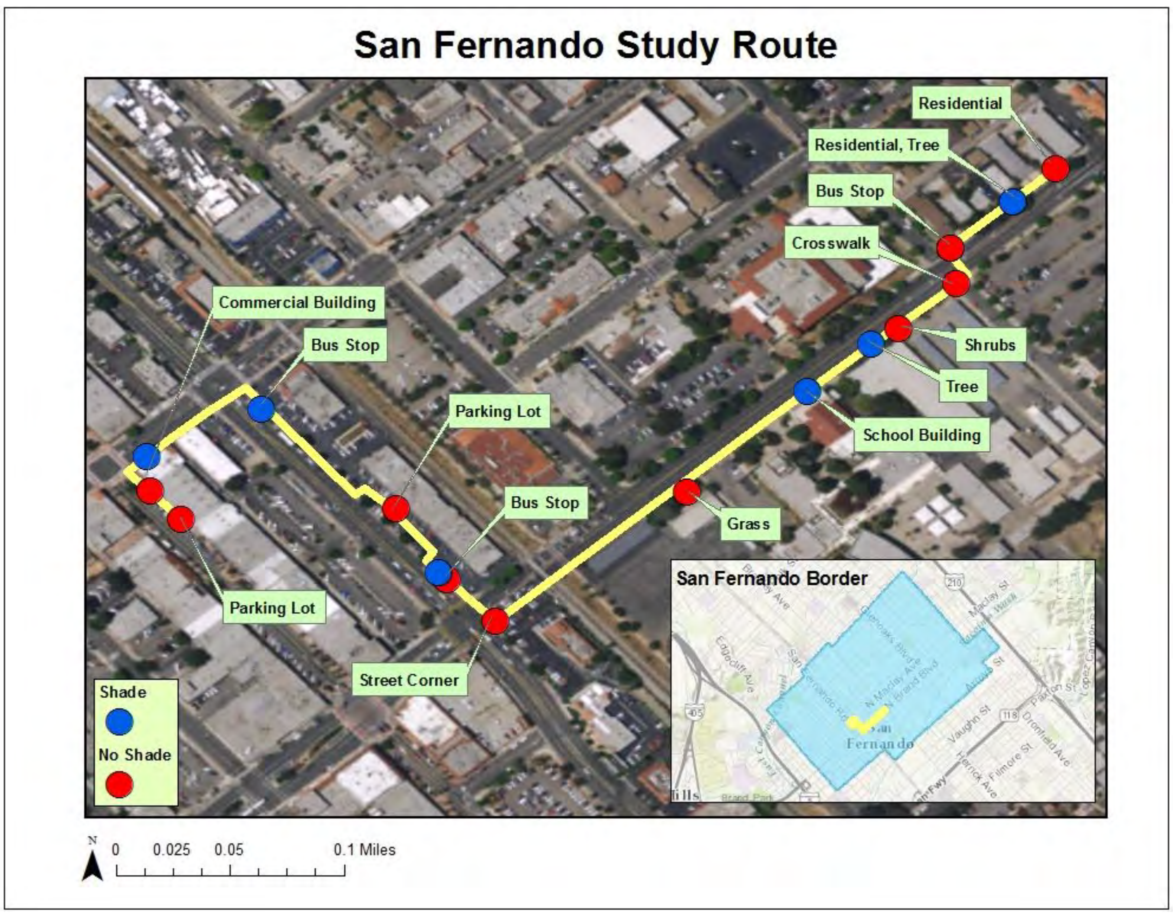


Figure 2: *Walking route for San Fernando. Each circle represents a data collection point. This route begins at the top right corner at a residence without shade. San Fernando border courtesy of the Los Angeles County GIS Data Portal.*

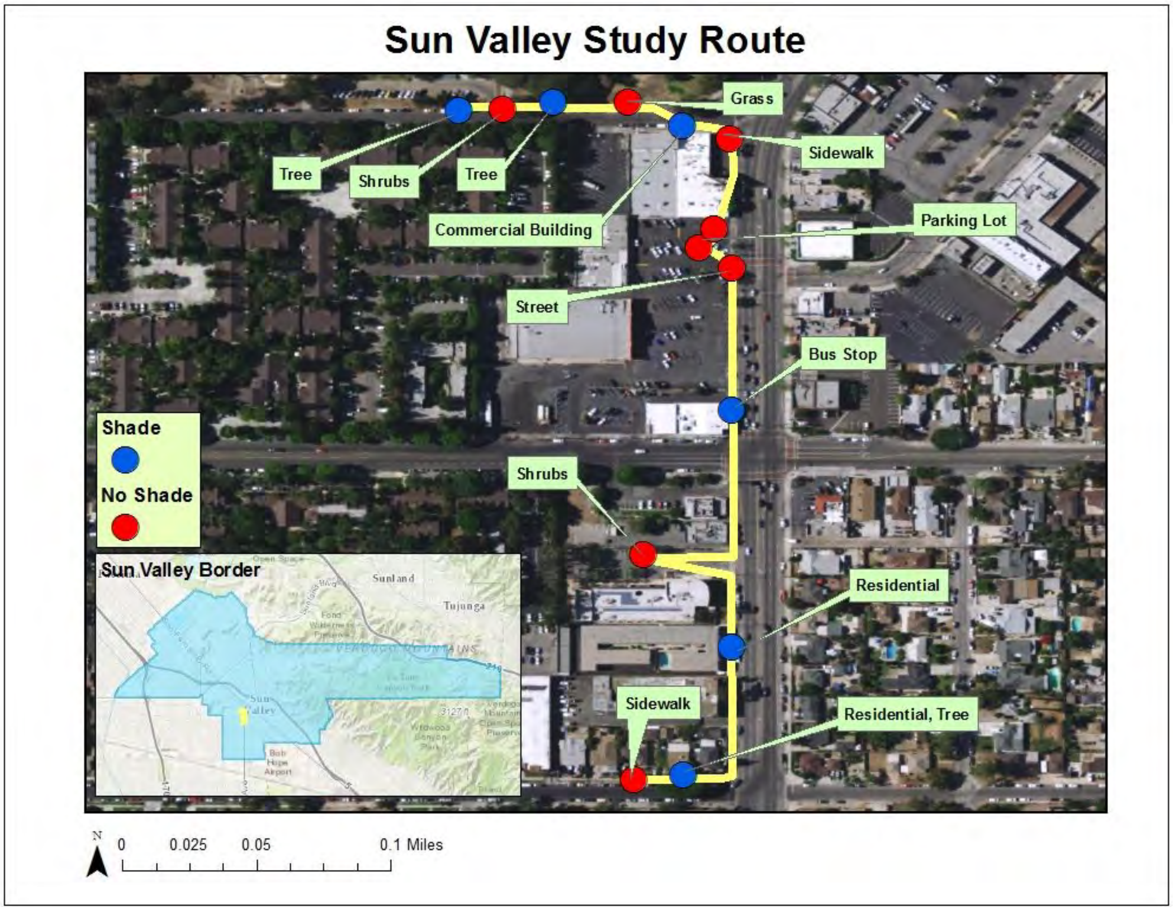


Figure 3: *Walking route for Sun Valley. Each circle represents a data collection point. This route begins at the top left with tree shade. Sun Valley border courtesy of the Los Angeles County GIS Data Portal.*

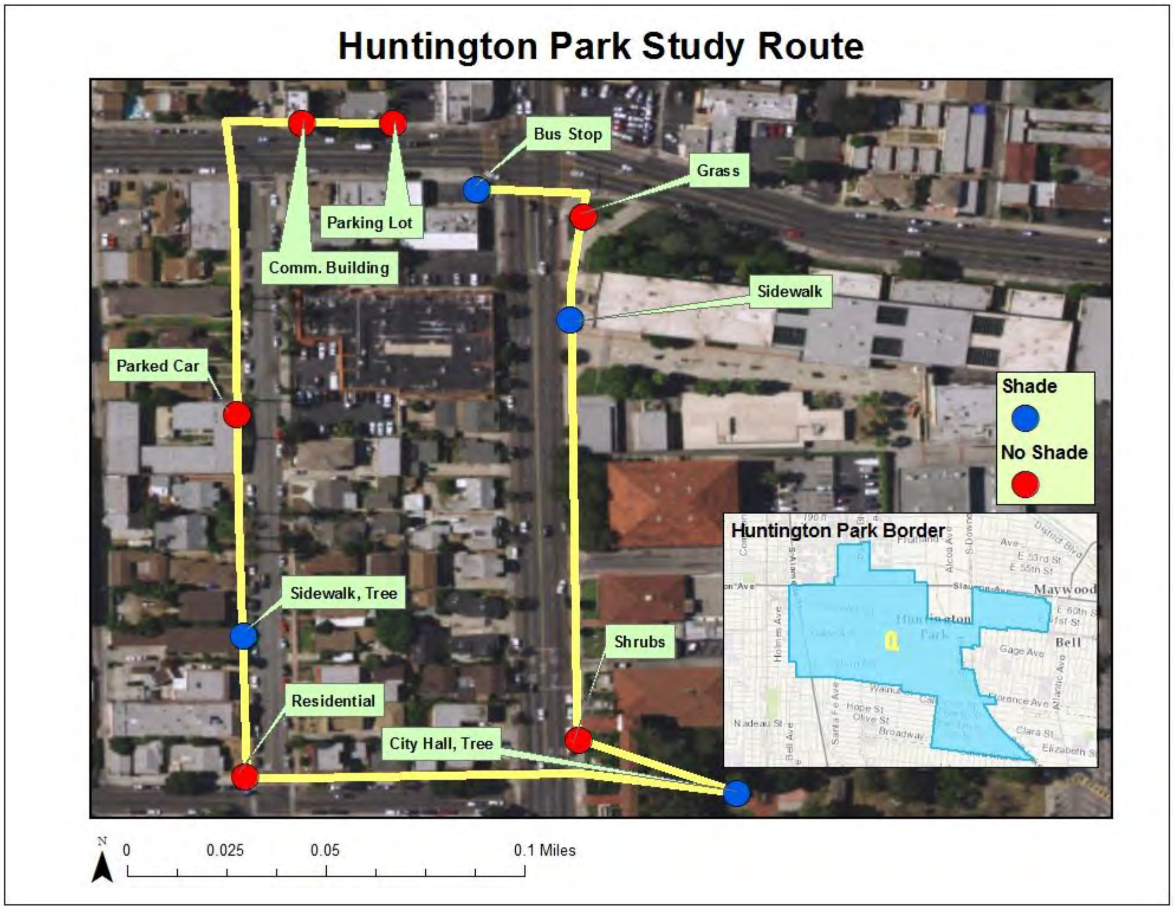


Figure 4: *Walking route for Huntington Park. Each circle represents a data collection point. This route begins with the bus stop with shade. Huntington Park border courtesy of the Los Angeles County GIS Data Portal.*

3. Monitor Potential Heat Event on Weekly Scale

Throughout the process of scouting sites for pedestrian routes, this team monitored the weather daily for temperature spikes to avoid missing the occurrence of heat events. This study identified heat event days as days when the forecasted temperature was at least 4°C (7 °F) above average historical temperatures for those days. This parameter was determined based on previous climate science studies on heat events. Data were also gathered on control days when the temperature recorded was within a reasonable range of the historical average temperature. The team utilized meteorological data from AccuWeather to determine whether a specific day exceeded the threshold temperature difference. In total, the team measured 3 days with significantly higher temperatures than their historical recordings along with 3 control days where the temperature was not a significant departure from historical averages.

4. Devices for Data Measurement

Temperature and Humidity Sensors

In order to place more emphasis on the pedestrian experience, the study measured **temperature** and **humidity** at the ground level instead of relying on temperatures recorded via weather stations. These ground-level measurements are a more accurate representation of how a heat event feels at a microclimate scale. Moreover, these results are indicative of what a pedestrian encounters when walking outside. This team used 3 handheld sensors from Dataq Industries, model number EL-USB-2-LCD. This sensor (Figure 5) has an Environmental temperature range from -35°C to +80°C (-31°F to +176°F) with an accuracy of ±0.5°C, and a relative humidity range of 0 to 100%rh with an accuracy of ±3%rh.

Figure 5: *Above is an image of a sensors purchased from Dataq Industries, model number* EL-USB-2-LCD. *A San Fernando team member is holding it during data collection.*

Infrared Cameras

The infrared camera used was the Seek Thermal Compact Imager for iOS Apple, which detects a range of temperatures from -40°F to 626°F. The 32,000 individual thermal pixels provide a wide 36-degree field of view. Photos were taken on iPhone 6 mobile phones. Supplementary to the data from the hand-held sensors, the infrared photos were used to visually capture thermal differences in surface temperatures along the study paths. The distinguishable color differences in the infrared images provided a clear visual representation of the pedestrian experience.

Moreover, the infrared images allowed for spatial location of varying temperature points within a frame. For each data point measured with the temperature sensor, 4 photos were captured to document the land cover class. The infrared camera and normal phone camera each captured two pictures of the site. The standard camera images were used as a reference for enhanced visualization. One picture was taken with a group member in the frame and the other without the group member. This was done to add a human body as a point of reference in the frame. The points from the sensors were then plotted alongside the images generated by the infrared camera. The purpose of our multi-device analysis was to present a comprehensive image of how varying land cover affects the temperature and humidity at the microclimate level.

Figure 6: *This image gives an example of how the infrared camera was used. in the field. The Seek Thermal interface has a calibrated temperature scale bar along with options to pinpoint the hottest and coolest points in a frame, and isolate temperature ranges. This photo was taken on a heat event day and by Melissa Ikeda, a member of the Communications Team for this Practicum. Equipment used: Seek Thermal XR Imager for iOS-Apple.*

5. *Data Measurement*

To control all site visits for all 3 neighborhoods, three teams were formed which visited the three neighborhoods simultaneously. The three teams were in communication so that data collection started at the same time at all 3 sites. Additionally, calibration times were set between 3 and 5 minutes for all the land cover classes to allow the sensor to reach the peak or valley temperature.

The detailed Data Collection Methodology was as follows:

1. Monitor for upcoming heat events
2. Prepare the sensors by setting up data recording frequency to log every minute on a PC
3. Depart from UCLA in 3 teams of 2 to respective site locations
4. Use GroupMe app to coordinate start time for temperature/humidity sensor
5. Start all sensors at the same time and wait 3-5 minutes for sensor to stabilize
6. While sensors stabilize, the partner with the sensor at hand fills in the observation table with notes about the specific land cover class, data collection site location, and any anecdotal evidence about their pedestrian experience
7. After the temperature stabilizes, the partner with the thermal camera (photographer), takes landscape-oriented photos with the camera set to record temperatures in Celsius units
8. Photographer then takes a photo of the same frame with the standard iPhone camera application
9. Photographer repeats steps 7 & 8 without their partner in the frame
10. Repeat steps 6-9 for all predetermined land cover class stops on route

Results

San Fernando

The averages for all land covers are calculated during heat events and non-heat events respectively. The highest average temperature during heat events was found next to parked cars on asphalt, at 42 °C (108 °F). The second highest point was at a parking lot, with an average of 39.5°C (103.1 °F). Conversely, the lowest average temperature was found at a residential site under tree shade, with a relatively low reading of 33.7 °C (93 °F). That is an almost 9°C (16.2 °F) difference between average temperature in the same neighborhood at different land covers.

When reviewing the data from all site visits, there was a general pattern seen with the hottest and coolest locations: the highest temperature occurs at either a parking lot or other asphalt-paved location, and the coolest spot occurred in a site under a tree. For example, on May 20th, a heat event day, the hottest point reached a high of 43 °C (110 °F) at a strip mall parking lot. On the same day, the lowest temperature was recorded at a light-colored house with tree shade at 34 °C (93 °F). This valley and peak in temperatures illustrates the variability that can be common even within a relatively close distance. In this graph, 16 land cover classes are condensed by averaging land cover classes such as the two residential houses and the three bus stops.

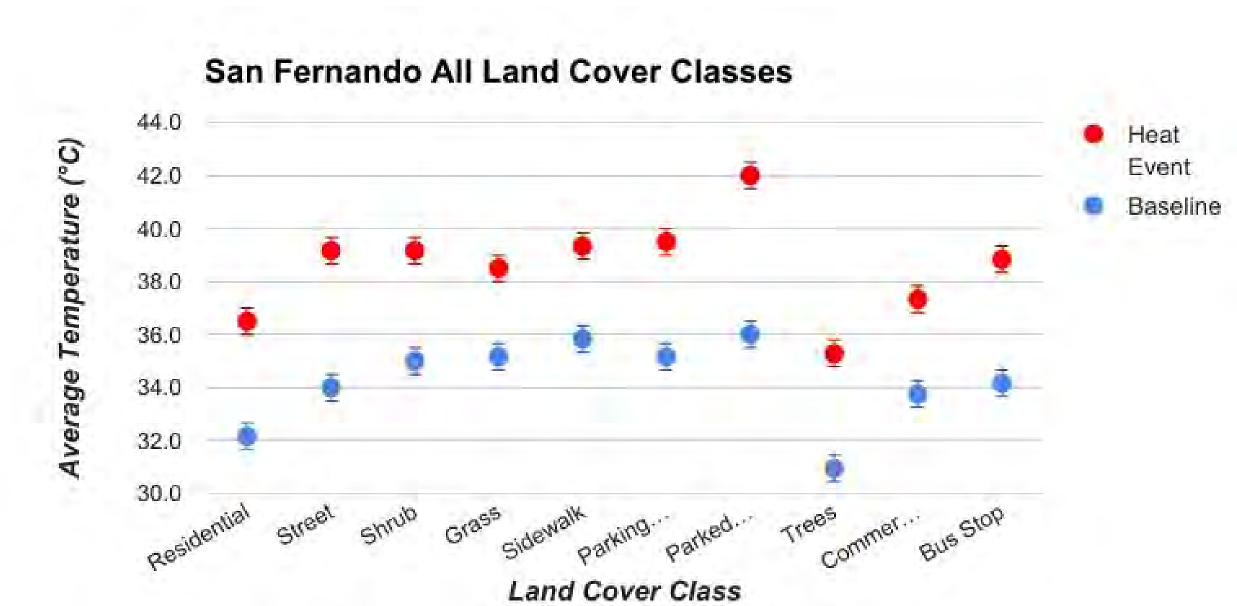


Figure 7: *This graph displays average temperature of all six data collection days in San Fernando (Equipment used: Temperature and Humidity Data Logger EL-21CFR-2-LCD from DATAQ Instrument)*

Location (street names, GPS coordinates)	Land Cover Class	Average heat events for individual land cover class (°C)	Delta Average heat events for individual land cover class (°C)	Average humidity events for individual land cover class (%rh)	Delta Average humidity events for individual land cover class (%rh)	Average baseline for individual land cover class (°C)	Delta average baseline for individual land cover class (°C)	Average baseline for individual land cover class (%rh)	Delta Average baseline for individual land cover class (%rh)
327 North Brand Blvd	residential	36.5		14.7		32.2		38.5	
319 North Brand Blvd	residential with shade	33.7	-2.8	16.2	1.5	29.2	-3.0	42.5	4.0
309 North Brand Blvd	trolley stop	39.0	5.3	13.5	-2.7	34.2	5.0	34.3	-8.2
third street and brand	street	39.2	0.2	12.7	-0.8	34.0	-0.2	34.0	-0.3
	shrub	39.2	0.0	14.2	1.5	35.0	1.0	33.0	-1.0
	tree	36.2	-3.0	14.8	0.7	31.7	-3.3	37.7	4.7
middle school	building	36.2	0.0	14.7	-0.2	33.2	1.5	35.7	-2.0
	grass	38.5	2.3	19.5	4.8	35.2	2.0	34.7	-1.0
brand and Truman	street corner	39.3	0.8	12.5	-7.0	35.3	0.2	31.8	-2.8
metro bus station	bus stop #6613	39.3	0.0	12.7	0.2	36.3	1.0	29.0	-2.8
	bus stop #6613	36.2	-3.2	13.8	1.2	31.3	-5.0	32.8	3.8
dominos	parking lot	39.5	3.3	13.3	-0.5	35.2	3.8	30.3	-2.5
metro bus station	bus stop #6617	38.7	-0.8	13.2	-0.2	34.2	-1.0	31.8	1.5
Los Tres Hermanos	commercial with shade	35.2	-3.5	15.2	2.0	31.7	-2.5	34.0	2.2
Victoria's furniture	commercial	38.5	3.3	13.2	-2.0	34.3	2.7	32.0	-2.0
Dona Mercedes rest	parked cars	42.0	3.5	11.5	-1.7	36.0	1.7	29.2	-2.8

Table 1: *This color-coded table displays average temperature and humidity of all six data collection days in San Fernando, red representing heat event days and blue baseline days.*

Other relatively high temperatures were recorded at land covers such as crosswalks and black benches at a bus stops. In San Fernando, there were three bus stops with different characteristics, which resulted in noticeable temperature differences. One bus stop had a beige concrete bench in full sun; however, a few feet away was a tree, where all bus riders convened consistently during the team's visit, presumably to take advantage of the cooler, shaded environment. Another bus stop had a black bench with no covering. The last bus stop had grey benches and a translucent cover. The area under the tree wherebus riders sat was the coolest and the bus stop with the translucent cover was the hottest. Most notably, the largest consecutive difference in temperature occurred between two land cover classes that were only 20 feet apart: from a residential home with tree shade to a bus stop without shade, there was a temperature increase of 5.3 °C (10 °F).

Site Name: San Fernando

Time	Location (street names, GPS coordinates)	Land Cover Class	observations	Anecdotal
12:10-12:15	327 North Brand Blvd	Residential	No trees, light blue house	Hot and no wind
12:18-12:23	319 North Brand Blvd	Residential	Trees, light beige house	Small breeze
12:25-12:30	309 North Brand Blvd	Trolley Stop	Black bench, no cover	Could sit on bench not too hot
12:32-12:33	Third Street And Brand	Street	Short side	Hot breeze
12:35-12:38		Shrub	4-5 ft	Neck sweating feet hot
12:39-12:44		Tree	2nd tree standing on concrete not as much canopy	Better than shrub
12:46-12:49	Middle School	Building	Beige color, outside on steps	Feels nice to sit on
12:52-12:55		Grass	By parking lot and between two trees	Sitting down and sun directly overhead
12:58-1:01	Brand And Truman	Street Corner	Busy intersection	Windy but hot
1:04-1:08	Metro Bus Station	Bus Stop #6613	Beige bench and no cover	Burns to sit on bench
1:09-1:13		Bus Stop #6613	Tree stump (shade) where all pedestrians sit	
1:15-1:20	Domino's	Parking Lot	Asphalt	Cars parking in and out constantly and feet are burning
1:22-1:26	Metro Bus Station	Bus Stop #6617	Translucent glass cover with silver bench perforated	
1:29-1:34	Los Tres Hermanos	Commercial	Under Tree	
1:35-1:40	Victoria's furniture	commercial	No shade, parking meter 1065	
1:41-1:46	Dona Mercedes rest	parked cars	Asphalt street, meter 1053	Hotter than Domino's, sweating and camera overheated

Table 2: *This table shows an example of the observational data from San Fernando*

In terms of humidity, heat event days were much drier than baseline days. This is likely attributable to dry air mass types that occurred during the heat events. On average during heat waves, the highest relative humidity was over grass with 19.5%rh, while the lowest was around parked cars with only 11%rh. In contrast, the highest relative humidity during baseline days was 42.5%rh at the residential home under shade, and the lowest was at 19%rh at a bus stop without shade. The humidity from baseline days more than double than that of heat event days.

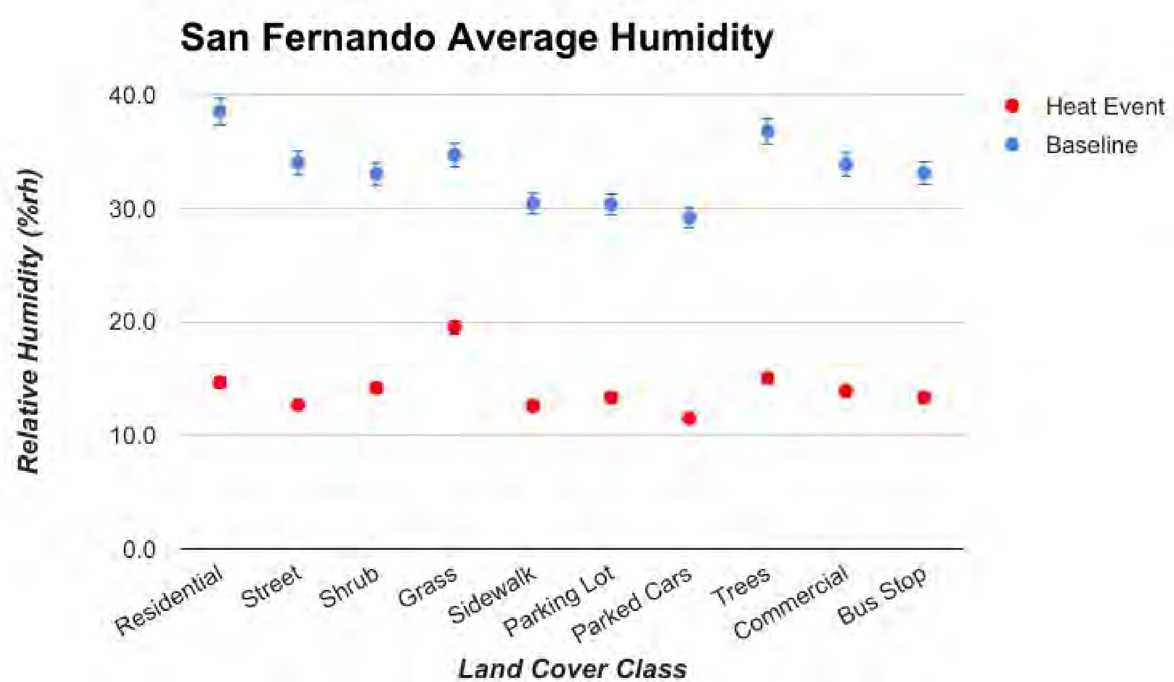


Figure 8: *Average relative humidity of all six data collections days in San Fernando. (Equipment used: Temperature and Humidity Data Logger EL-21CFR-2-LCD from DATAQ Instrument)*

Figure 9: *Side-by-side images displaying the unseen heat of asphalt. The hottest point in this frame reaches 69 °C. (Equipment used: Seek Thermal XR Imager for iOS-Apple)*

Sun Valley

After collecting data from Sun Valley, the data had very similar trends to that of San Fernando. The highest temperature occurred on May 20th over an asphalt parking lot. The asphalt was dark, had a lower albedo, and was located in a site without shade, which contributed to a temperature of 41 °C (106 °F). The tree shade in the parking lot reduced the temperature by about 2-3 °C (3-6 °F) on a heat event day. This seemingly small difference in temperature can dramatically alter one's experience outside.

Land Cover Class	Trees	04-30-17	04-30-17 (%rh)	05-12-17 (°C)	05-12-17 (%rh)	05-20-17 (°C)	05-20-17 (%rh)	05-21-17 (°C)	05-21-17 (%rh)	06-02-17 (°C)	06-02-17 (%rh)	06-04-17 (°C)
Tree	yes	32.5	14.5	27	43.5	34	14.5	32.5	28	29	45	28
Shrub	no	37	13.5	29.5	41	39	13.5	37.5	21.5	34	37	32.5
Tree	yes	34.5	11.5	27.5	42.5	35.5	15	34.5	26	32.5	37.5	30
Grass	no	33	13.5	27	43	39	15	39.5	22	33.5	37	31.5
Commercial Building	no	36.5	12.5	27.5	42.5	37.5	13	37	24.5	33.5	37.5	31
Sidewalk	no	34.5	11.5	28	41.5	40	12	39	23	35	35	32
Parking Lot	no	36.5	11.5	29.5	39	41	13	40	21	36.5	31.5	35
Parked Cars	no	37	10.5	27.5	41	38	12	38	23	35	32.5	35
Street	no	34	13	27	43	36.5	12.5	36	24	34.5	34.5	32
Bus stop	no	32.5	12.5	27	43	37	12	36.5	25	33	36.5	31.5
Shrub	yes	33	12	26.5	43.5	36	13	36	25.5	33	36.5	31
Residential building	no	32.5	12	27.5	42.5	36	13	35	27	33	36.5	30.5
Residential tree shade	yes	31.5	14	26.5	44	35	12	34	27.5	32	37	29.5
Sidewalk	no	34	13	29	38.5	39	10.5	38	23.5	34	36.5	32.5

Table 3: *This color-coded table displays average temperature and humidity of all six data collection days in Sun Valley, red representing heat event days and blue baseline days.*

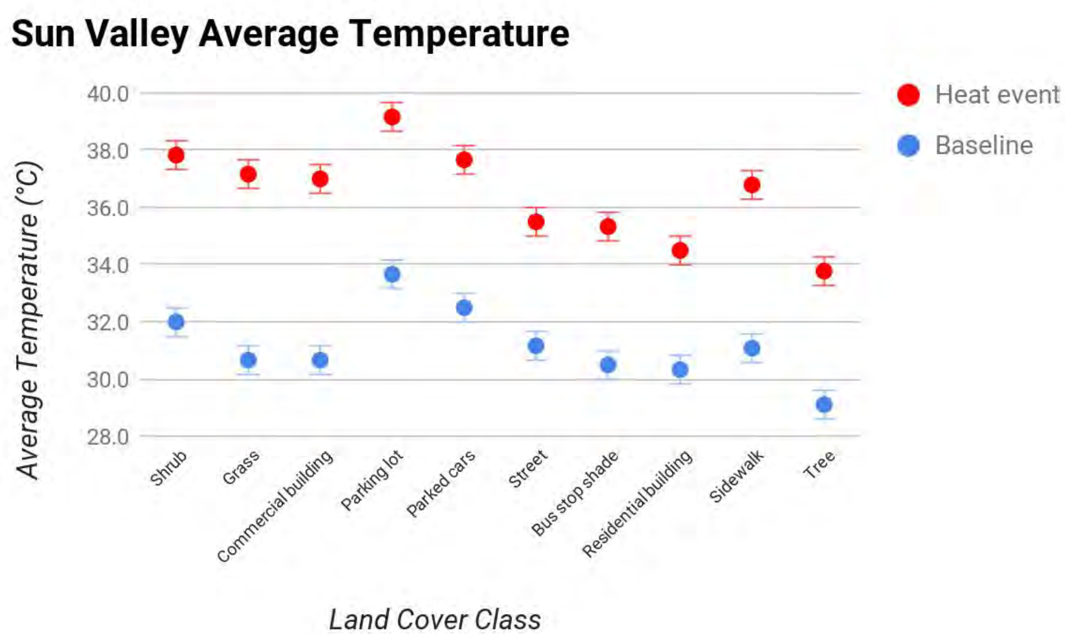


Figure 10: *Average temperature of all six data collection days in Sun Valley. (Equipment used: Temperature and Humidity Data Logger EL-21CFR-2-LCD from DATAQ Instrument)*

When considering humidity, the sensor data shows that heat event days are significantly drier than baseline days, which is consistent with San Fernando. The average humidity during a heat event was 16% relative humidity and 41% average relative humidity on the baseline days. After comparing all three heat events with the three baseline days, a clear trend emerges that asphalt, sidewalks, streets, and parked cars, have the lowest relative humidity. On heat event days, the relative humidity around these three land cover classes dropped approximately 4%rh, and is likely attributable to the dry air mass types present during these particular heat events. The land cover classes that had the highest relative humidity were areas with trees and grass, presumed to be due to the fact that plants give off moisture through a process called evapotranspiration. The relative humidity on an average heat event day was about 18%rh compared to the average baseline day of about 40%rh.

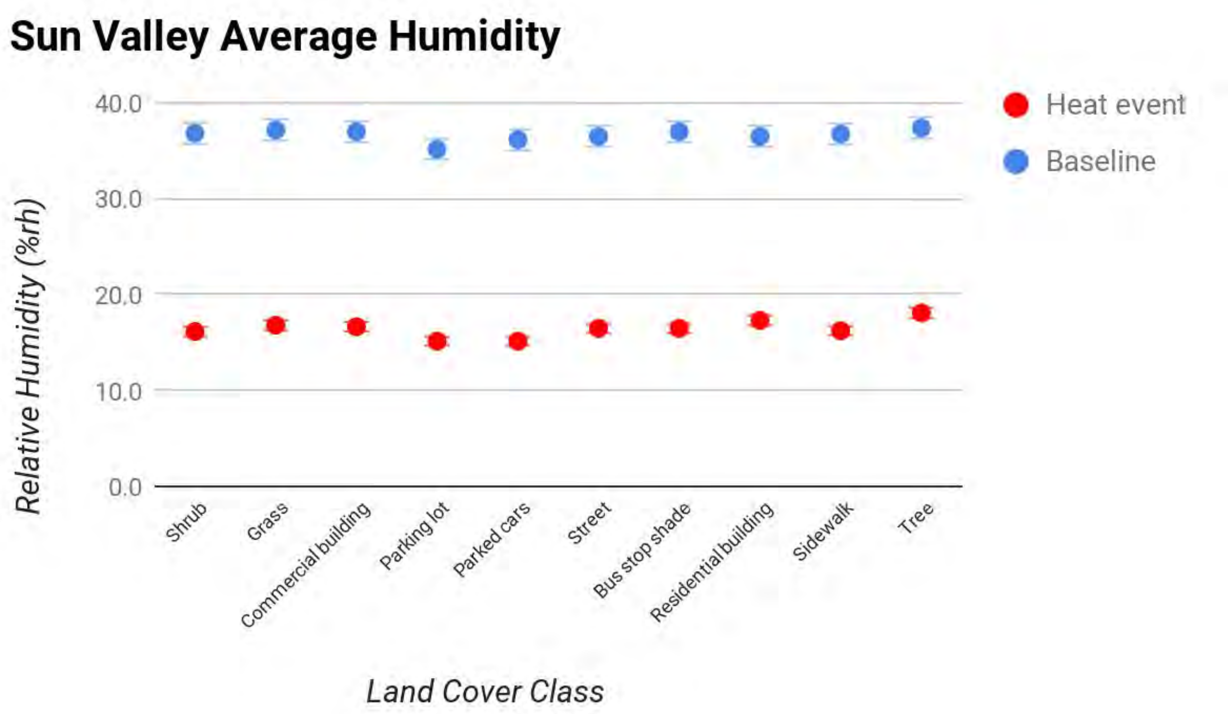


Figure 11: *Average relative humidity of all six data collection days in Sun Valley. (Equipment used: Temperature and Humidity Data Logger EL-21CFR-2-LCD from DATAQ Instrument)*

Huntington Park

The results for Huntington Park show similar trends to those of San Fernando and Sun Valley. The highest average temperature during the heat events was found at a parked car by the curb, directly under sunlight at 37 °C (99 °F). The land cover that had the lowest average temperature during the heat events was inside the courtyard of the Huntington Park City Hall at 32 °C (89°F). For the baseline days, the highest point was at a parking lot at 33.5 °C (91 °F) and lowest was at the City Hall courtyard at 29.7 °C (84 °F).

Land Cover Class	04-30-17 (°C)	04-30-17 (%rh)	05-12-17 (°C)	05-12-17 (%rh)	05-20-17 (°C)	05-20-17 (%rh)	05-21-17 (°C)	05-21-17 (%rh)	06-02-17 (°C)	06-02-17 (%rh)	06-04-17 (°C)	06-04-17 (%rh)
Bus stop	31.5	23.0	26.0	48.0	31.5	35.0	33.5	24.0	32.5	55.5	32.5	44.5
Grass	33.5	21.0	27.5	44.5	34.0	25.5	35.0	23.5	33.0	57.0	31.5	45.0
Residential house	35.5	23.5	28.0	46.5	35.0	28.5	35.5	22.5	33.5	59.0	32.5	43.0
Sidewalk	37.0	21.5	28.5	48.0	34.5	35.5	36.5	22.5	33.0	60.5	31.5	47.0
Parked car	35.5	20.5	29.0	41.0	34.5	22.5	37.5	21.0	35.0	59.0	34.0	51.5
Commercial restaurant	35.0	21.5	27.5	44.0	34.5	29.5	37.0	21.0	36.0	52.0	32.0	47.0
Parking lot	33.5	35.5	29.5	39.5	35.5	31.0	35.5	24.5	37.0	50.5	34.0	50.5
School gate	33.0	22.5	27.5	43.5	33.5	29.0	37.0	22.5	35.5	49.0	32.0	45.0
City hall	33.5	25.0	28.5	45.0	34.0	32.0	35.5	23.5	35.5	50.0	30.0	49.0
Trees inside city hall	34.5	22.5	27.5	41.5	32.0	33.5	33.0	27.5	32.5	49.5	29.0	56.0

Table 3: *This color-coded table displays average temperature and humidity of all six data collection days in Huntington Park,, red representing heat event days and blue baseline days.*

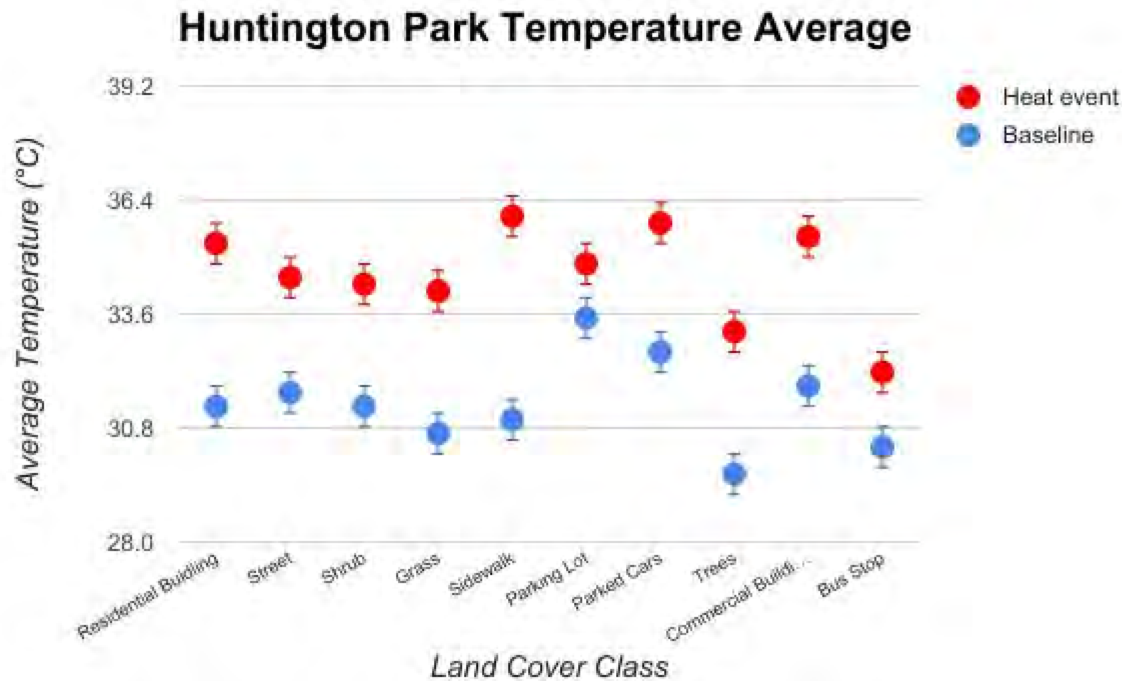


Figure 12: *Average temperature of all six data collection days in Huntington Park. (Equipment used: Temperature and Humidity Data Logger EL-21CFR-2-LCD from DATAQ Instrument)*

It is especially interesting to compare the data recorded from inside the City Hall with other data points. On the half-mile route, the distribution of trees was roughly the same throughout the community, except for in the City Hall courtyard, where there was an abnormally large amount of tree coverage. According to the anecdotal data, the two team members felt "significant cooling" during heat events in this area.

The sensor data show that for relative humidity in Huntington Park, the highest average was in the parking lot with many surrounding trees at 29%rh and lowest near a parked car at 21%rh. The baseline data, showing a similar trend to those from the other two sites, are higher in humidity. The highest reading was at a sidewalk with little tree shade at 51.8%rh, and the lowest is in front of a school gate without shade or vegetation nearby at 45.8%rh. On average, from a parking lot to the front gate of a high school, the humidity drops by 5%rh.

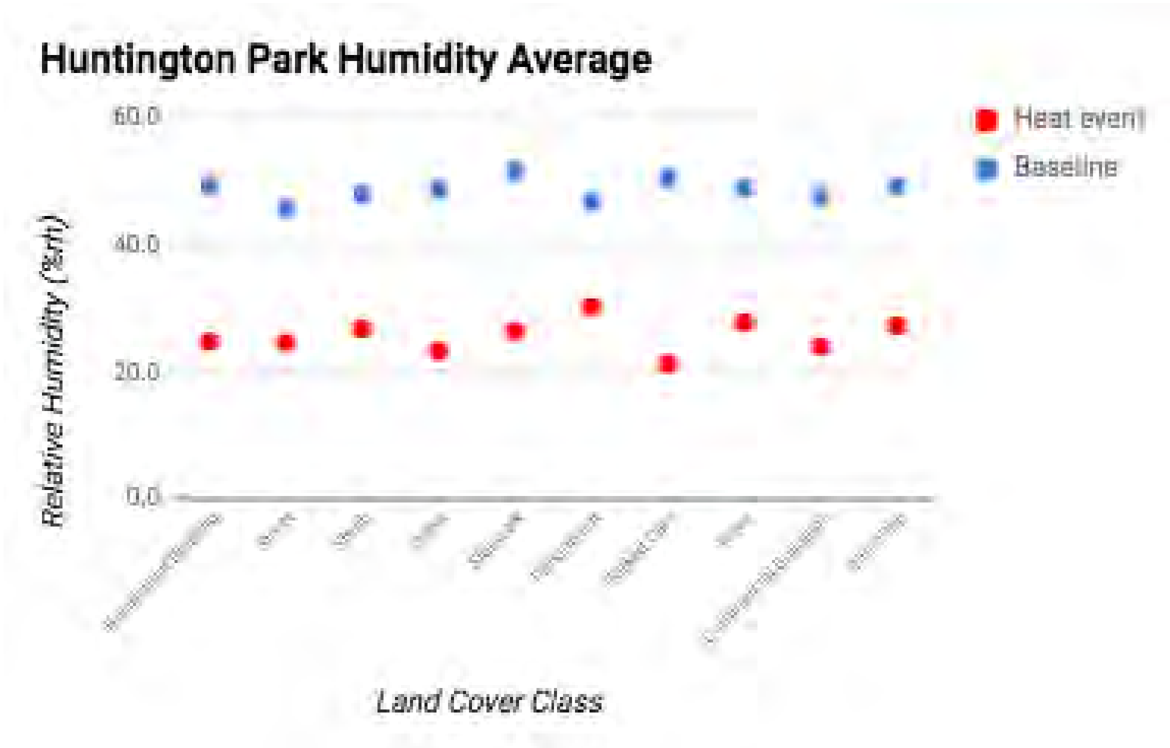


Figure 13: *Average relative humidity for all six data collection days in Huntington Park. (Equipment used: Temperature and Humidity Data Logger EL-21CFR-2-LCD from DATAQ Instrument)*

Impact of Shade Across Land Cover Classes

When conditions permitted, the team collected data for the same type of land cover class, with one in direct sunlight and another under shade. The shade could be provided by trees or from features in the built environment . For example, in San Fernando, the team collected data from two bus stops, one with an awning and the other without. For locations that had tree shade, the team collected data from both within and outside of the shade. On average, the data show it was 3 °C (5.4 °F) cooler under the shade for the same bus stop. Figure 13 shows an example of average temperature difference between shaded areas and non-shaded areas during heat events in San Fernando. While the temperature on a sidewalk without shade reached a high of 38.8 °C (102 °F), the same land cover under shade was only 35.6°C (95°F).

Figure 14: *This image displays the bus stop in San Fernando where there is tree shade near the bus stop. Data was collected sitting at the bus stop bench and at the tree planter where pedestrians most frequently sat as they waited for the bus. Photo taken by Melissa Ikeda.*

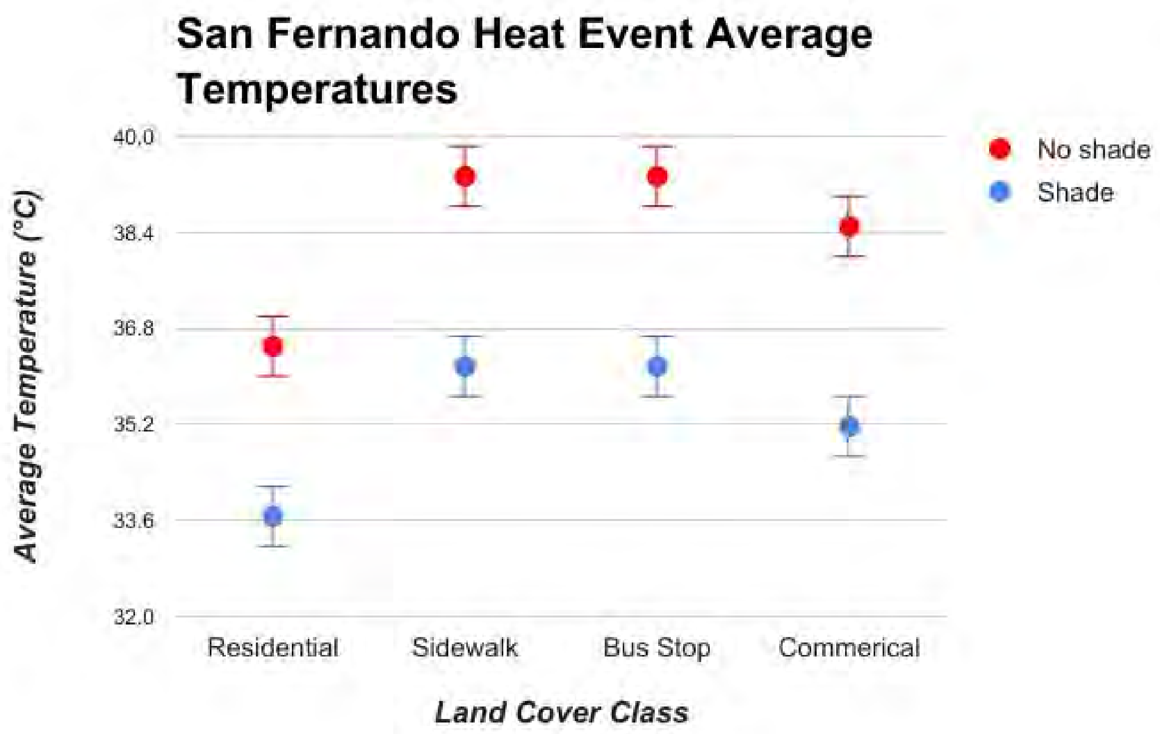


Figure 15: *Average temperature for shade and without shade for the same land cover classes in San Fernando. (Equipment used: Temperature and Humidity Data Logger EL-21CFR-2-LCD from DATAQ Instrument)*

The cooling benefits provided by shade can also be observed from data from the other two sites. In addition to the effects on temperature, shading also influences humidity. Sensor data show that there is an increasing trend, though by a small amount, in relative humidity for the same land cover under shade than without shade on heat event days. The increase varies from 0.5%rh to 1%rh for data from all three sites. For the baseline relative humidity data, the trend is similar with a larger increase from 3%rh to 8%rh.

Discussion

A control group is an indispensable factor in data collection in order to have an unbiased comparison and analysis. In order to have a better understanding of the parameters we obtained from heat event days, this study used average days for baseline data collection days. After comparing the temperature and humidity between heat events days and baseline days, the most straightforward conclusion is that heat events do have an intensive temperature incline and humidity decline, which could influence the heat resiliency of communities.

There was a difference of up to 5°C (9 °F) and up to 20%rh between heat event data points and baseline data points. Additionally, this comparison shows that locations with trees are affected less by heat events than locations directly exposed to sun. For example, in San Fernando, the parking lot, which is exposed to direct sunlight, was 3.7 °C (7 °F) hotter during a heat event than on a baseline day. In comparison, the coolest area was the residential site with a tree with an average temperature 33.7°C during heat events, while the hottest land cover class, parked cars, had an average temperature of 42 °C. This 10°C difference can be attributed to the shading effect of trees.

However, numerical data could not entirely convey the effects of temperature increases and humidity decreases and on the pedestrian experience. Therefore, we included the observational data and the flow charts. The anecdotal data collected during each site visit narrated how our team members felt when collecting during heat event days and non-heat event days. For example, on May 20th, a heat event, each neighborhood's anecdotal data included terms such as "sweating" and "uncomfortable." Notably, one team member described her feet burning through her sneakers as she stood on an asphalt surface while waiting several minutes for the sensor to calibrate.

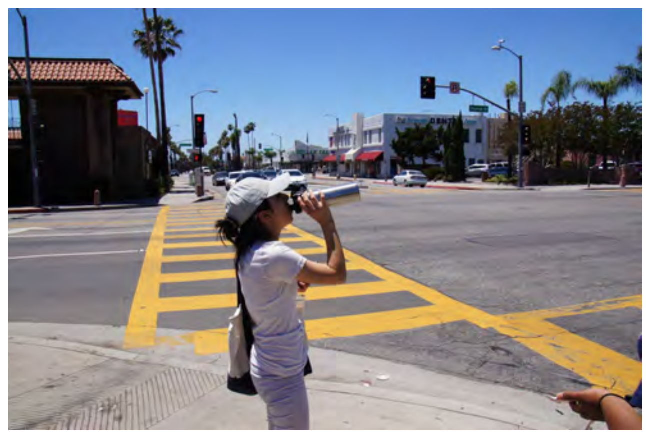


Figure 16: *This image displays Ingrid Maradiaga hydrating in San Fernando during a heat event. Photo taken by Melissa Ikeda.*

As a visual representation of these physical experiences, we constructed a flow chart that indicates the temperature differences between land cover classes. The following flow chart displays the average temperatures for each land cover class during a heat event. Based on the differences highlighted between each stop, we could see that there was a tremendous temperature difference between land cover classes that were as close as only 20 feet apart. This shows that in half a mile, a person can encounter highly variable temperatures with a range of up to 10°C.

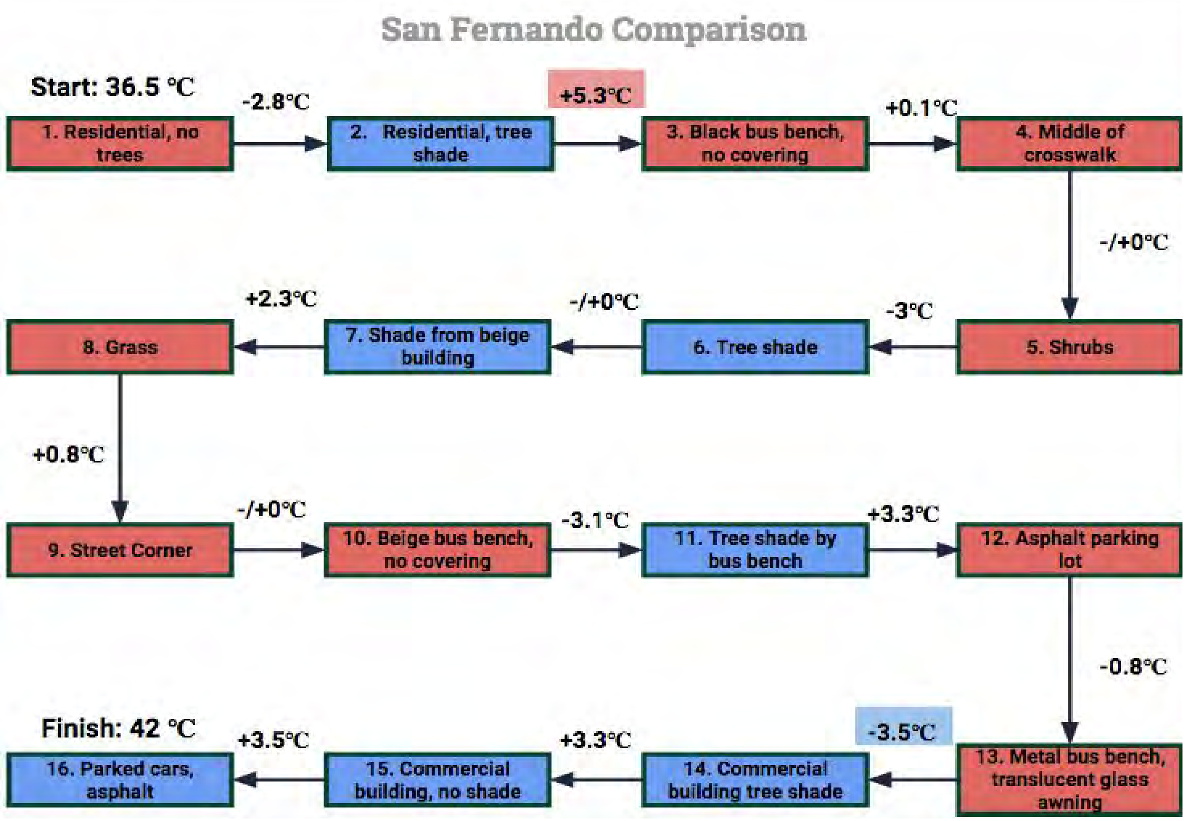


Figure 17: *This flow chart displays the average differences in temperature between consecutive data collection points in San Fernando. Red boxes indicate points without shade whereas blue boxes indicate points with shade. The red and blue highlighted deltas indicate the hottest and coolest transitions between data collection points.*

After comparing the data between all three neighborhoods, there were notable patterns. For example, the the color of urban materials (ground, walls, benches, etc.) appeared to have a strong influence on temperature at that site, presumed to be due to changes in albedo. In San Fernando, there were three bus stop benches all made with different material: black plastic bench, beige concrete bench, and silver perforated bench. When averaging temperatures for all heat events, the beige bus stop had the highest temperature and the silver bus bench had the lowest. This could be a result of the concrete material absorbing the heat despite its light color and the holes in the silver bench reflecting heat and providing a heat escape through its perforations.

Additionally, there were strong differences between vegetative land cover classes. The data showed that grass is not an effective vegetative land cover for cooling. For instance, in Huntington Park sidewalk alongside grass was the highest temperature during heat event days at 37 °C. The data also showed that shrubs were even more ineffective for cooling. This shows that evapotranspiration from low rise vegetation does not have an evident impact during heat event days. When comparing all vegetative land cover classes in San Fernando during a heat event, shrubs had an average temperature of 39.2 °C, grass had an average temperature of 38.5 °C, and trees had an average temperature of 35.3 °C. Therefore, practitioners and policy makers should strongly consider trees as an effective solution for urban cooling in the face of climate change.

Key Points

- Tree shade provided the strongest cooling effect
- Overall, any form of shade aided with cooling
- Shrubs and grass proved to be ineffective in cooling
- Overall, humidity was the highest around vegetative land covers and the lowest around urban materials
- Locations that are close in proximity (sometimes 20 feet apart) can experience drastically different temperatures and humidities due to difference in land cover class

Limitations

Low occurrence of heat events:

Given that we were limited by the few occurrences of heat events, this database is bound by the lack of the data sets. More data sets would have allowed for statistical significance tests.

Heat event definition:

The literature showed vague definitions for heat events. For consistency, the same parameters used in this study for heat events should be followed for subsequent studies.

Seasonal variation:

Moreover, the accuracy of the data collection is impacted by the intensity and time of heat events. As data collection days occurred between the months of April and June, there was variability even amongst heat event days. Heat event days in April were expectedly cooler than heat event days in May.

Inconsistencies among different routes:

It was difficult to include all the same types of land cover classes due to the different topography and urban environments of the locations. More specifically, there was difficulty in reaching varying land cover classes in Huntington Park.

Recommendations

Urban design and development must be driven by improving climate resilience for proper mitigation. This study demonstrates that shade, particularly from trees which can provide a cooling of 6-8 °C, can make an enormous difference in climate vulnerability during heat waves. Therefore, it is important that urban planning include data that quantifies what people experience outside. This improved climate resilience has the potential to reduce heat-related health risks and ultimately save lives.

However, to effectively invest in land cover, there must be more engagement and dialogue between members of the community, policy makers, developers and other key stakeholders. Climate resilience can only achieved when all stakeholders work together. There must be education and awareness within the community on the effects of land cover class on microclimates in order for community members to engage accordingly in improving their surroundings by planting trees, taking on projects to increase reflectivity at home, and, when necessary, advocate for inclusion of trees, shade and reflective surfaces in development projects. This data analysis could also be condensed into a shorter report that includes all visual data representations with straightforward interpretations and evaluations, and could serve as an indispensable tool in illustrating the significant impacts that land cover choices make.

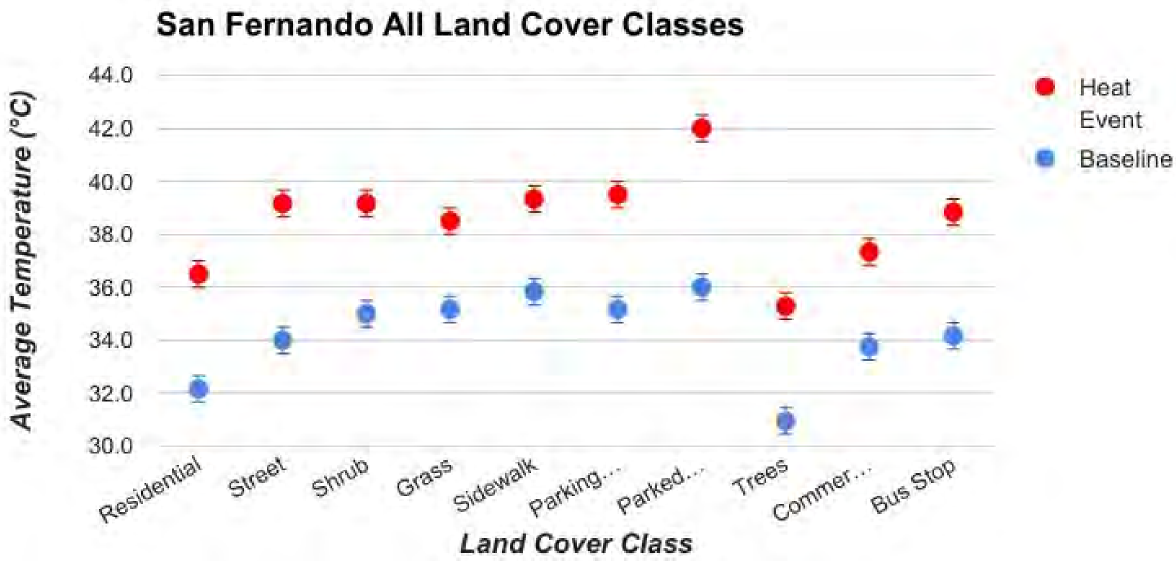
Additionally, this study team recommends that these data be used to conduct a cost-benefit analysis on different options for land cover conversion, which can provide a tool for stakeholders to use for project development. For example, the analysis could highlight the health-related risks during a heat event that could be alleviated by changing land cover classes. In order to prepare the data for this type of analysis, there must be development and refinement within this framework. The methodology used for this study should first be revised around the limitations described. Consequently, the revised methodology will improve the accuracy of critically important data that can be used for future analysis and research.

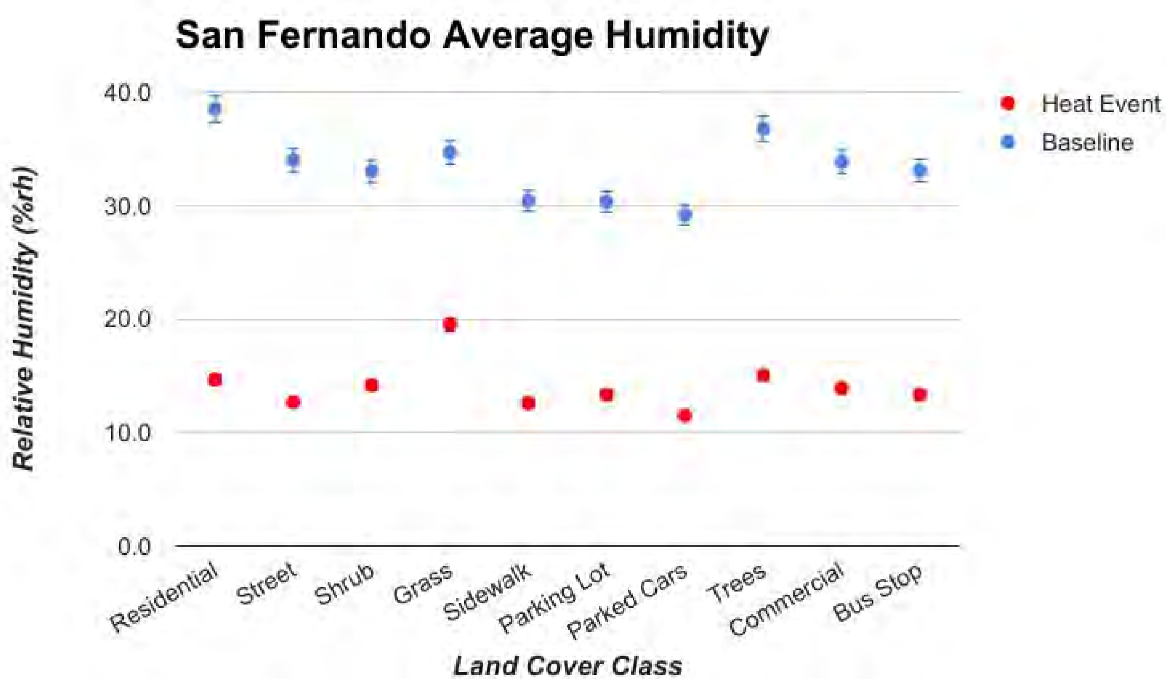
Appendix

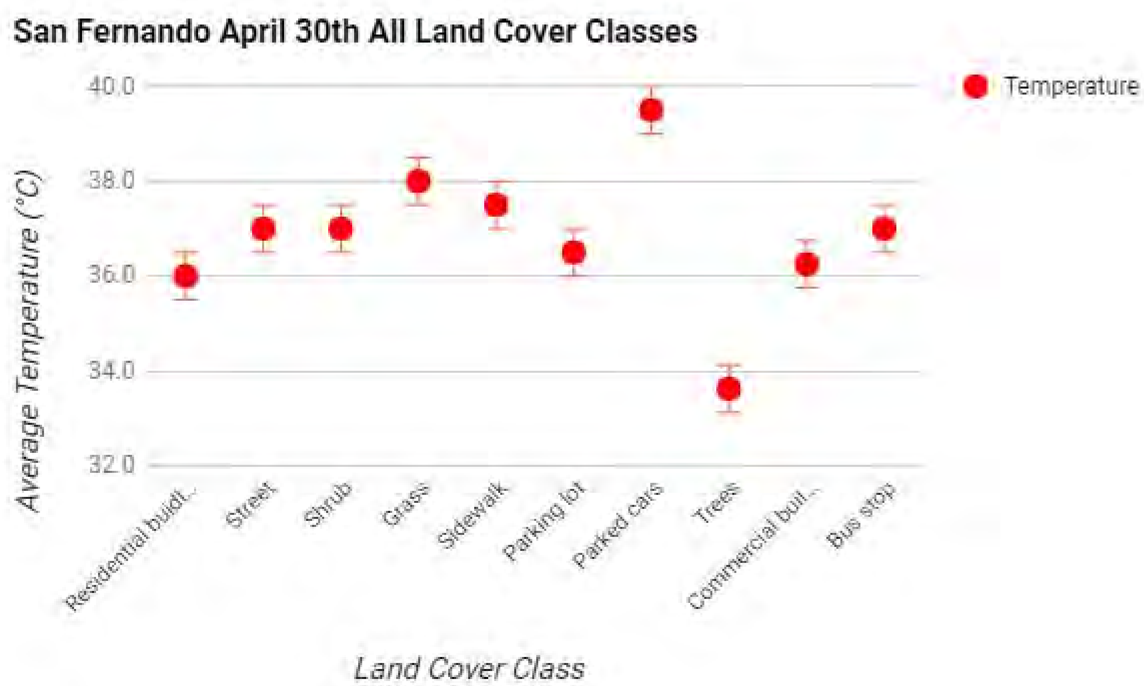
Heat Event Days and Non-Heat Event Days

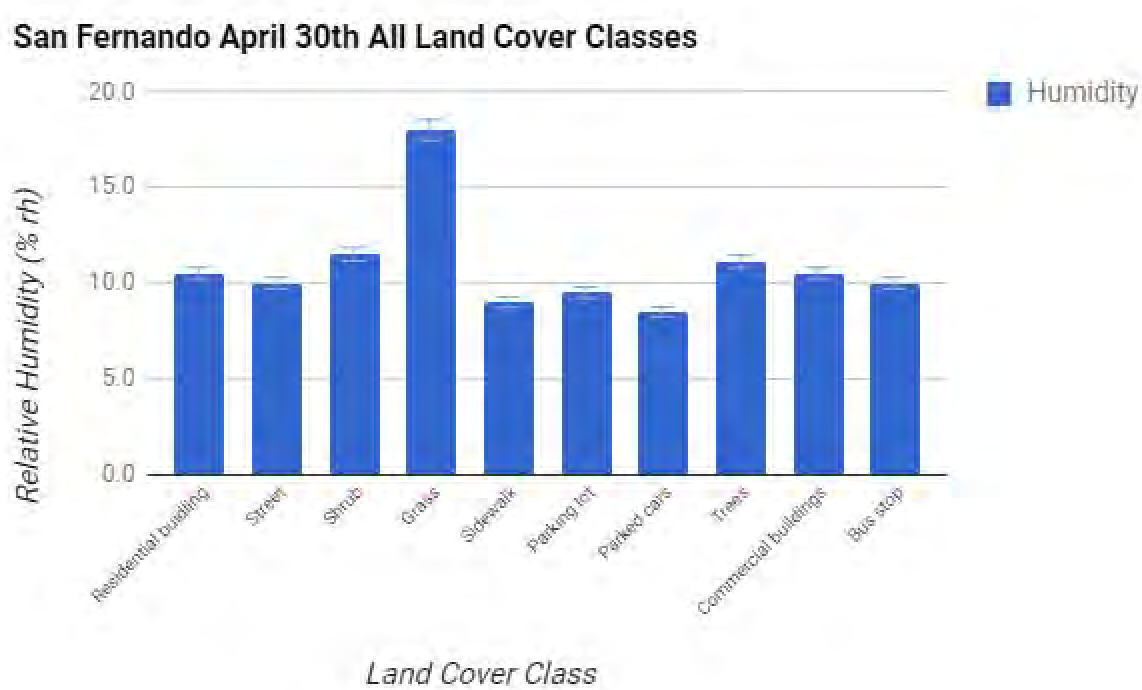
Date	
04-30-17	Heat Event
05-12-17	Non-Heat Event
05-20-17	Heat Event
05-21-17	Heat Event
06-02-17	Non-Heat Event
06-02-17	Non-Heat Event

San Fernando Data Graphs



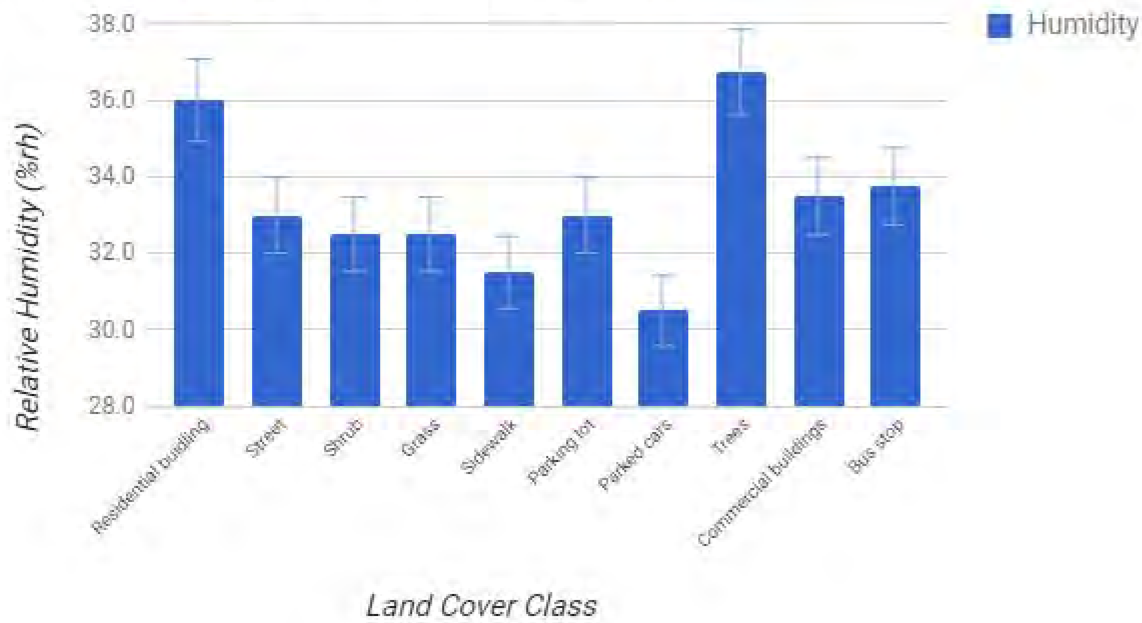



San Fernando April 30th All Land Cover Classes
Temperature
Average Temperature (°C)
40.0
38.0
36.0
34.0
32.0
Residential buidl...
Street
Shrub
Grass
Sidewalk
Parking lot
Parked cars
Trees
Commercial buil...
Bus stop
Land Cover Class

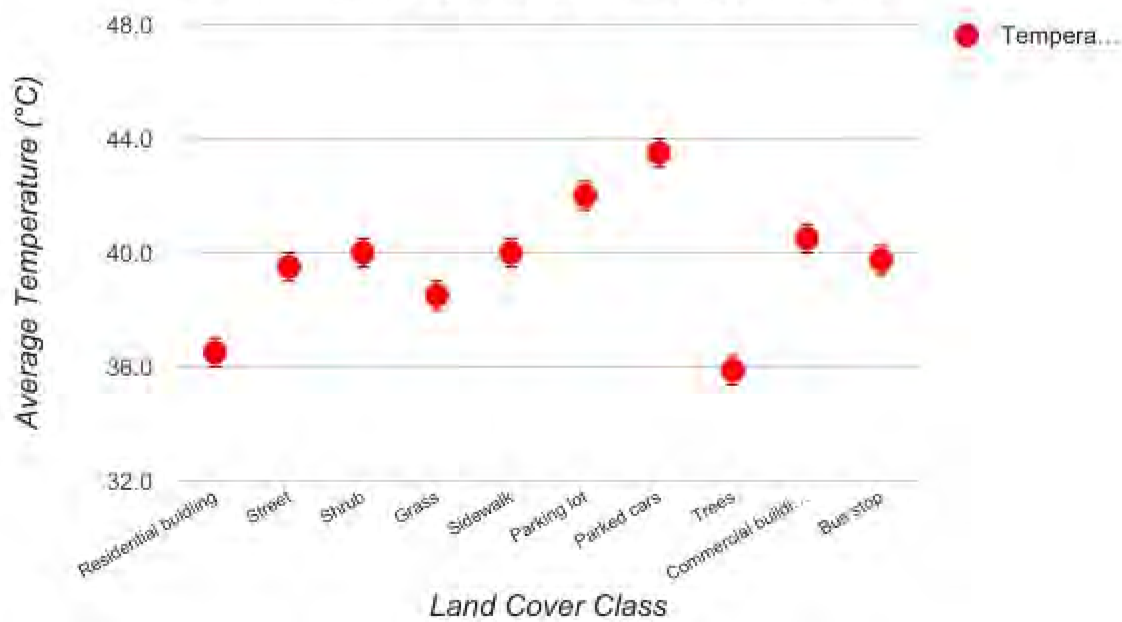

San Fernando April 30th All Land Cover Classes
Humidity
Relative Humidity (% rh)
20.0
15.0
10.0
5.0
0.0
Residential buidling
Street
Shrub
Grass
Sidewalk
Parking lot
Parked cars
Trees
Commercial buildings
Bus stop
Land Cover Class


San Fernando May 12th All Land Cover Classes
Average Temperature (°C)
35.0
32.5
30.0
27.5
25.0
Tempera...
Residential building
Street
Shrub
Grass
Sidewalk
Parking lot
Parked cars
Trees
Commercial buildi...
Bus stop
Land Cover Class

San Fernando May 12th All Land Cover Classes

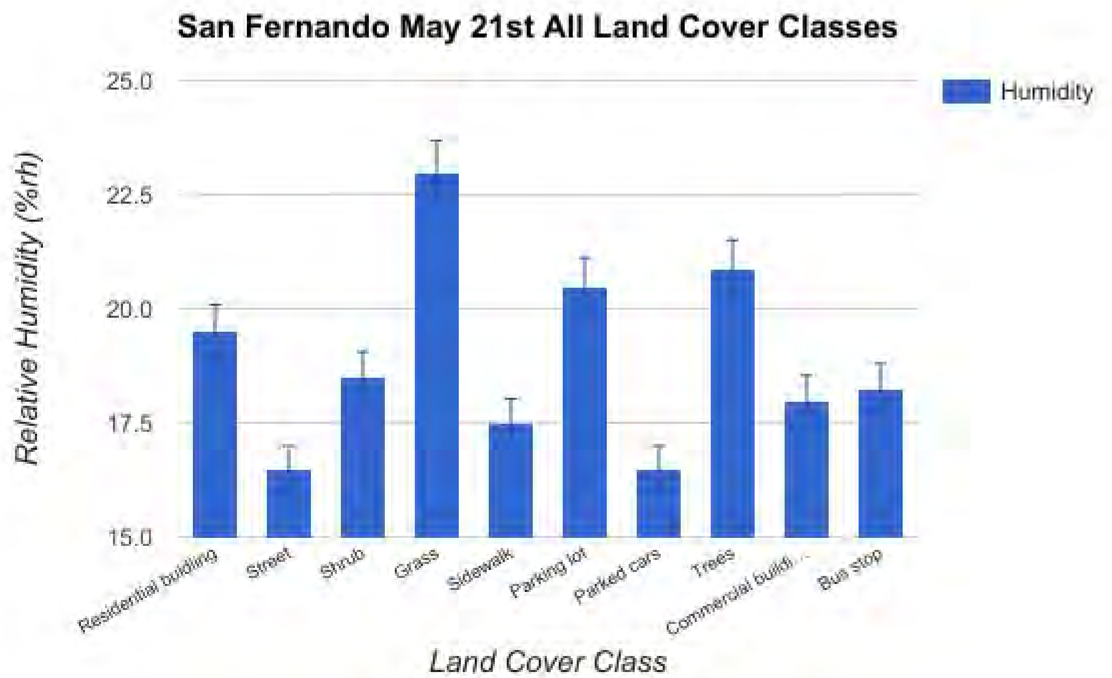


San Fernando May 20th All Land Cover Classes

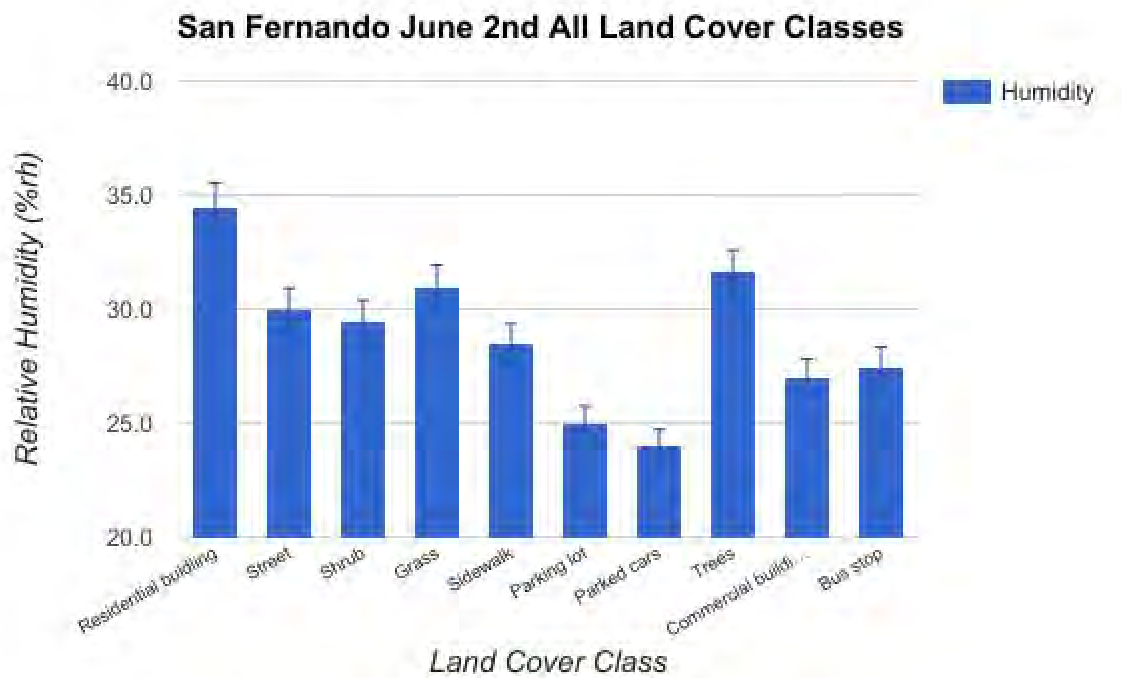



San Fernando May 20th All Land Cover Classes
Humidity
Relative Humidity (%rh)
22.0
18.0
14.0
10.0
6.0
Residential building
Street
Shrub
Grass
Sidewalk
Parking lot
Parked cars
Trees
Commercial buildings
Bus stop
Land Cover Class

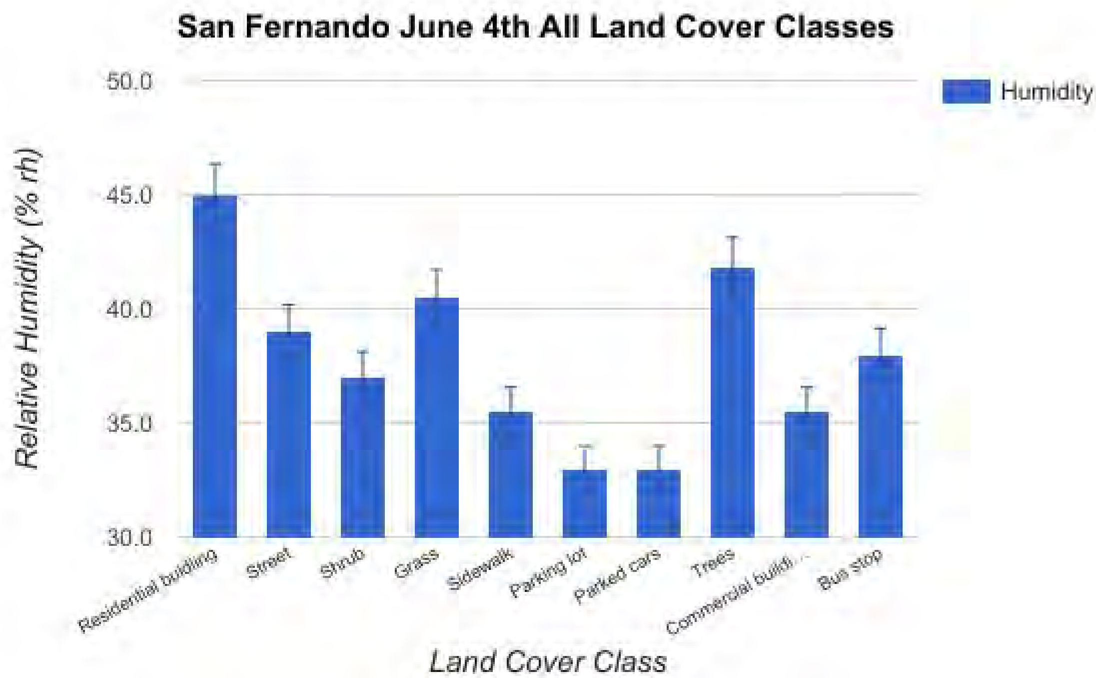

San Fernando May 21st All Land Cover Classes
Tempera...
Average Temperature (°C)
45.0
42.5
40.0
37.5
35.0
Residential building
Street
Shrub
Grass
Sidewalk
Parking lot
Parked cars
Trees
Commercial buildi...
Bus stop
Land Cover Class

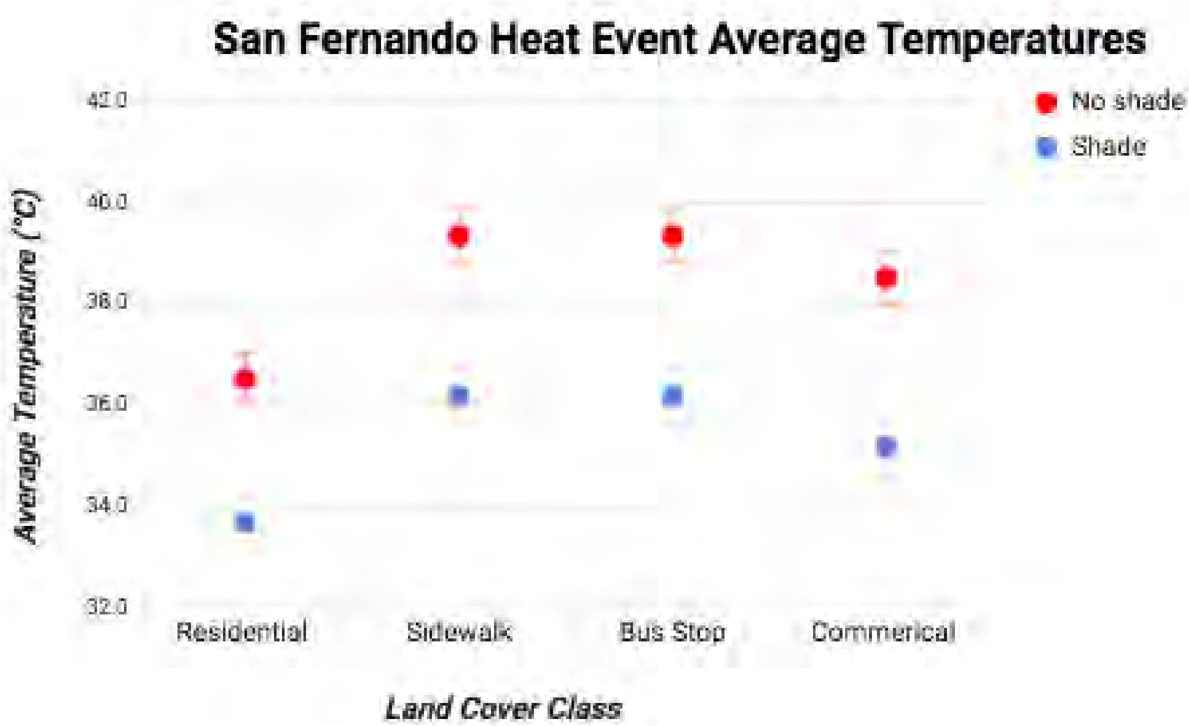

San Fernando May 21st All Land Cover Classes
Humidity
Relative Humidity (%rh)
25.0
22.5
20.0
17.5
15.0
Residential building
Street
Shrub
Grass
Sidewalk
Parking lot
Parked cars
Trees
Commercial buildi...
Bus stop
Land Cover Class

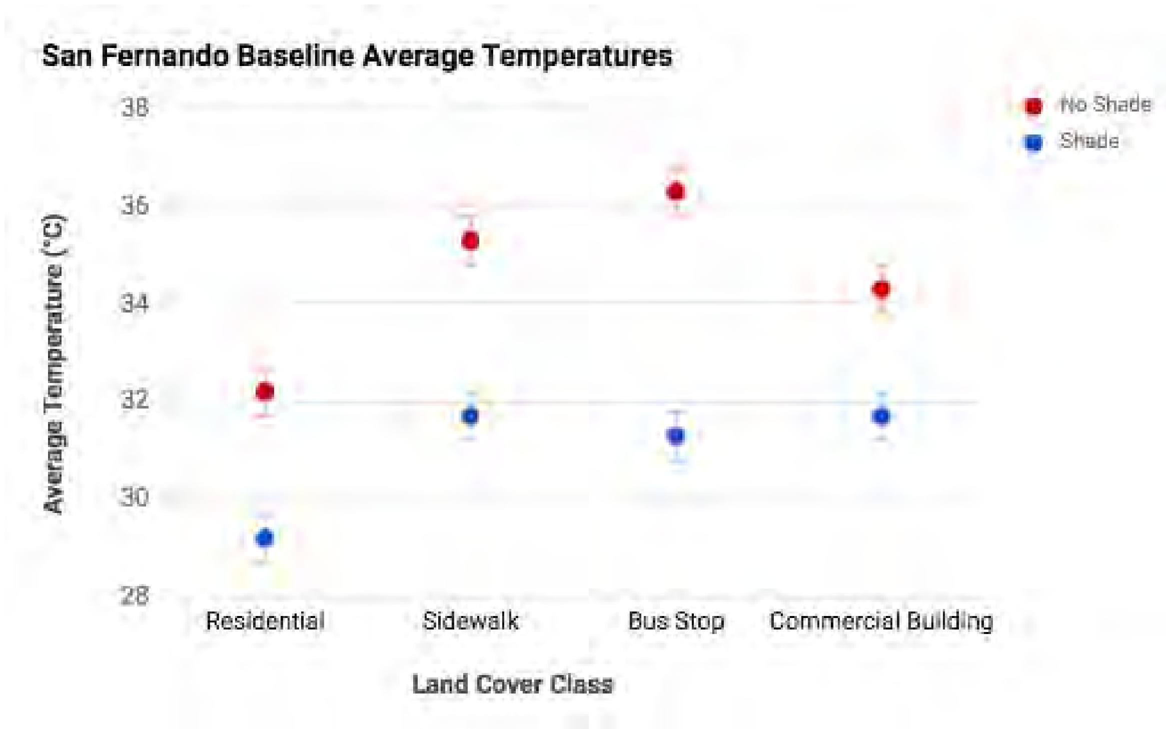

San Fernando June 2nd All Land Cover Classes
Tempera...
Average Temperature (°C)
40.0
38.0
36.0
34.0
32.0
Residential building
Street
Shrub
Grass
Sidewalk
Parking lot
Parked cars
Trees
Commercial buildi...
Bus stop
Land Cover Class

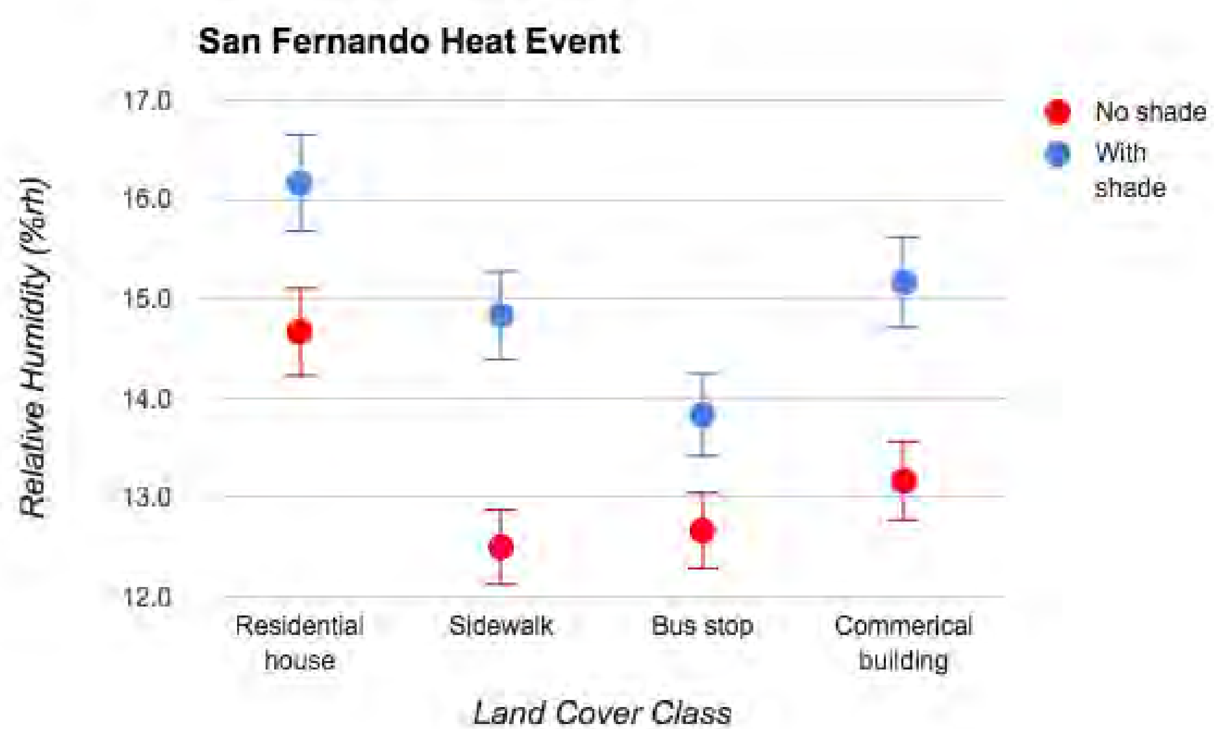

San Fernando June 2nd All Land Cover Classes
Humidity
Relative Humidity (%rh)
40.0
35.0
30.0
25.0
20.0
Residential building
Street
Shrub
Grass
Sidewalk
Parking lot
Parked cars
Trees
Commercial buildi...
Bus stop
Land Cover Class

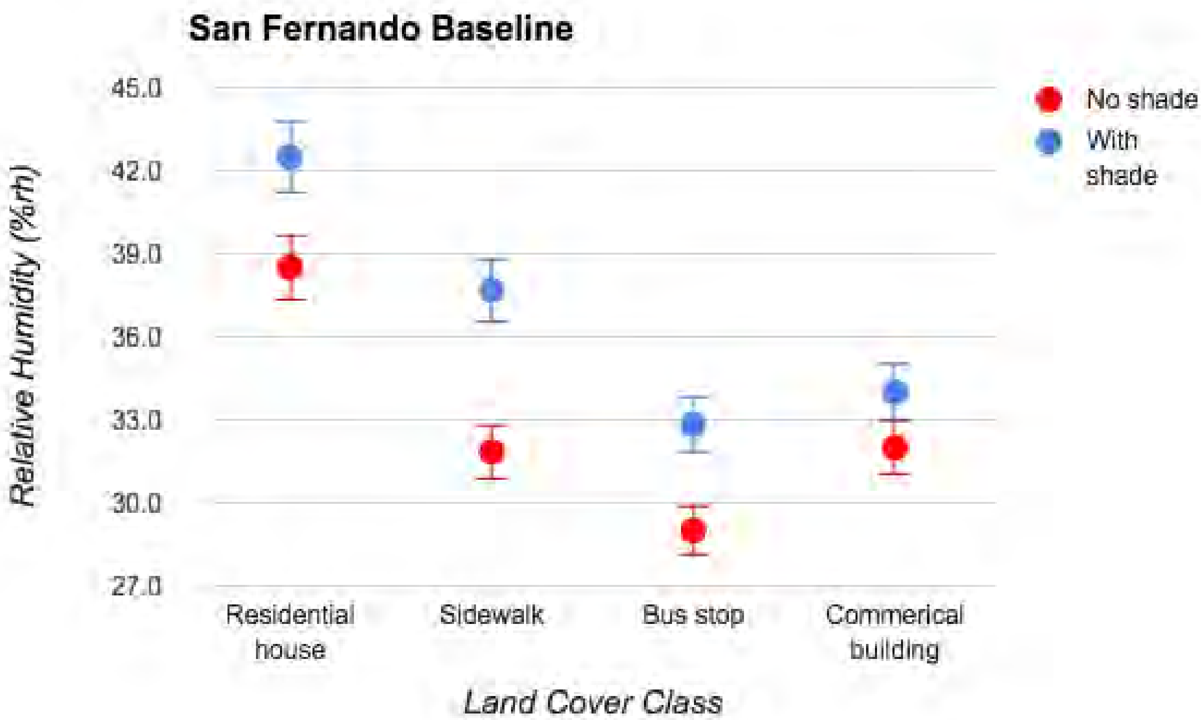

San Fernando June 4th All Land Cover Classes
Tempera...
Average Temperature (°C)
38.0
36.0
34.0
32.0
30.0
Residential building
Street
Shrub
Grass
Sidewalk
Parking lot
Parked cars
Trees
Commercial buildi...
Bus stop
Land Cover Class


San Fernando June 4th All Land Cover Classes
Humidity
Relative Humidity (% rh)
50.0
45.0
40.0
35.0
30.0
Residential building
Street
Shrub
Grass
Sidewalk
Parking lot
Parked cars
Trees
Commercial buildi...
Bus stop
Land Cover Class


San Fernando Heat Event Average Temperatures
No shade
Shade
Average Temperature (°C)
42.0
40.0
38.0
36.0
34.0
32.0
Residential
Sidewalk
Bus Stop
Commerical
Land Cover Class

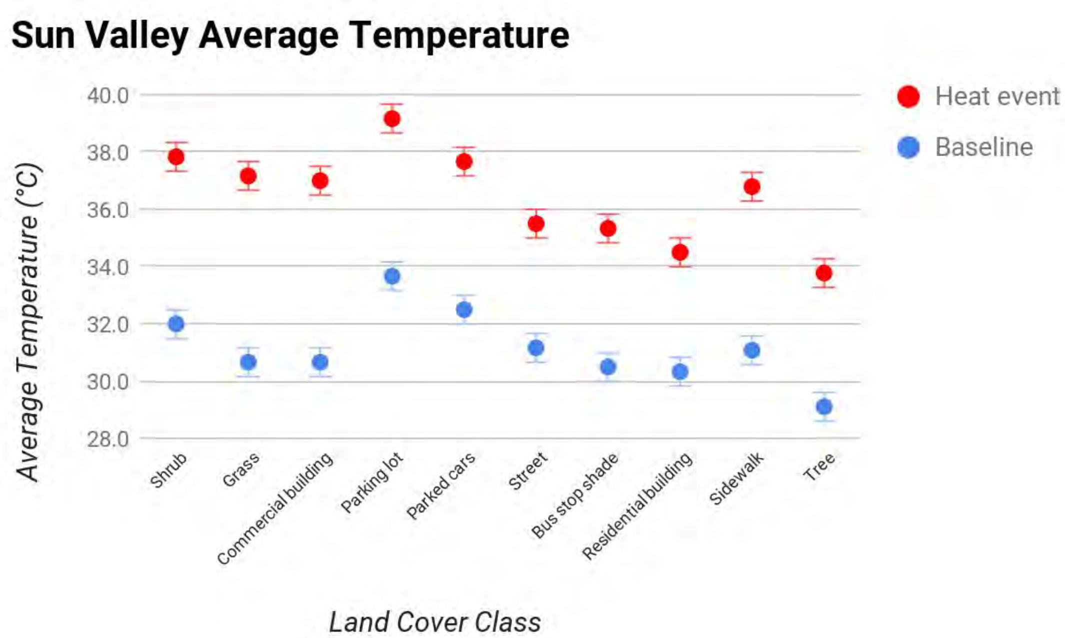

San Fernando Baseline Average Temperatures
No Shade
Shade
Average Temperature (°C)
38
36
34
32
30
28
Residential
Sidewalk
Bus Stop
Commercial Building
Land Cover Class

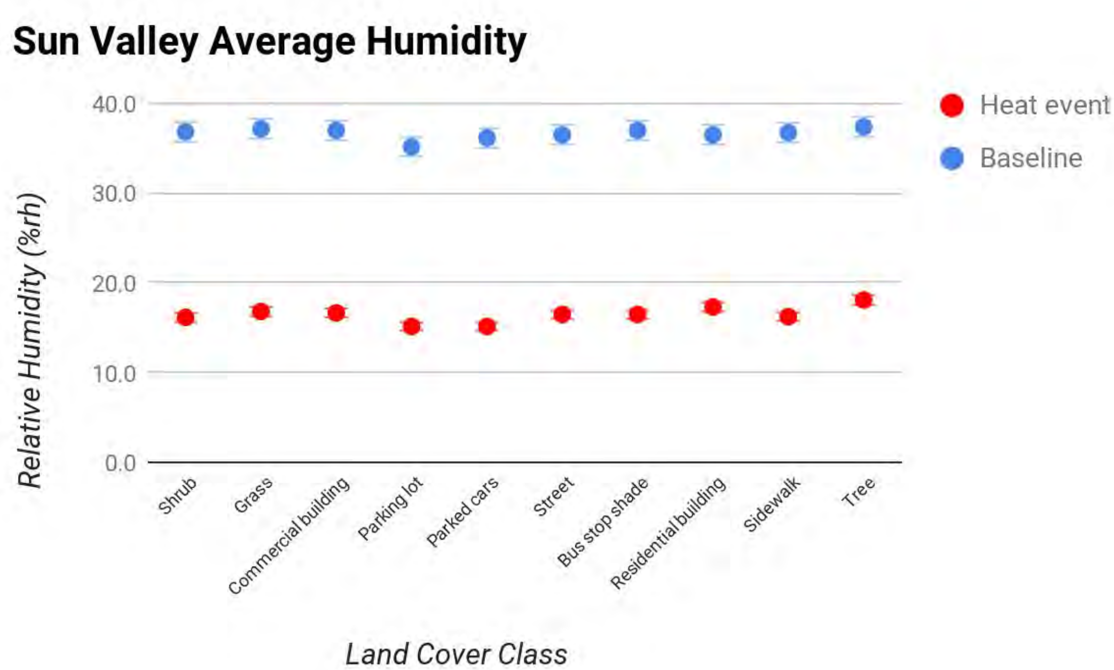

San Fernando Heat Event
No shade
With shade
Relative Humidity (%rh)
17.0
16.0
15.0
14.0
13.0
12.0
Residential house
Sidewalk
Bus stop
Commerical building
Land Cover Class

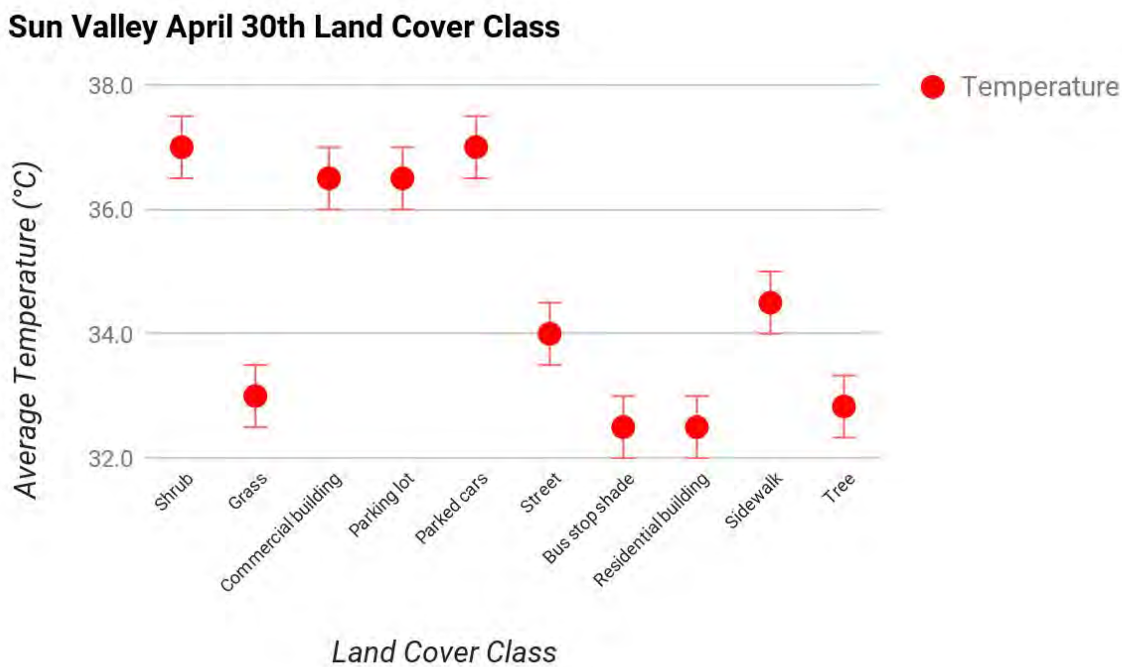


San Fernando Baseline
45.0
42.0
39.0
36.0
33.0
30.0
27.0
Relative Humidity (%rh)
No shade
With shade
Residential house
Sidewalk
Bus stop
Commerical building
Land Cover Class

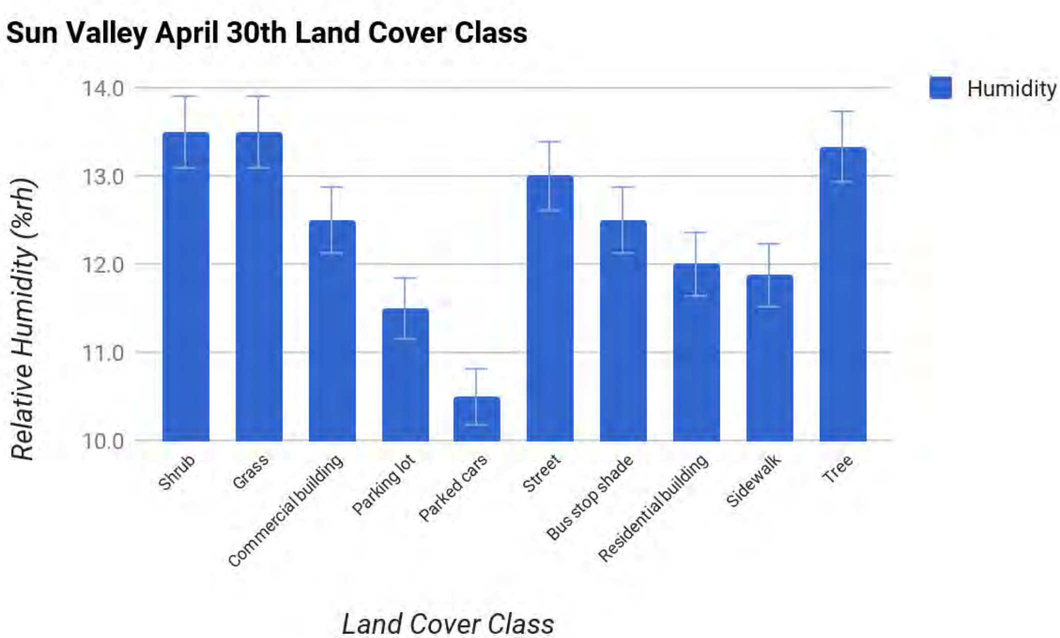
Sun Valley Data Graphs



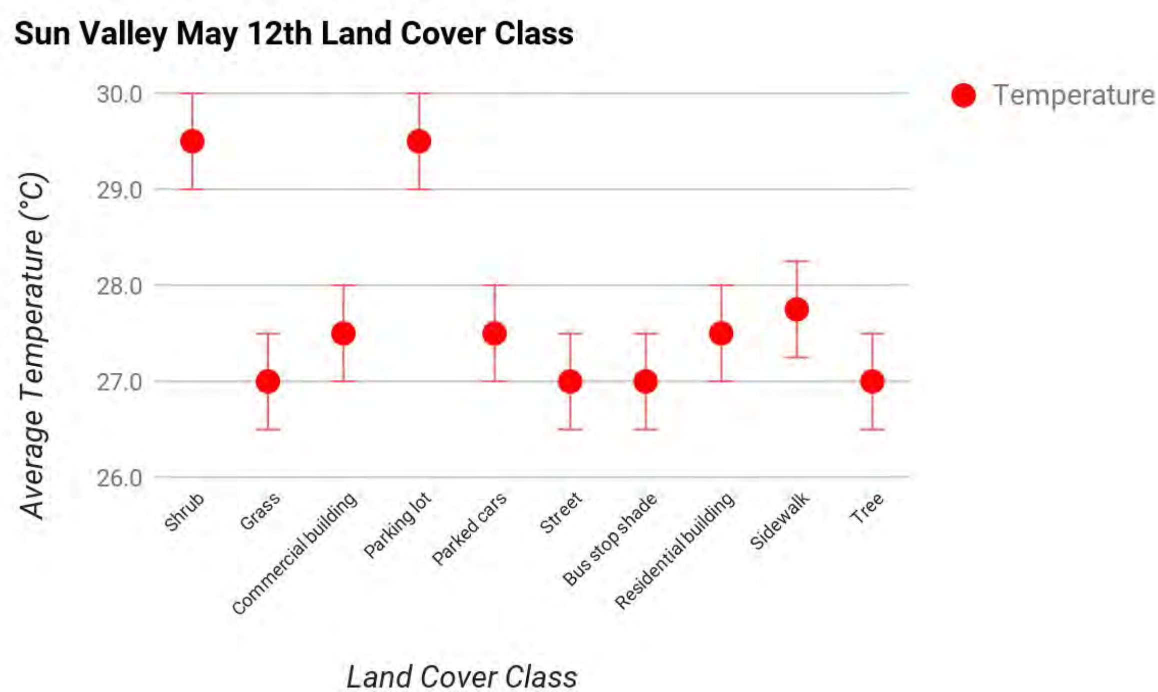


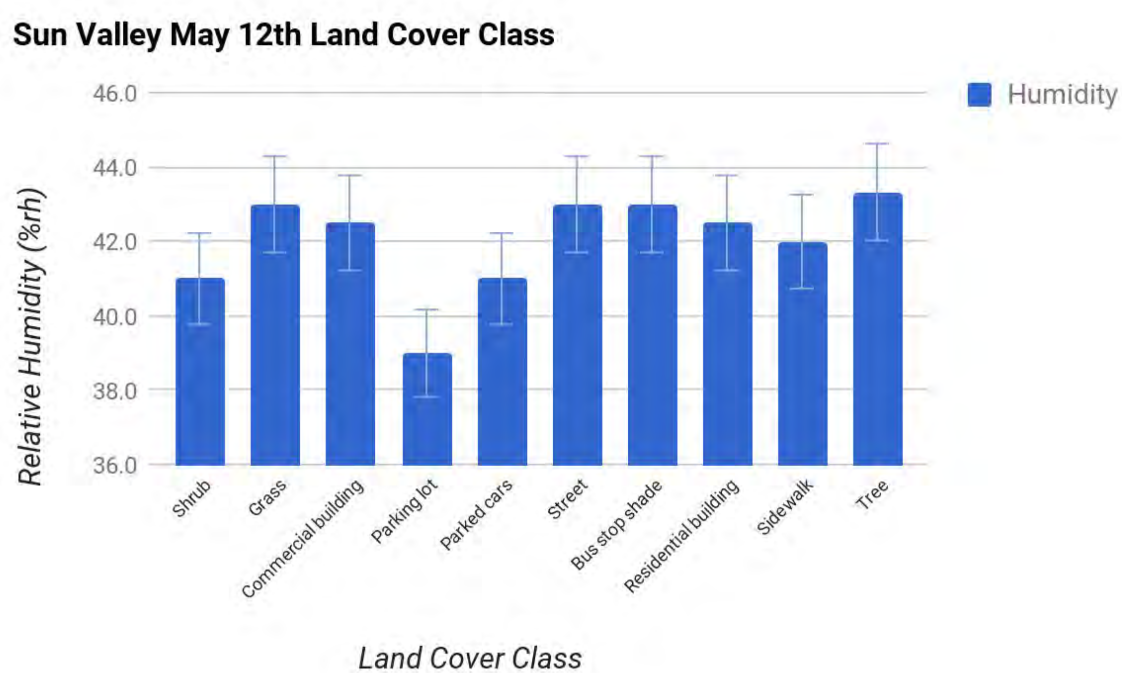


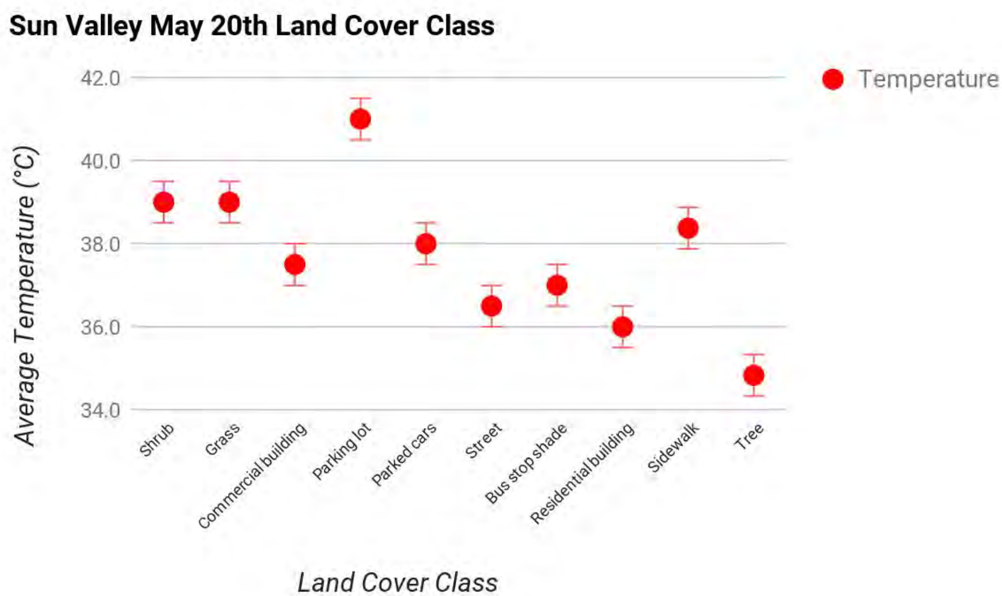
Sun Valley April 30th Land Cover Class
38.0
36.0
34.0
32.0
Average Temperature (°C)
Temperature
Shrub
Grass
Commercial building
Parking lot
Parked cars
Street
Bus stop shade
Residential building
Sidewalk
Tree
Land Cover Class



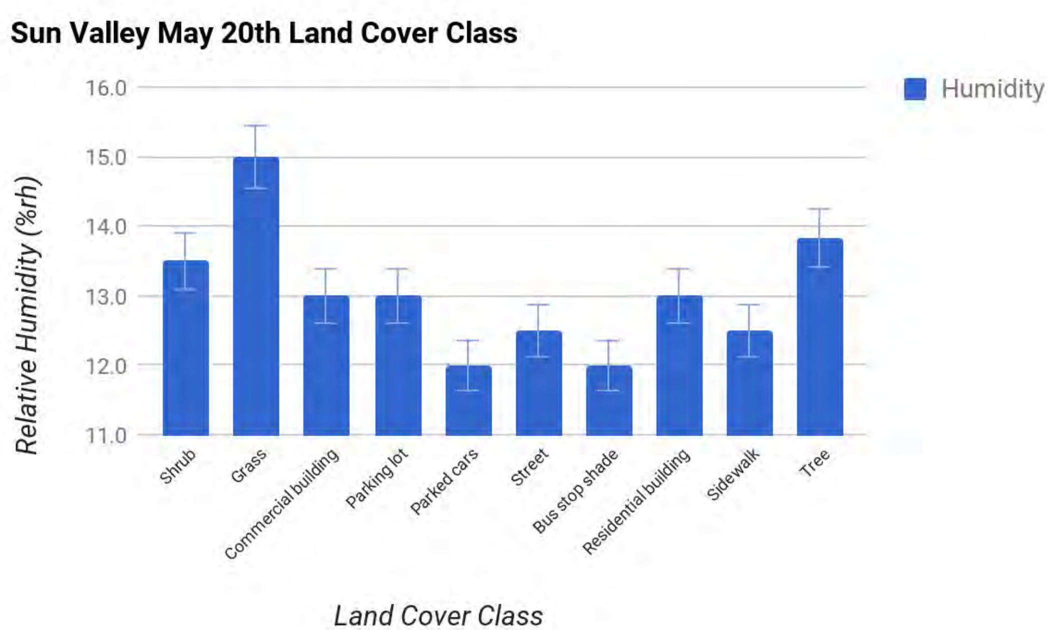
Sun Valley April 30th Land Cover Class
14.0
13.0
12.0
11.0
10.0
Relative Humidity (%rh)
Humidity
Shrub
Grass
Commercial building
Parking lot
Parked cars
Street
Bus stop shade
Residential building
Sidewalk
Tree
Land Cover Class


Sun Valley May 12th Land Cover Class
Temperature
Average Temperature (°C)
30.0
29.0
28.0
27.0
26.0
Shrub
Grass
Commercial building
Parking lot
Parked cars
Street
Bus stop shade
Residential building
Sidewalk
Tree
Land Cover Class

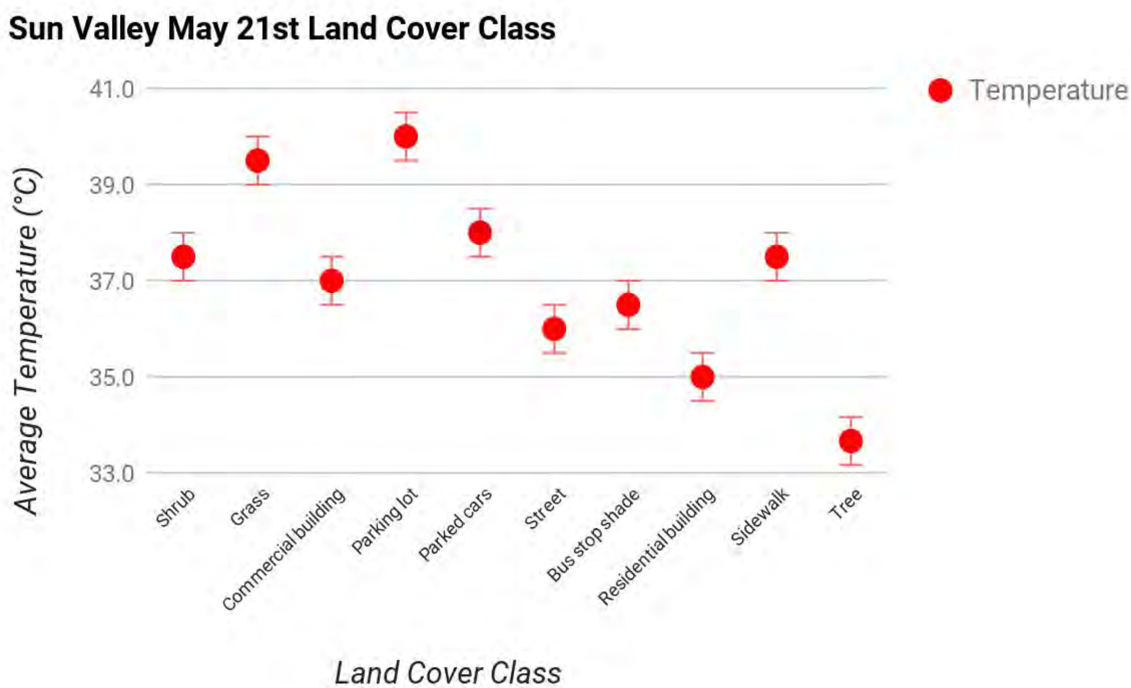

Sun Valley May 12th Land Cover Class
Humidity
Relative Humidity (%rh)
46.0
44.0
42.0
40.0
38.0
36.0
Shrub
Grass
Commercial building
Parking lot
Parked cars
Street
Bus stop shade
Residential building
Sidewalk
Tree
Land Cover Class

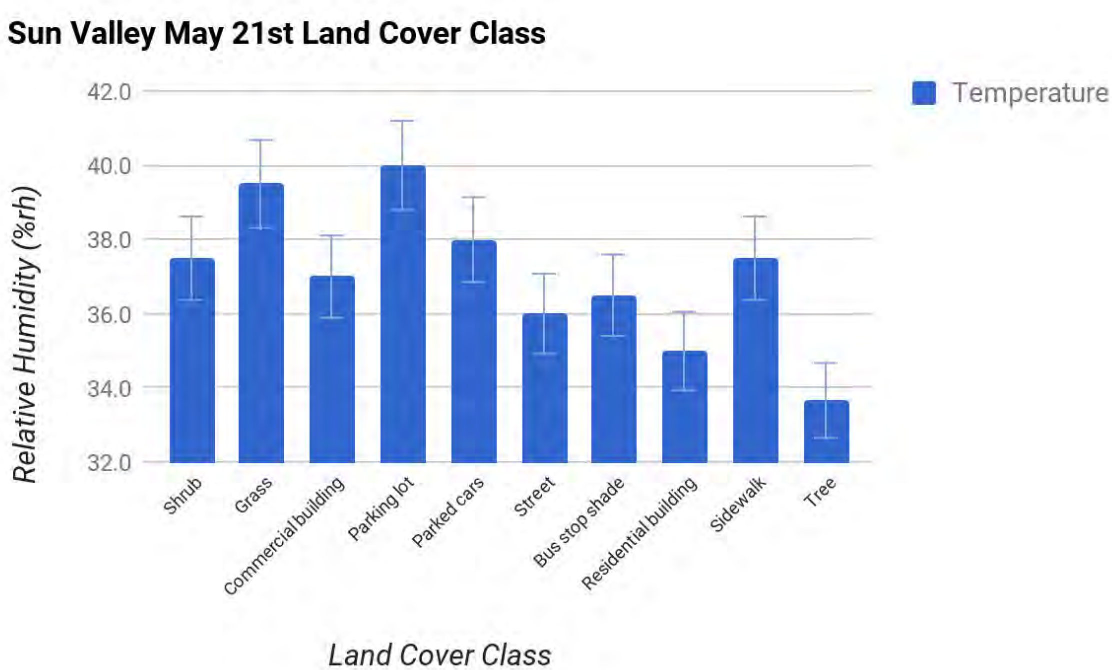


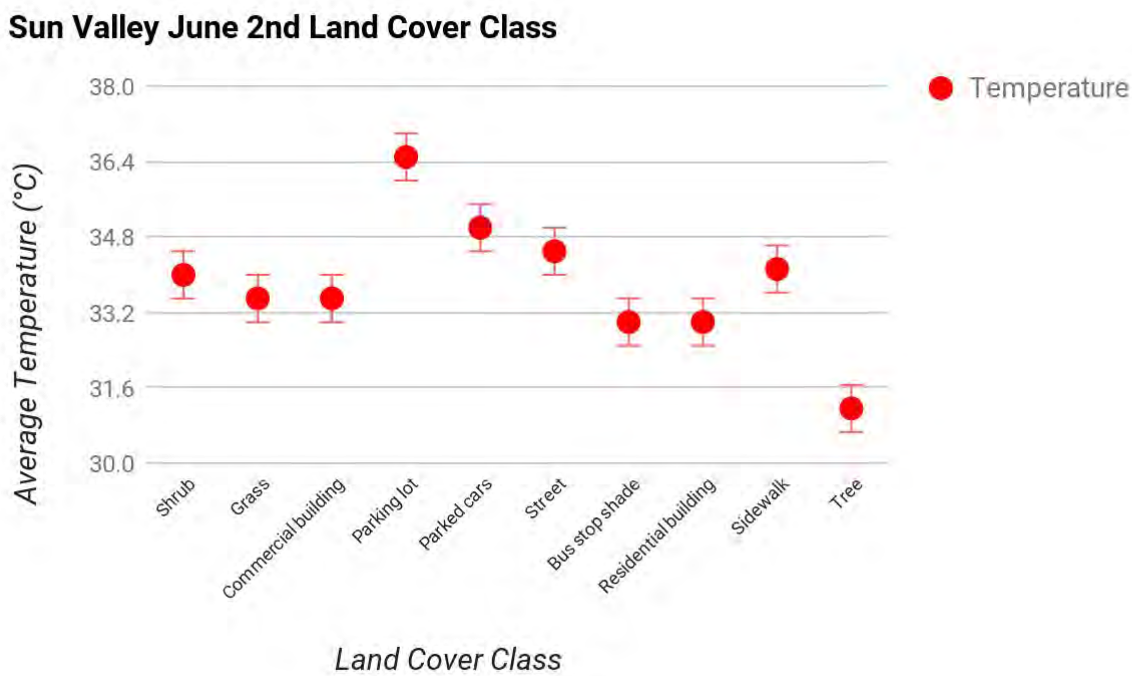
Sun Valley May 20th Land Cover Class
Temperature
Average Temperature (°C)
42.0
40.0
38.0
36.0
34.0
Shrub
Grass
Commercial building
Parking lot
Parked cars
Street
Bus stop shade
Residential building
Sidewalk
Tree
Land Cover Class

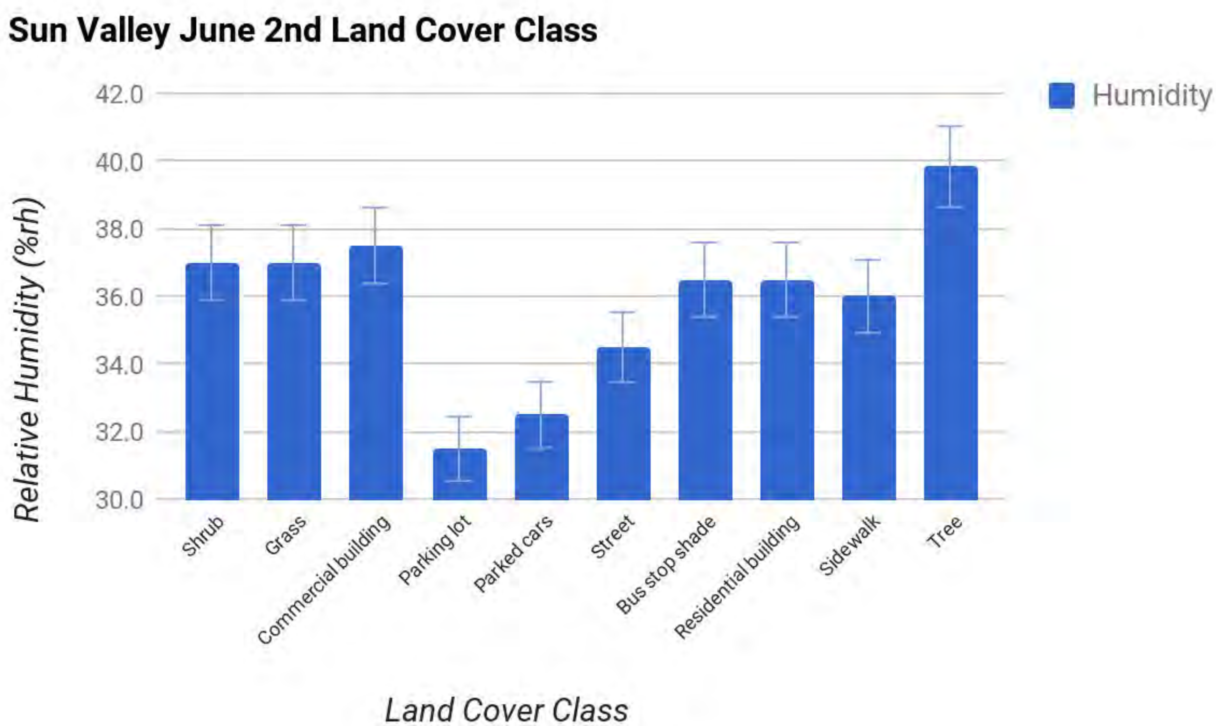


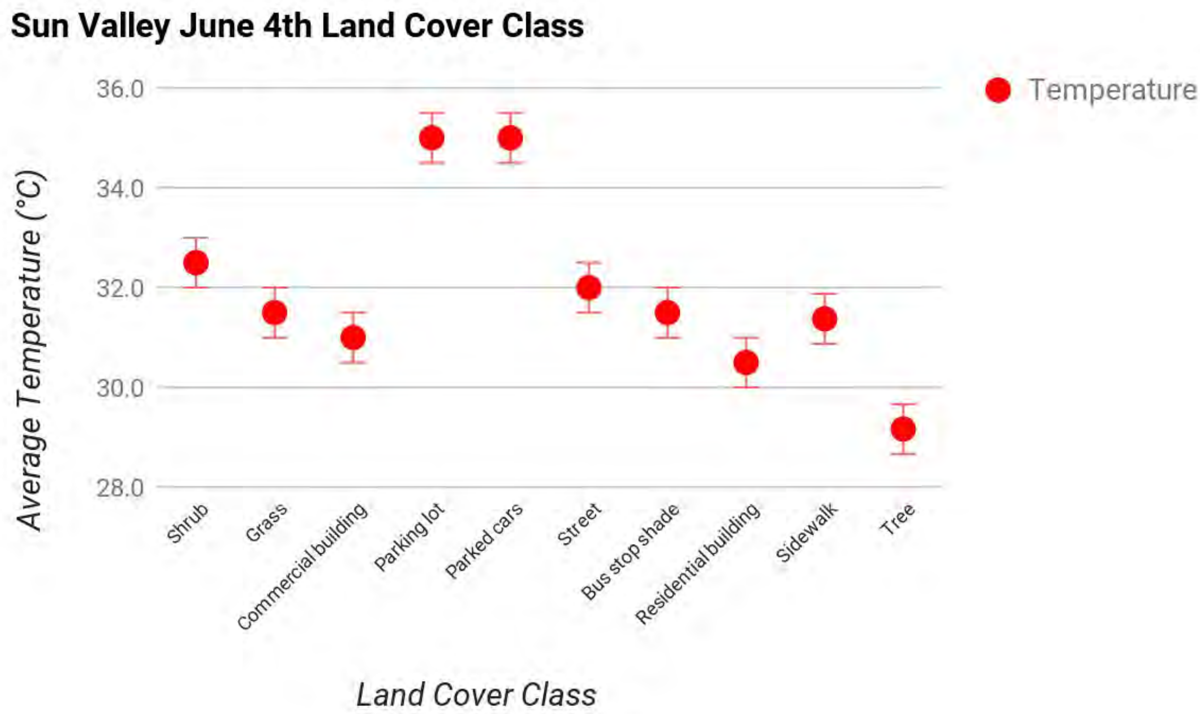
Sun Valley May 20th Land Cover Class
Humidity
Relative Humidity (%rh)
16.0
15.0
14.0
13.0
12.0
11.0
Shrub
Grass
Commercial building
Parking lot
Parked cars
Street
Bus stop shade
Residential building
Sidewalk
Tree
Land Cover Class


Sun Valley May 21st Land Cover Class
Temperature
41.0
39.0
37.0
35.0
33.0
Average Temperature (°C)
Shrub
Grass
Commercial building
Parking lot
Parked cars
Street
Bus stop shade
Residential building
Sidewalk
Tree
Land Cover Class

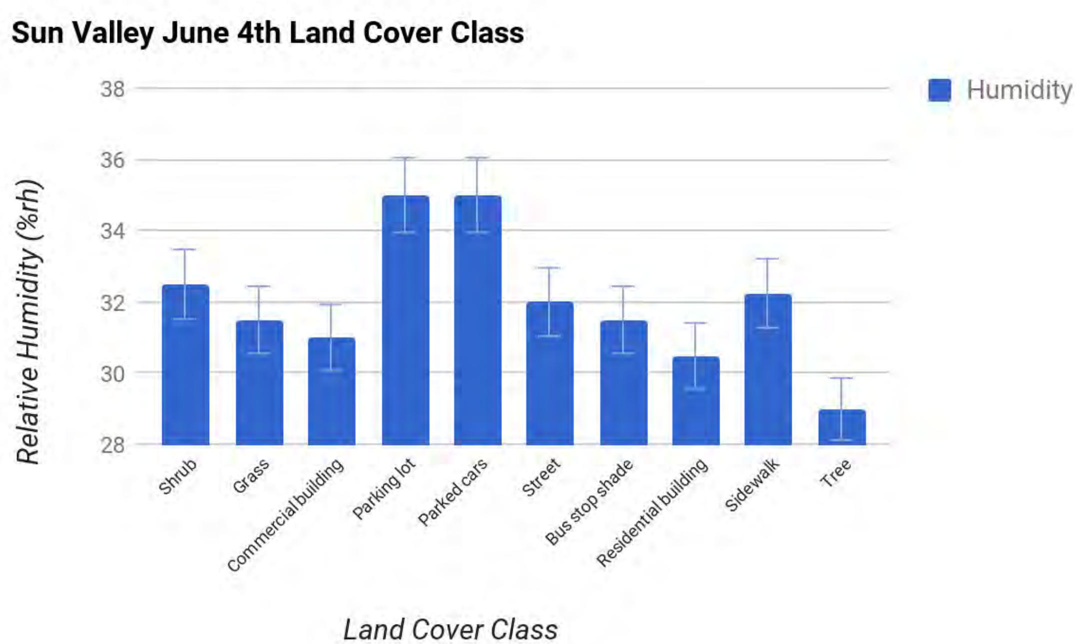

Sun Valley May 21st Land Cover Class
Temperature
42.0
40.0
38.0
36.0
34.0
32.0
Relative Humidity (%rh)
Shrub
Grass
Commercial building
Parking lot
Parked cars
Street
Bus stop shade
Residential building
Sidewalk
Tree
Land Cover Class


Sun Valley June 2nd Land Cover Class
Temperature
Average Temperature (°C)
38.0
36.4
34.8
33.2
31.6
30.0
Shrub
Grass
Commercial building
Parking lot
Parked cars
Street
Bus stop shade
Residential building
Sidewalk
Tree
Land Cover Class

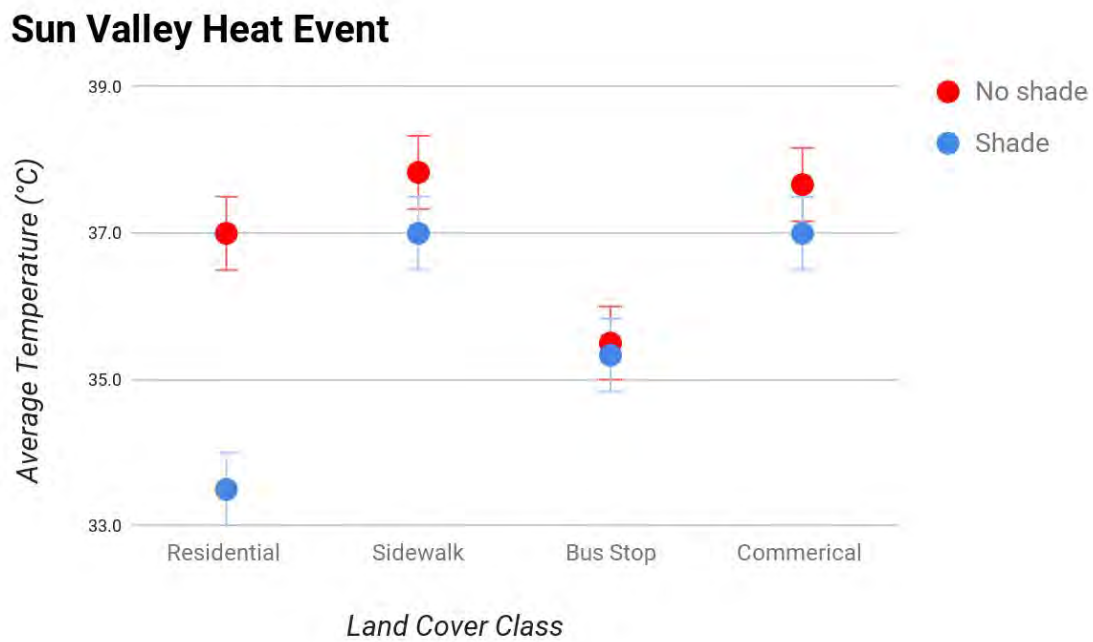

Sun Valley June 2nd Land Cover Class
Humidity
Relative Humidity (%rh)
42.0
40.0
38.0
36.0
34.0
32.0
30.0
Shrub
Grass
Commercial building
Parking lot
Parked cars
Street
Bus stop shade
Residential building
Sidewalk
Tree
Land Cover Class

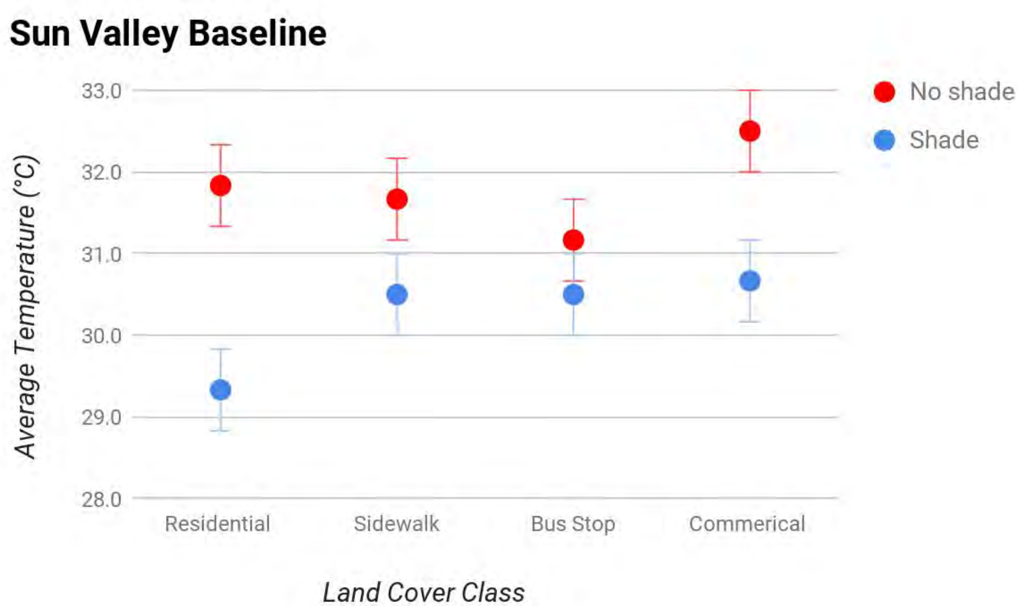


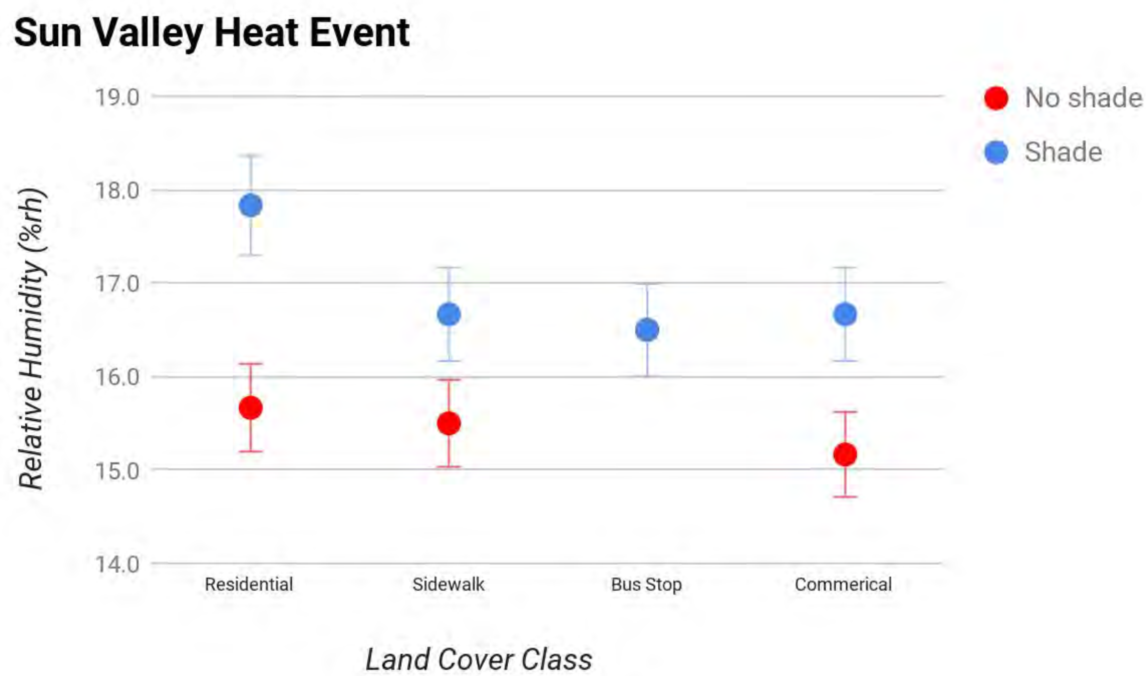
Sun Valley June 4th Land Cover Class
Temperature
36.0
34.0
32.0
30.0
28.0
Average Temperature (°C)
Shrub
Grass
Commercial building
Parking lot
Parked cars
Street
Bus stop shade
Residential building
Sidewalk
Tree
Land Cover Class

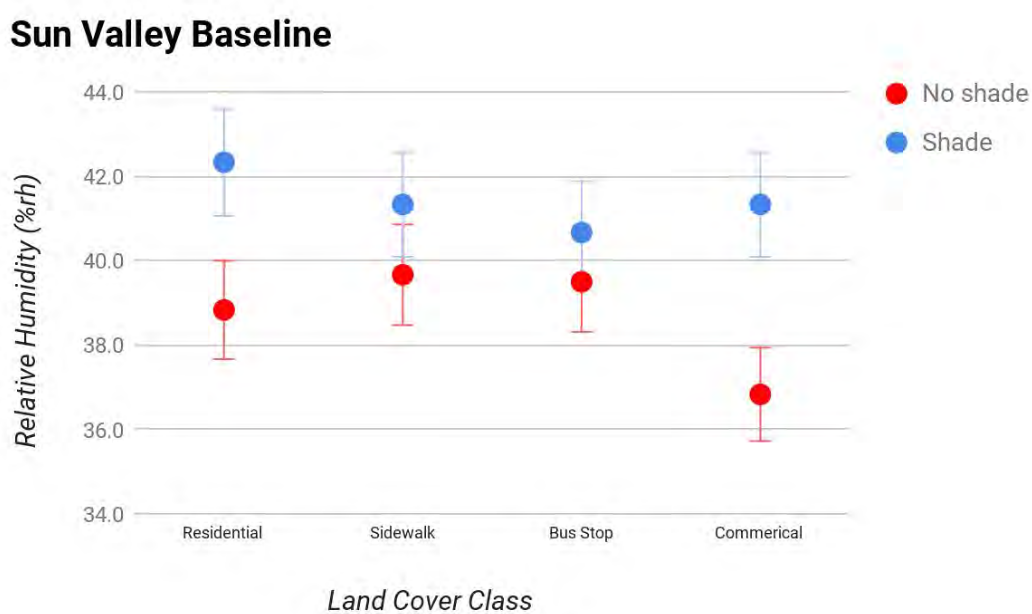


Sun Valley June 4th Land Cover Class
Humidity
38
36
34
32
30
28
Relative Humidity (%rh)
Shrub
Grass
Commercial building
Parking lot
Parked cars
Street
Bus stop shade
Residential building
Sidewalk
Tree
Land Cover Class

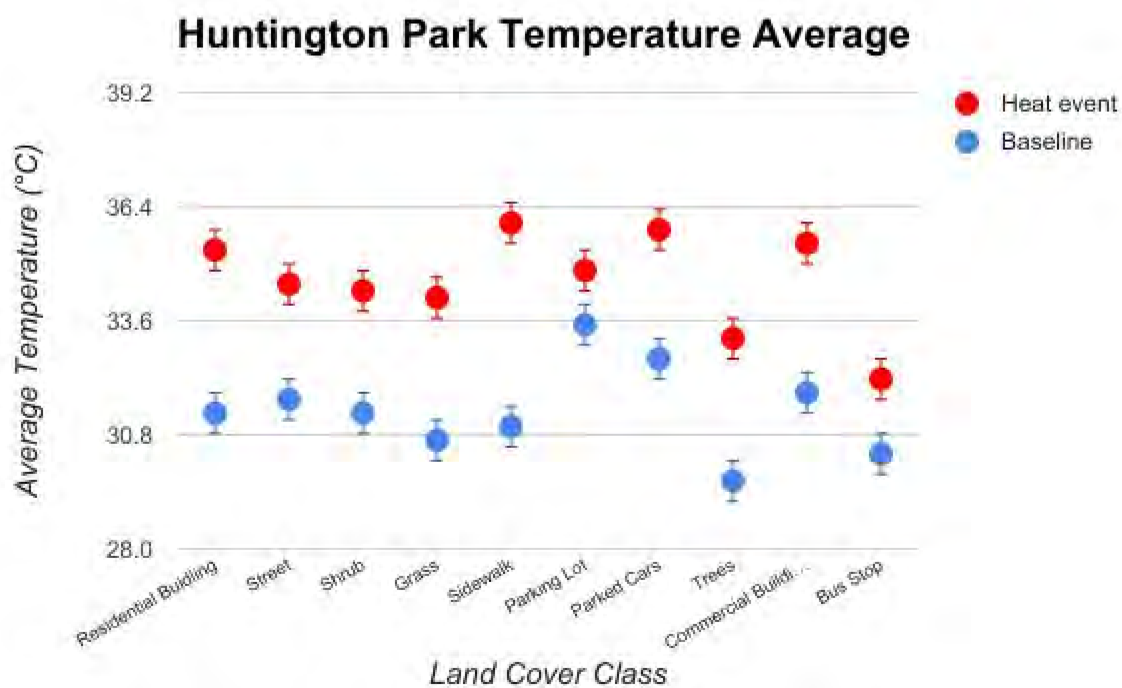

Sun Valley Heat Event
39.0
37.0
35.0
33.0
Average Temperature (°C)
No shade
Shade
Residential
Sidewalk
Bus Stop
Commerical
Land Cover Class

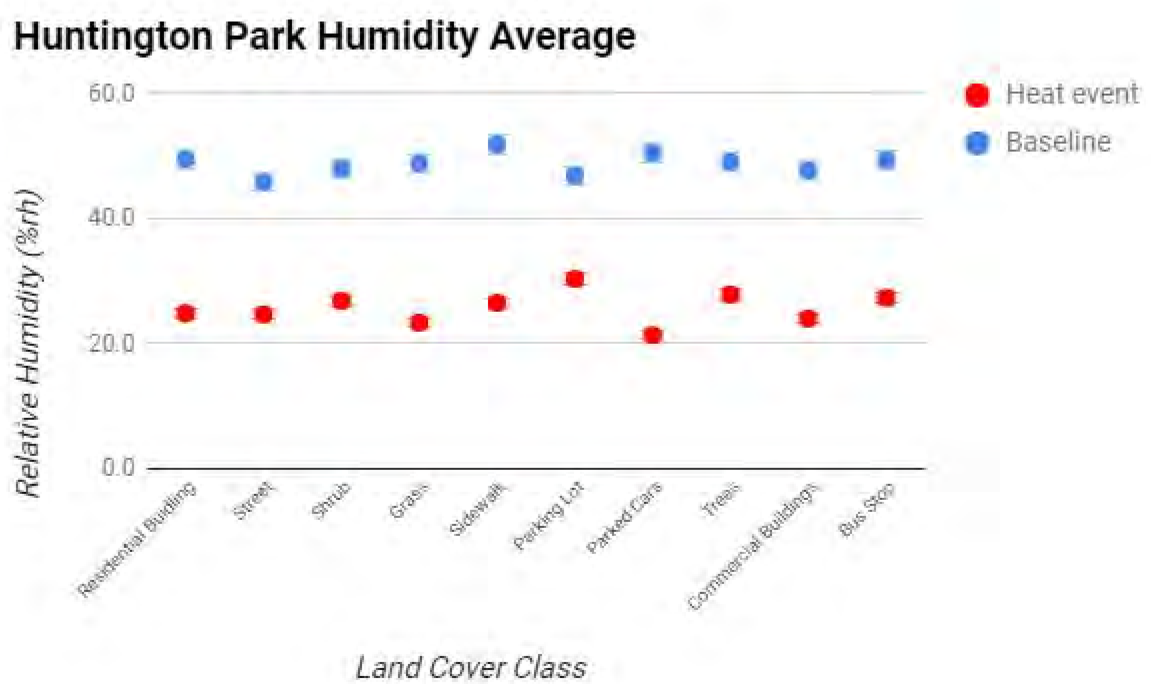

Sun Valley Baseline
33.0
32.0
31.0
30.0
29.0
28.0
Average Temperature (°C)
No shade
Shade
Residential
Sidewalk
Bus Stop
Commerical
Land Cover Class

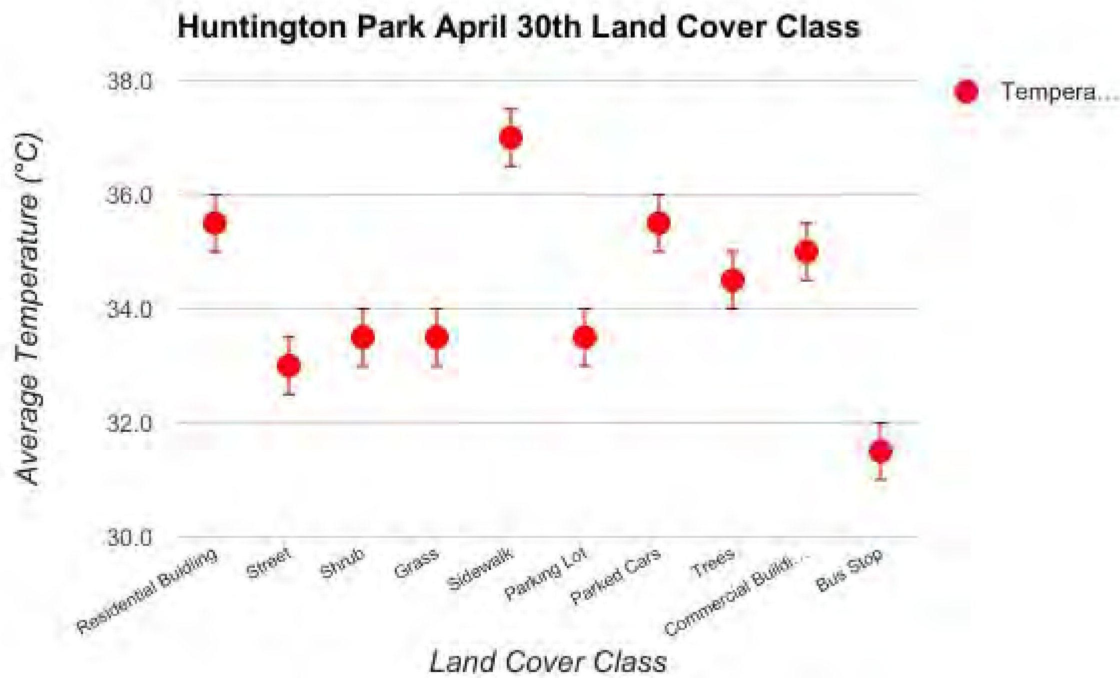

Sun Valley Heat Event
No shade
Shade
Relative Humidity (%rh)
19.0
18.0
17.0
16.0
15.0
14.0
Residential
Sidewalk
Bus Stop
Commerical
Land Cover Class

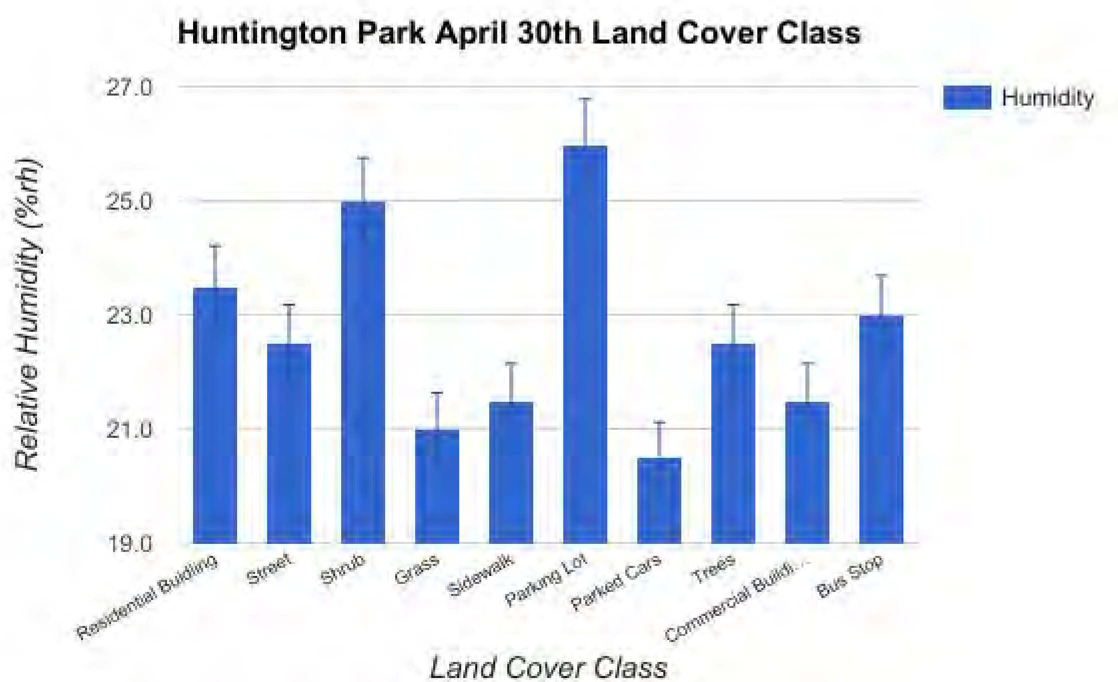

Sun Valley Baseline
No shade
Shade
Relative Humidity (%rh)
44.0
42.0
40.0
38.0
36.0
34.0
Residential
Sidewalk
Bus Stop
Commerical
Land Cover Class

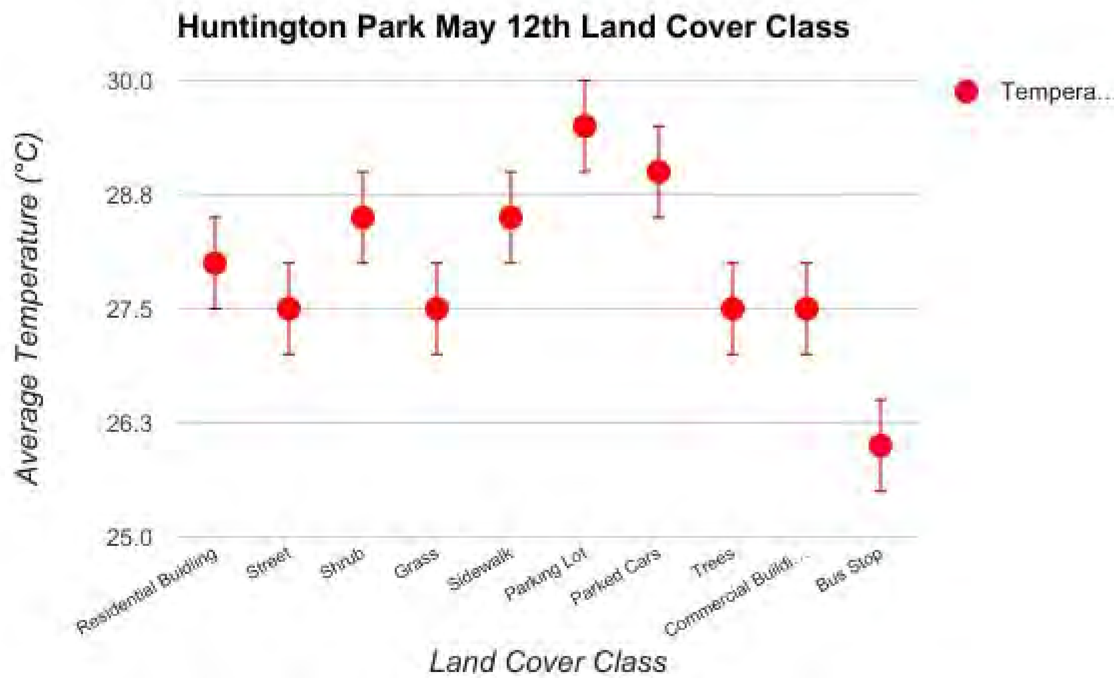
Huntington Park Data Graphs

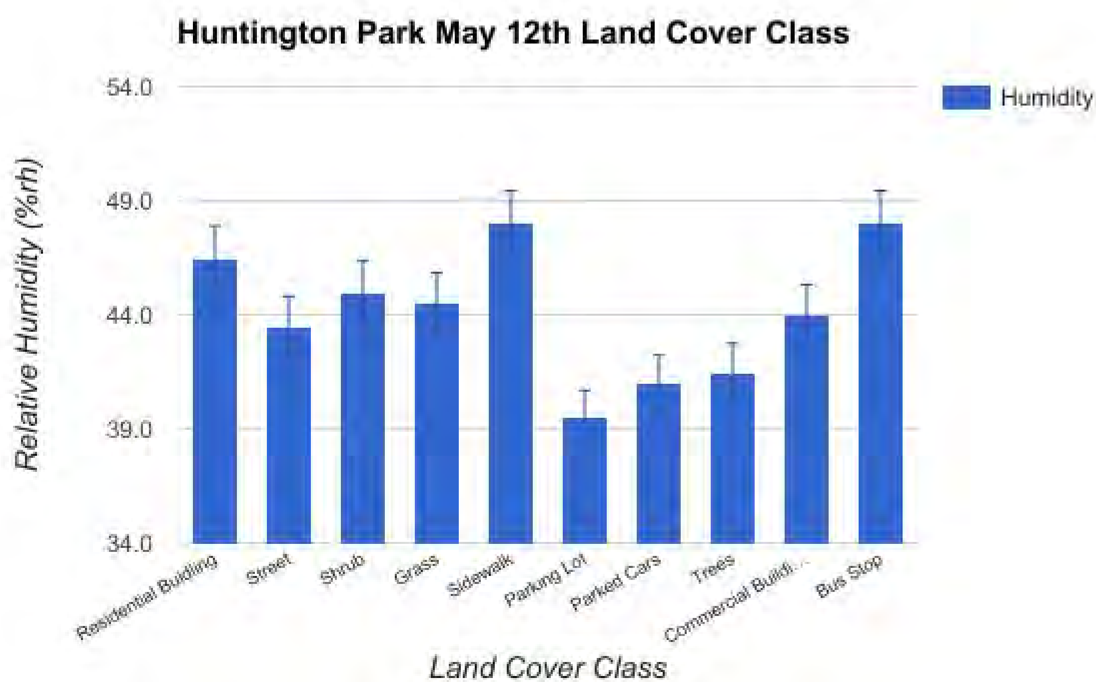


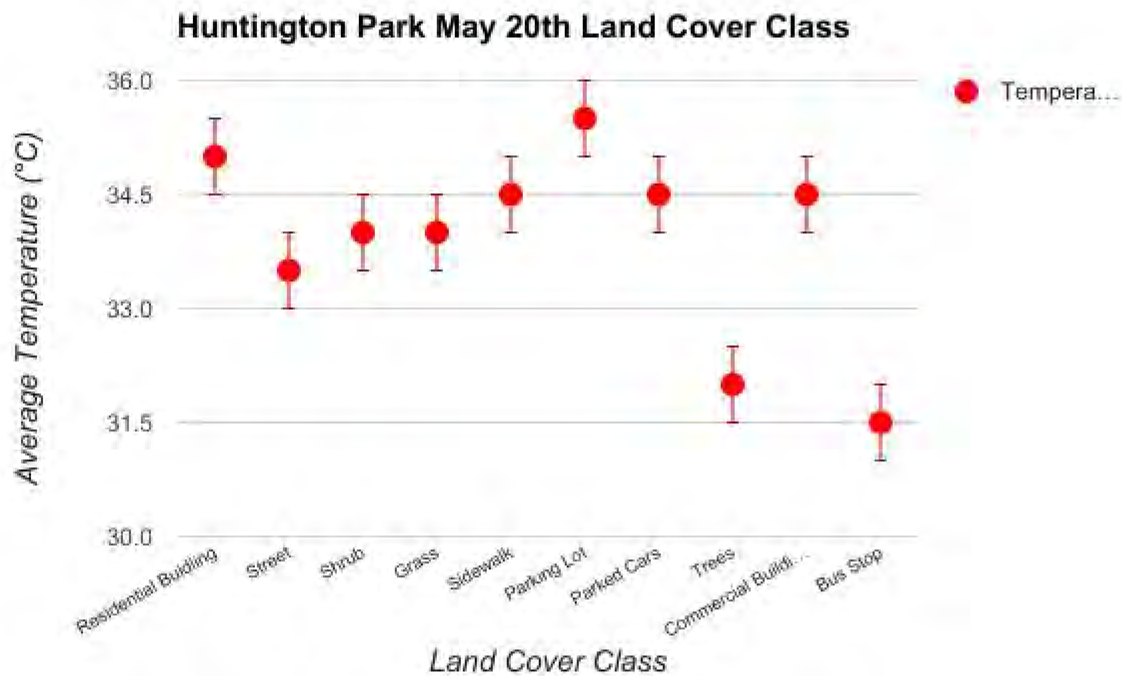


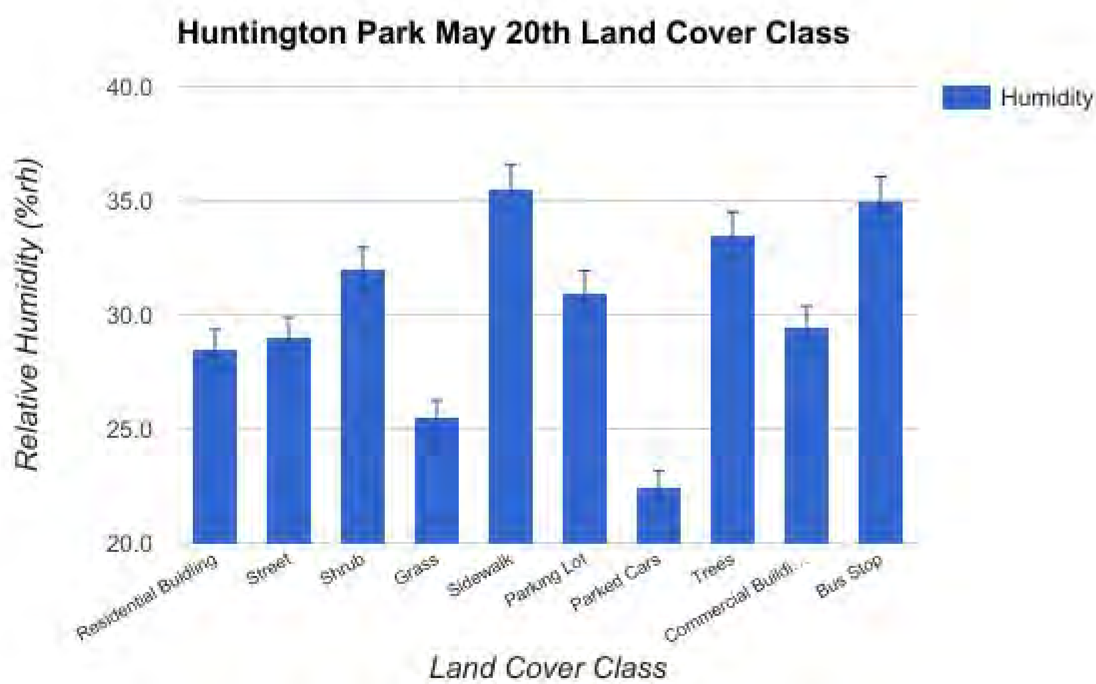

Huntington Park April 30th Land Cover Class
Average Temperature (°C)
38.0
36.0
34.0
32.0
30.0
Tempera...
Residential Building
Street
Shrub
Grass
Sidewalk
Parking Lot
Parked Cars
Trees
Commercial Buildi...
Bus Stop
Land Cover Class

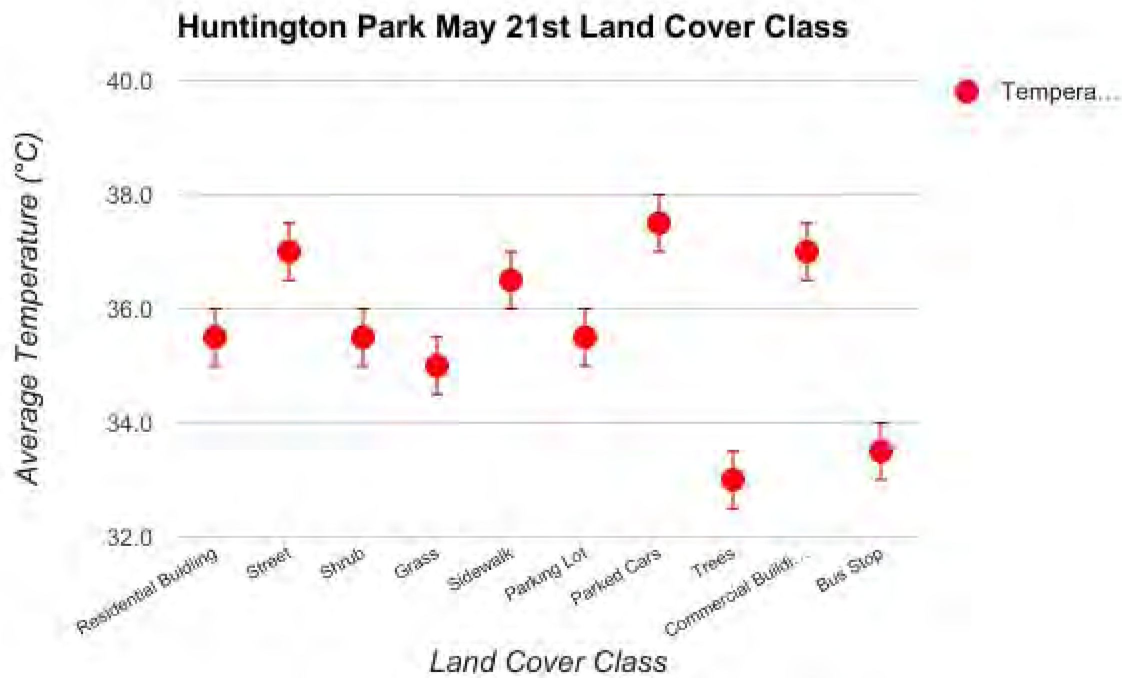

Huntington Park April 30th Land Cover Class
Relative Humidity (%rh)
27.0
25.0
23.0
21.0
19.0
Humidity
Residential Building
Street
Shrub
Grass
Sidewalk
Parking Lot
Parked Cars
Trees
Commercial Buildi...
Bus Stop
Land Cover Class

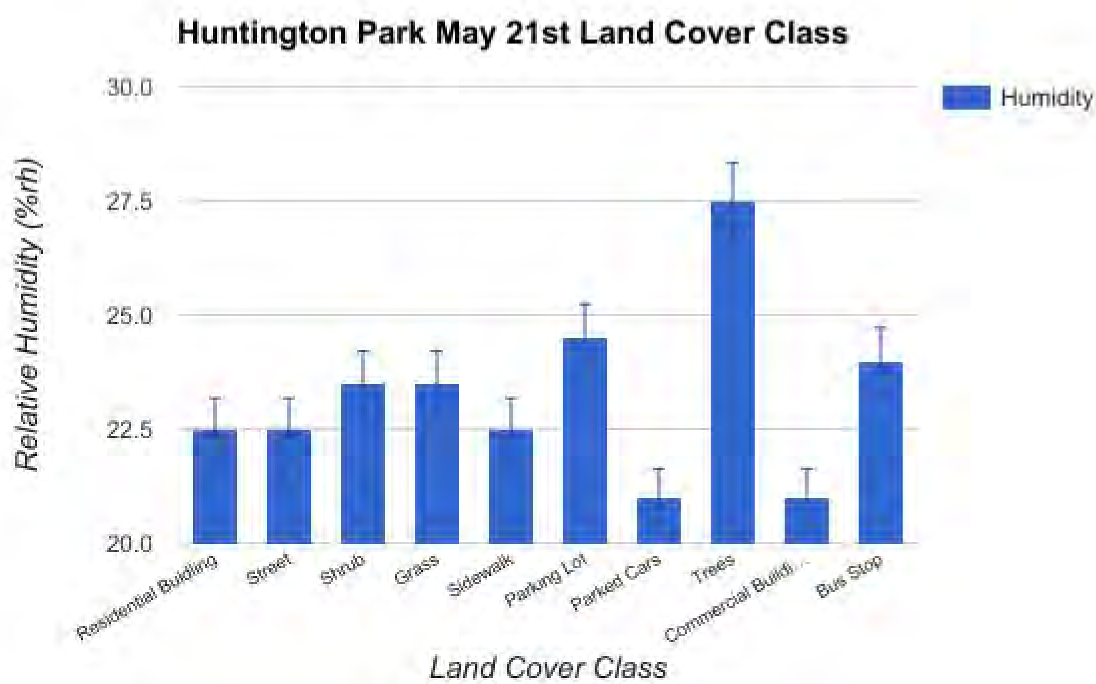

Huntington Park May 12th Land Cover Class
Average Temperature (°C)
30.0
28.8
27.5
26.3
25.0
Tempera...
Residential Building
Street
Shrub
Grass
Sidewalk
Parking Lot
Parked Cars
Trees
Commercial Buildi...
Bus Stop
Land Cover Class

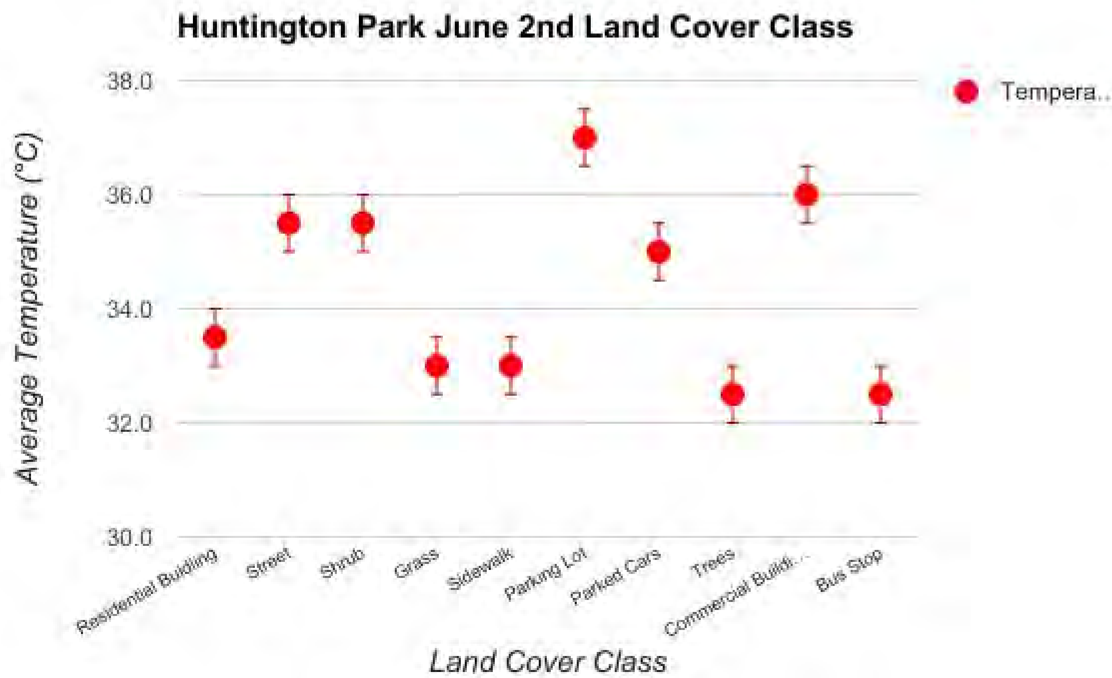

Huntington Park May 12th Land Cover Class
Relative Humidity (%rh)
54.0
49.0
44.0
39.0
34.0
Humidity
Residential Building
Street
Shrub
Grass
Sidewalk
Parking Lot
Parked Cars
Trees
Commercial Buildi...
Bus Stop
Land Cover Class

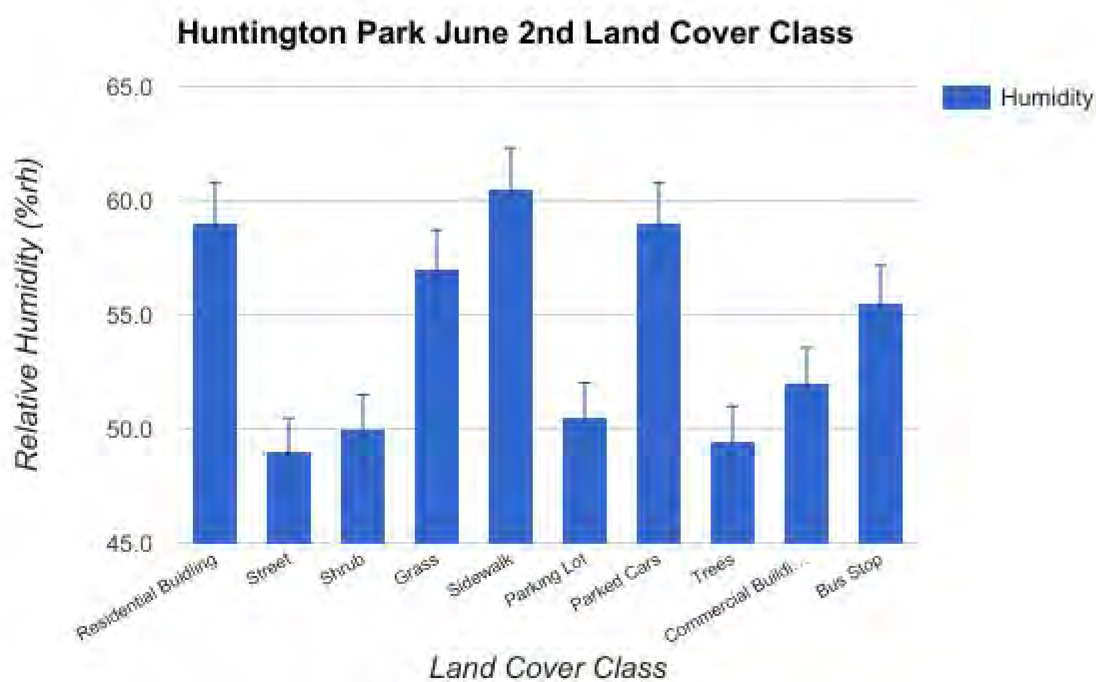

Huntington Park May 20th Land Cover Class
36.0
34.5
33.0
31.5
30.0
Tempera...
Average Temperature (°C)
Residential Building
Street
Shrub
Grass
Sidewalk
Parking Lot
Parked Cars
Trees
Commercial Buildi...
Bus Stop
Land Cover Class

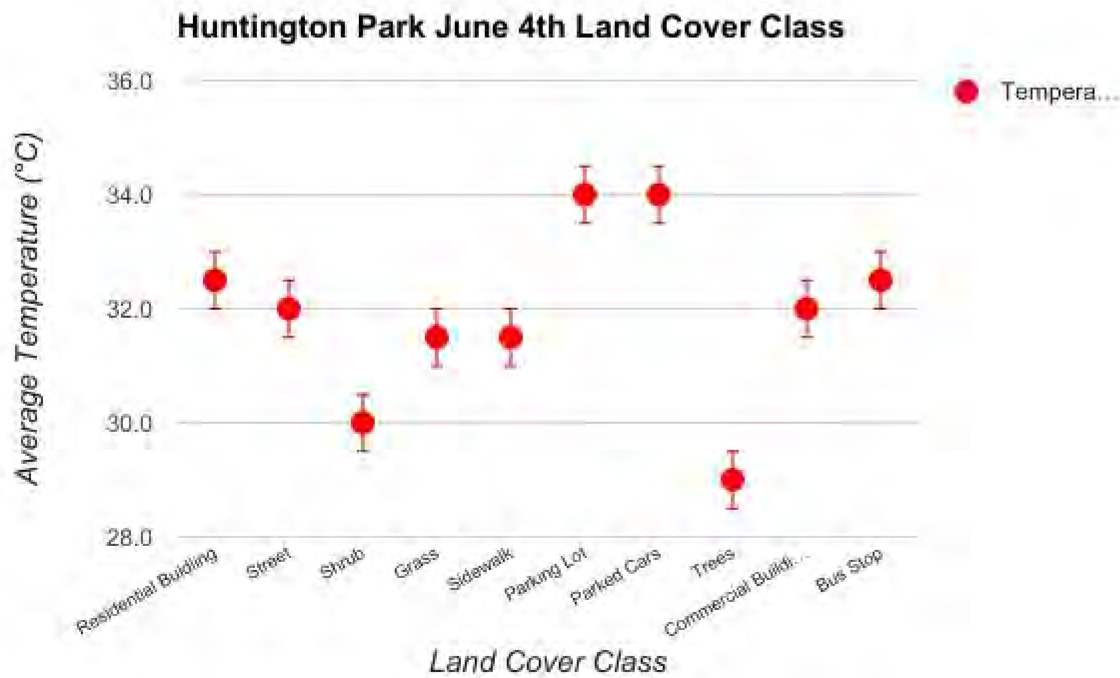

Huntington Park May 20th Land Cover Class
40.0
35.0
30.0
25.0
20.0
Humidity
Relative Humidity (%rh)
Residential Building
Street
Shrub
Grass
Sidewalk
Parking Lot
Parked Cars
Trees
Commercial Buildi...
Bus Stop
Land Cover Class

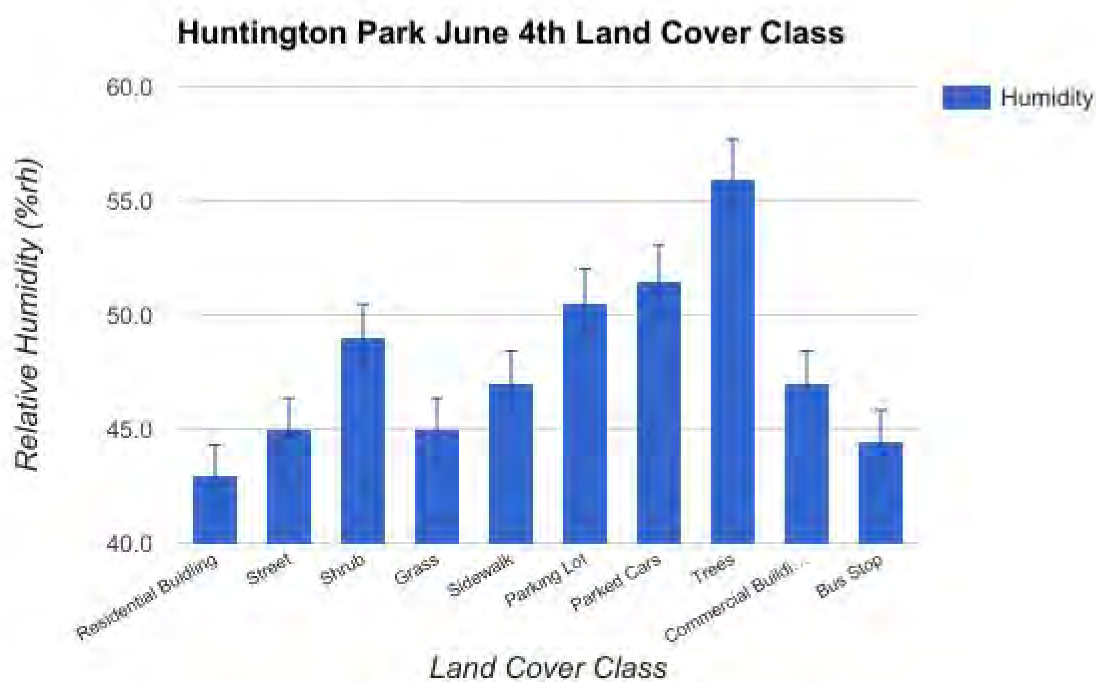

Huntington Park May 21st Land Cover Class
40.0
38.0
36.0
34.0
32.0
Average Temperature (°C)
Tempera...
Residential Building
Street
Shrub
Grass
Sidewalk
Parking Lot
Parked Cars
Trees
Commercial Buildi...
Bus Stop
Land Cover Class


Huntington Park May 21st Land Cover Class
30.0
27.5
25.0
22.5
20.0
Relative Humidity (%rh)
Humidity
Residential Building
Street
Shrub
Grass
Sidewalk
Parking Lot
Parked Cars
Trees
Commercial Buildi...
Bus Stop
Land Cover Class


Huntington Park June 2nd Land Cover Class
Average Temperature (°C)
38.0
36.0
34.0
32.0
30.0
Tempera...
Residential Building
Street
Shrub
Grass
Sidewalk
Parking Lot
Parked Cars
Trees
Commercial Buildi...
Bus Stop
Land Cover Class


Huntington Park June 2nd Land Cover Class
Relative Humidity (%rh)
65.0
60.0
55.0
50.0
45.0
Humidity
Residential Building
Street
Shrub
Grass
Sidewalk
Parking Lot
Parked Cars
Trees
Commercial Buildi...
Bus Stop
Land Cover Class

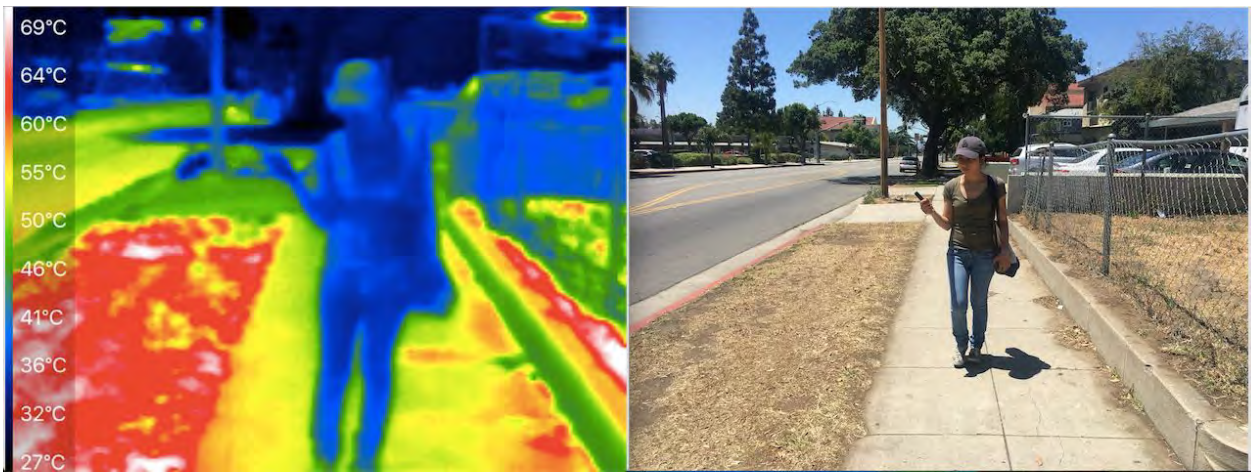

Huntington Park June 4th Land Cover Class
Tempera...
Average Temperature (°C)
36.0
34.0
32.0
30.0
28.0
Residential Building
Street
Shrub
Grass
Sidewalk
Parking Lot
Parked Cars
Trees
Commercial Buildi...
Bus Stop
Land Cover Class


Huntington Park June 4th Land Cover Class
Humidity
Relative Humidity (%rh)
60.0
55.0
50.0
45.0
40.0
Residential Building
Street
Shrub
Grass
Sidewalk
Parking Lot
Parked Cars
Trees
Commercial Buildi...
Bus Stop
Land Cover Class

Infrared Images

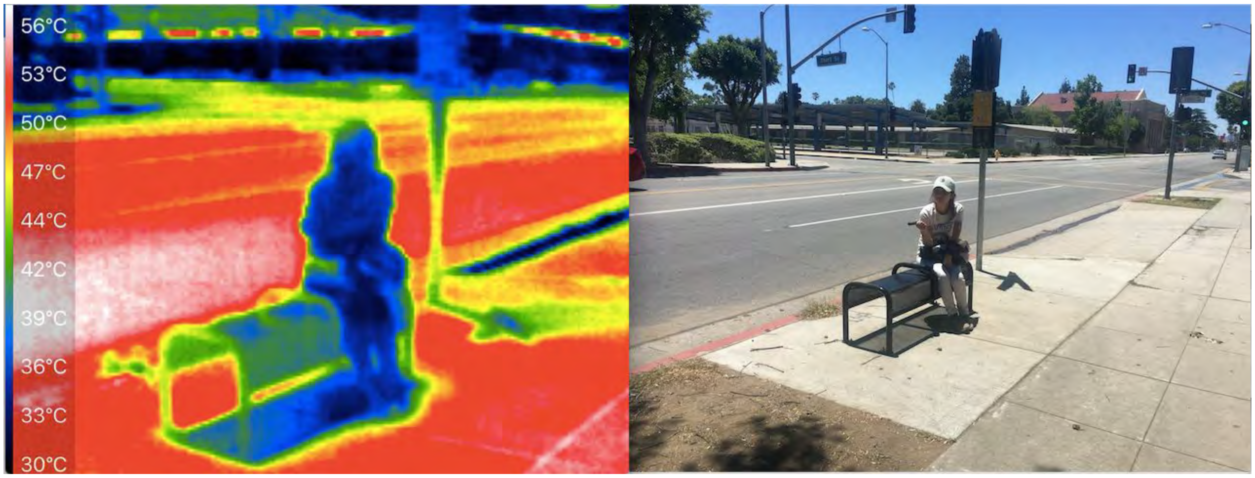
San Fernando

Residential, Average Heat Event Temperature: 36.5 °C

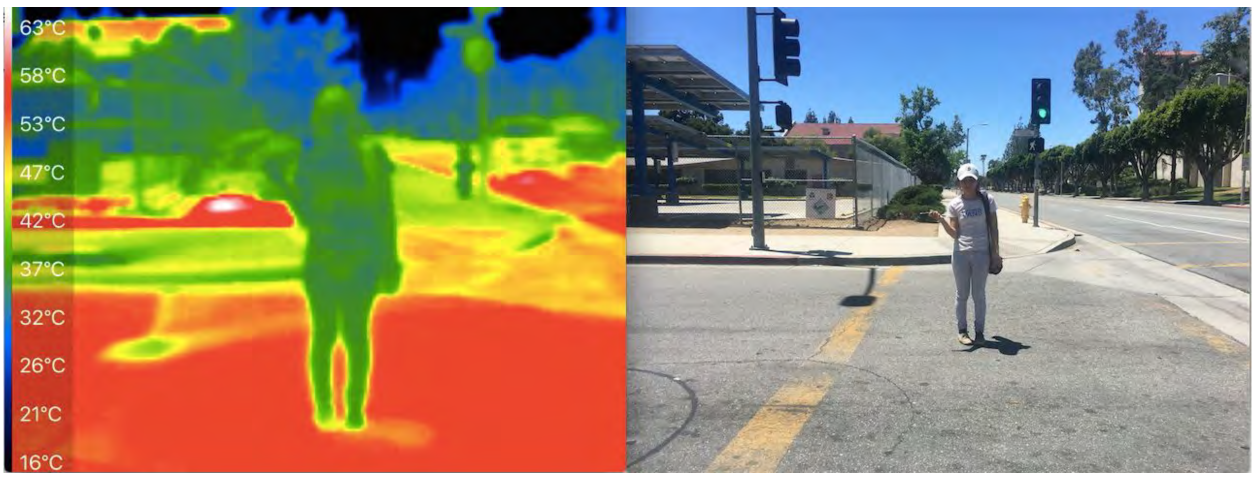


Residential, Tree, Average Heat Event Temperature: 33.7 °C

Bus Stop, Average Heat Event Temperature: 39.0 °C

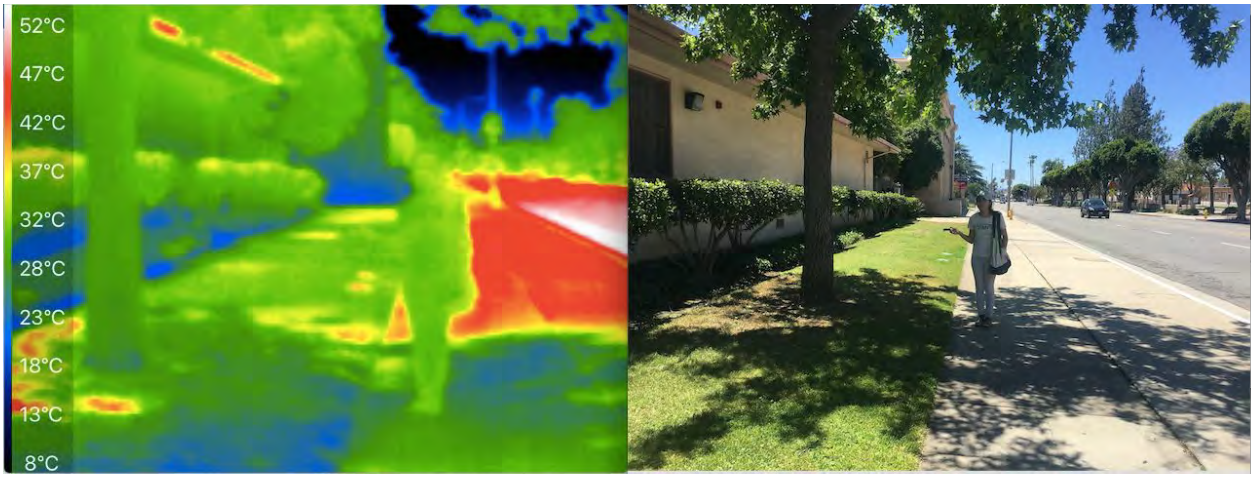


Crosswalk, Average Heat Event Temperature: 39.2 °C

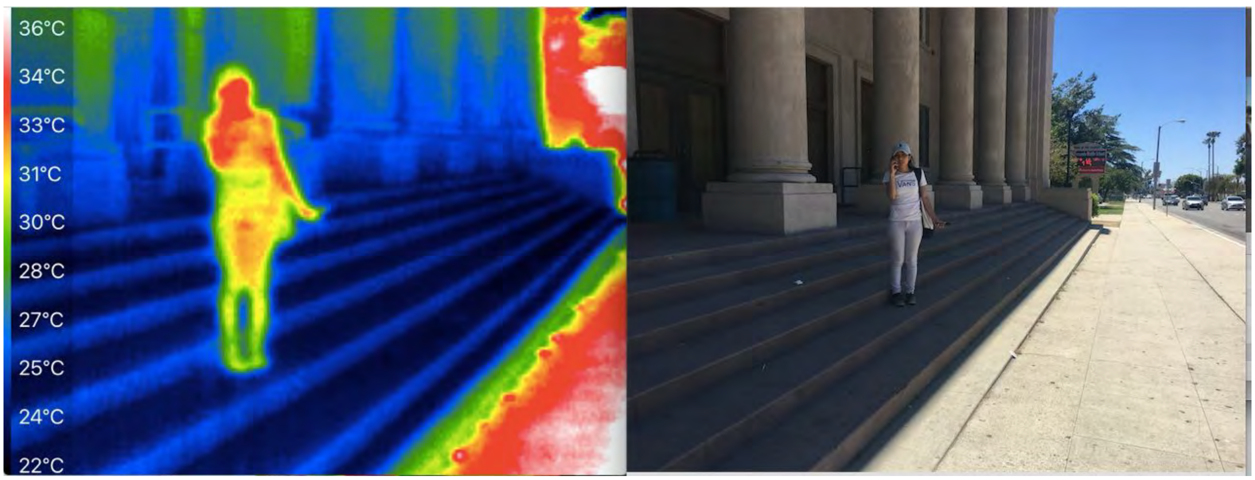


Shrubs, Average Heat Event Temperature: 39.2°C

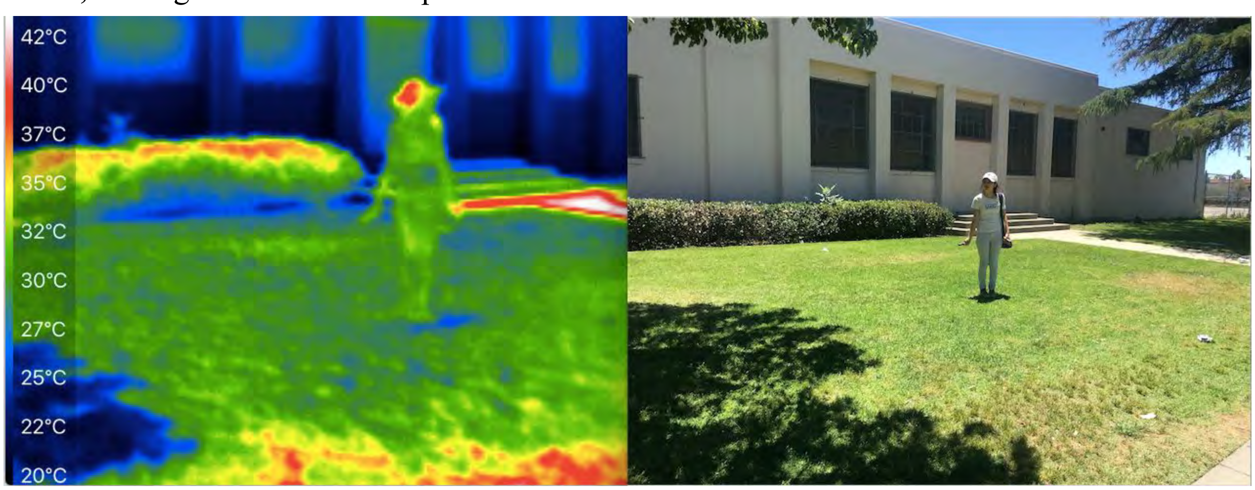
Tree, Average Heat Event Temperature: 36.2 °C



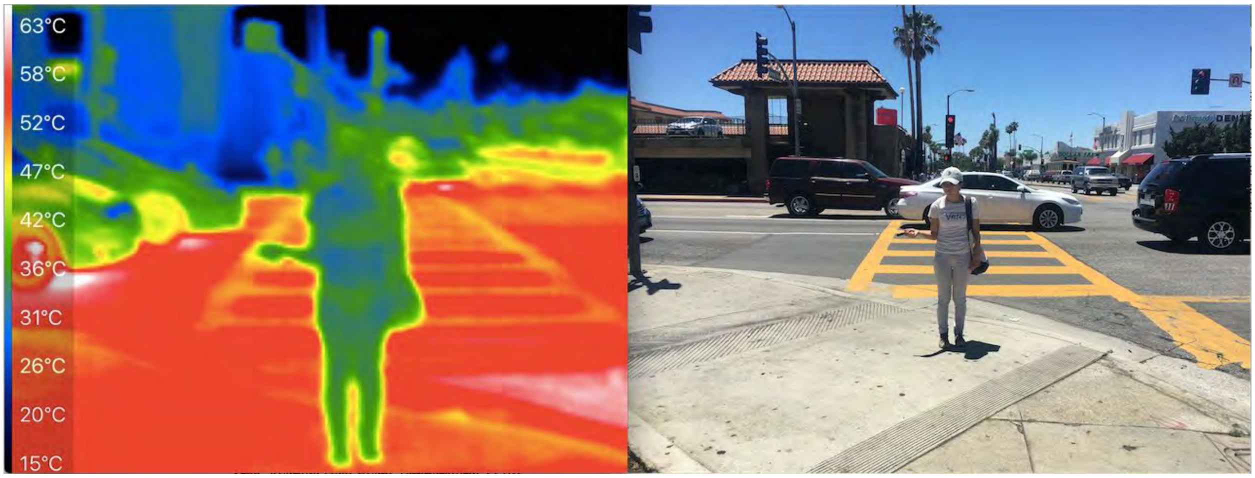
School Building, Average Heat Event Temperature: 36.2 °C



Grass, Average Heat Event Temperature: 38.5 °C



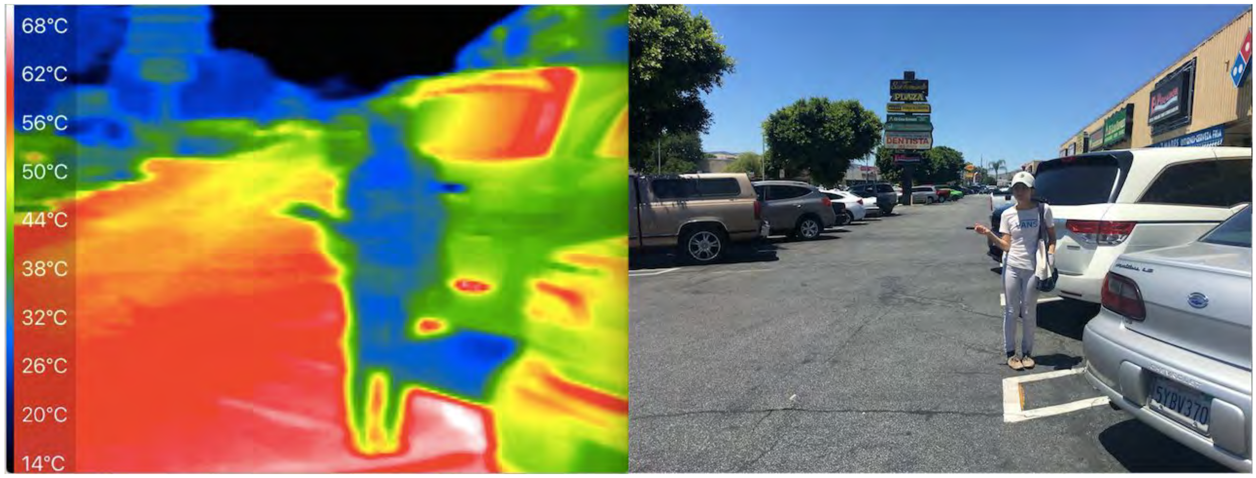
Street Corner, Average Heat Event Temperature: 39.3 °C



Bus Stop, Average Heat Event Temperature: 39.3 °C

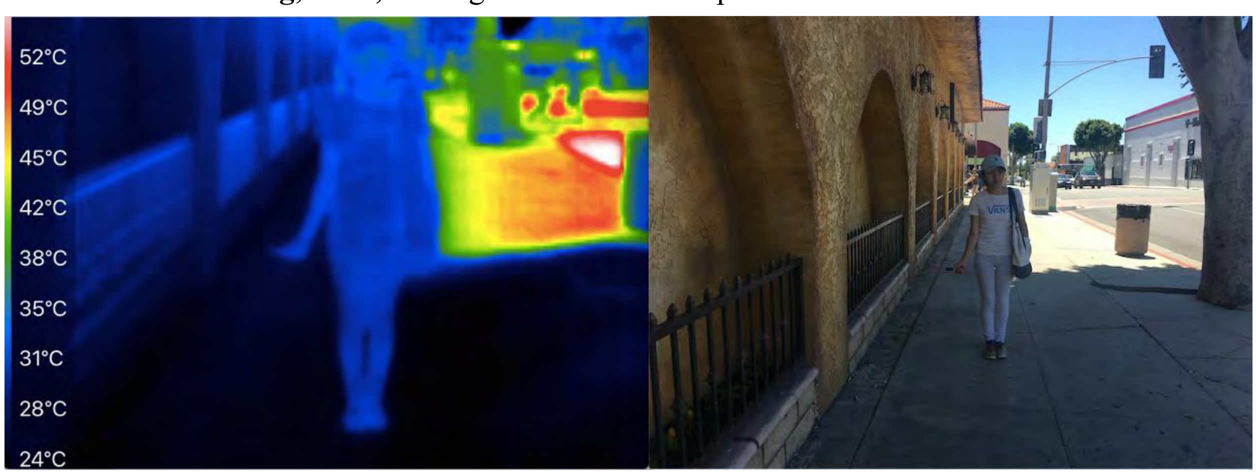
Bus Stop, Tree, Average Heat Event Temperature: 36.2°C

Parking Lot, Average Heat Event Temperature: 39.5 °C

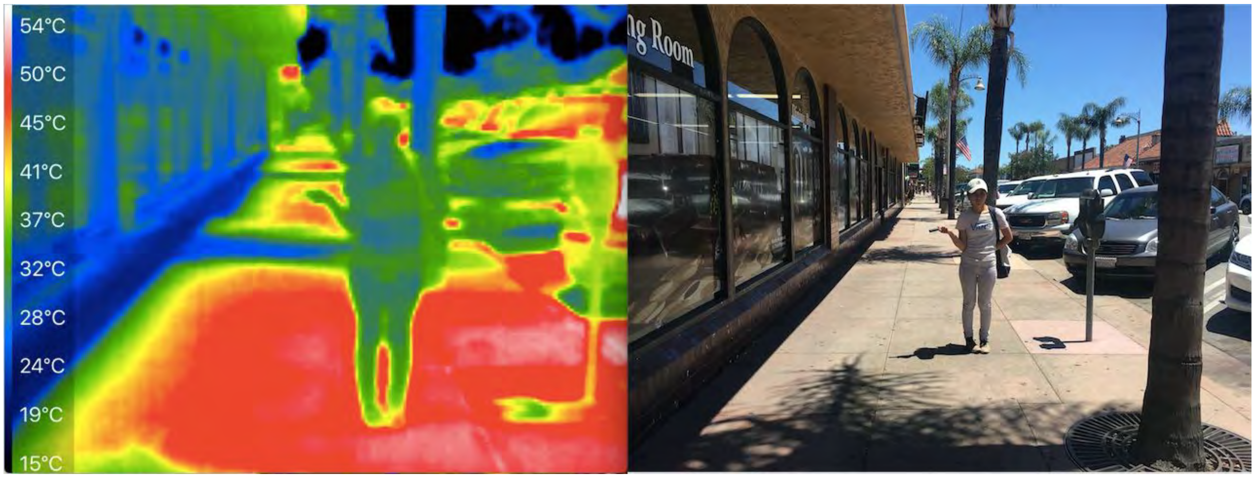


Bus Stop, Average Heat Event Temperature: 38.7 °C

Commercial Building, Tree, Average Heat Event Temperature: 35.2 °C



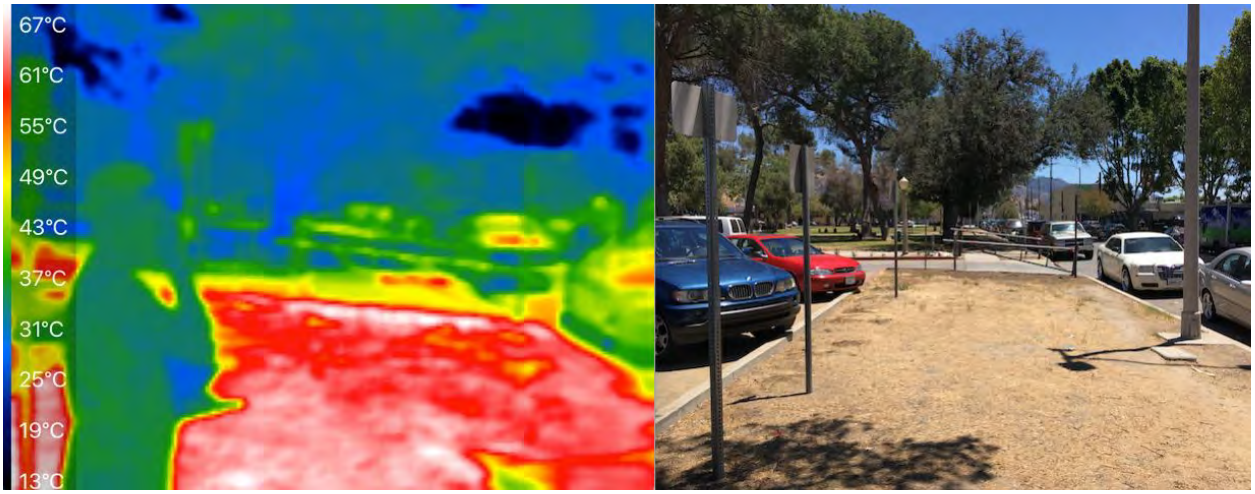
Commercial Building, Average Heat Event Temperature: 38.5 °C



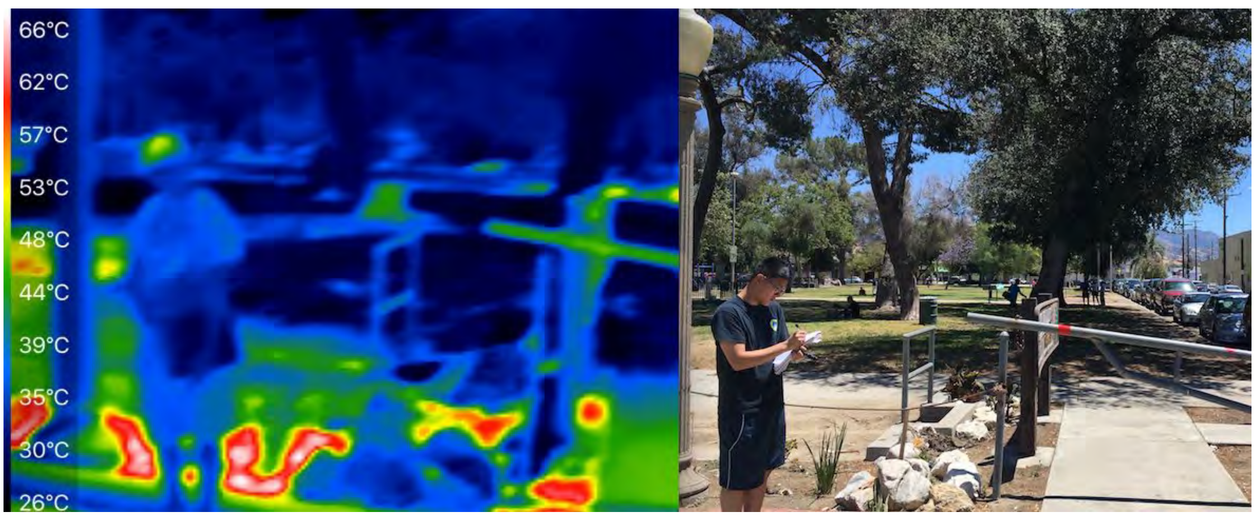
Parked Car, Average Heat Event Temperature: 42.0 °C

Sun Valley

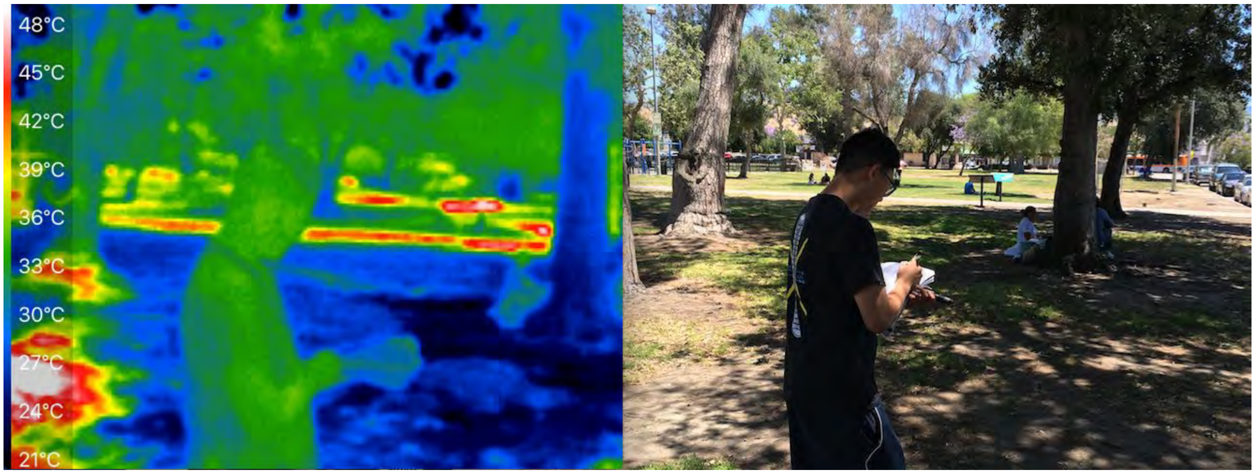
Tree, Average Heat Event Temperature: 33.0 °C



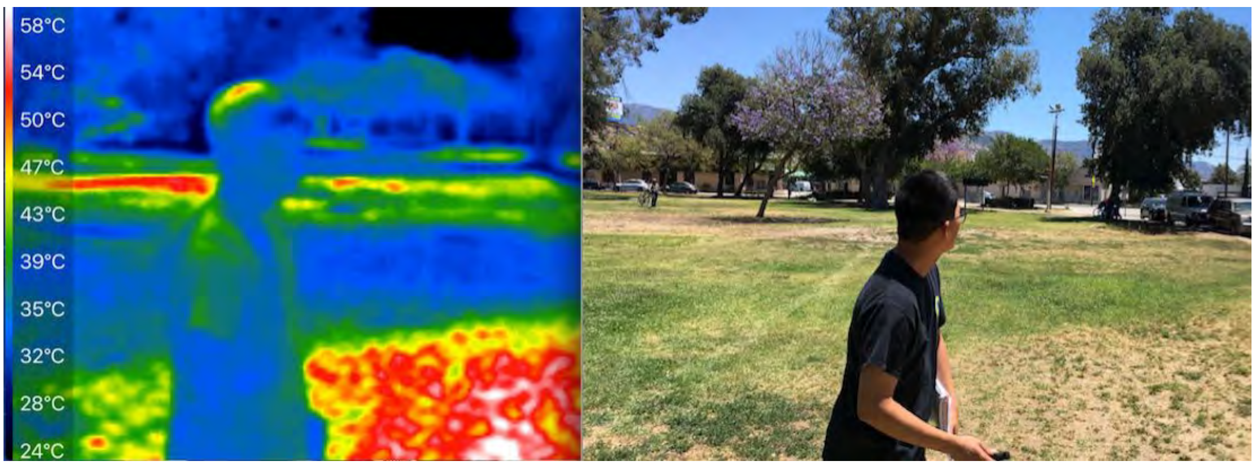
Shrubs, Average Heat Event Temperature: 37.8 °C



Tree, Average Heat Event Temperature: 34.8 °C

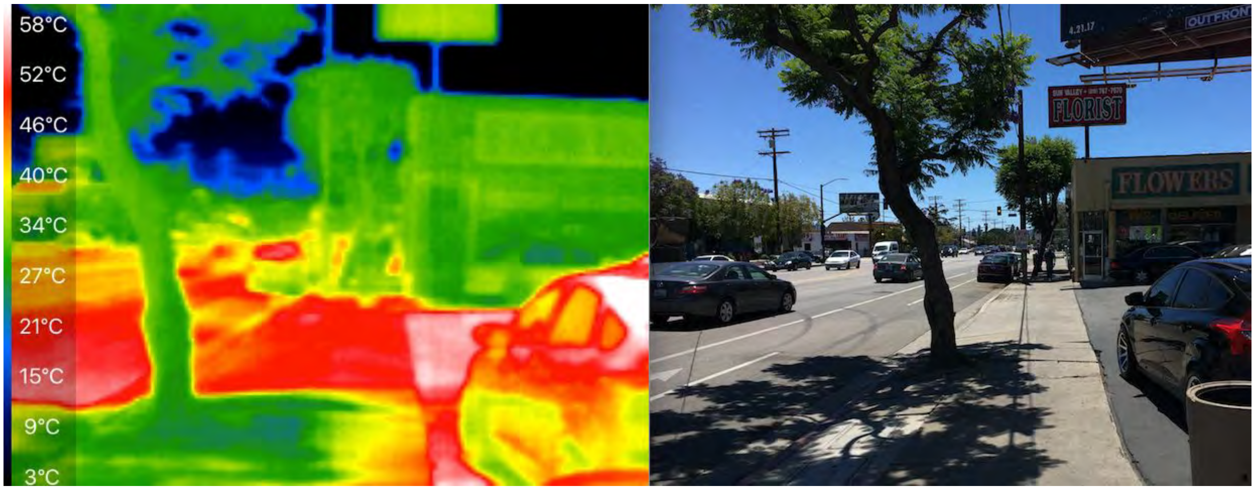


Grass, Average Heat Event Temperature: 37.2 °C

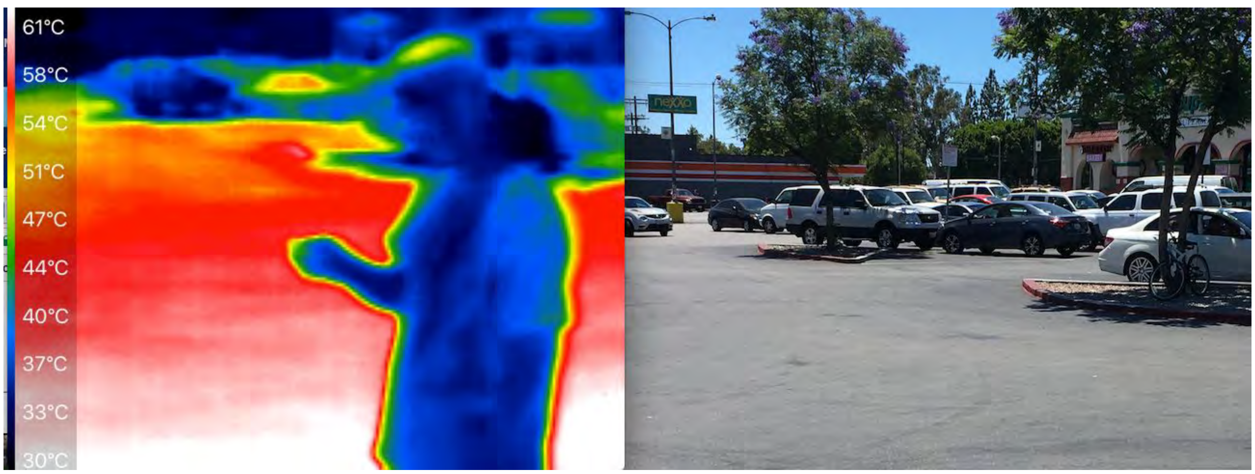


Commercial Building, Average Heat Event Temperature: 37.0 °C

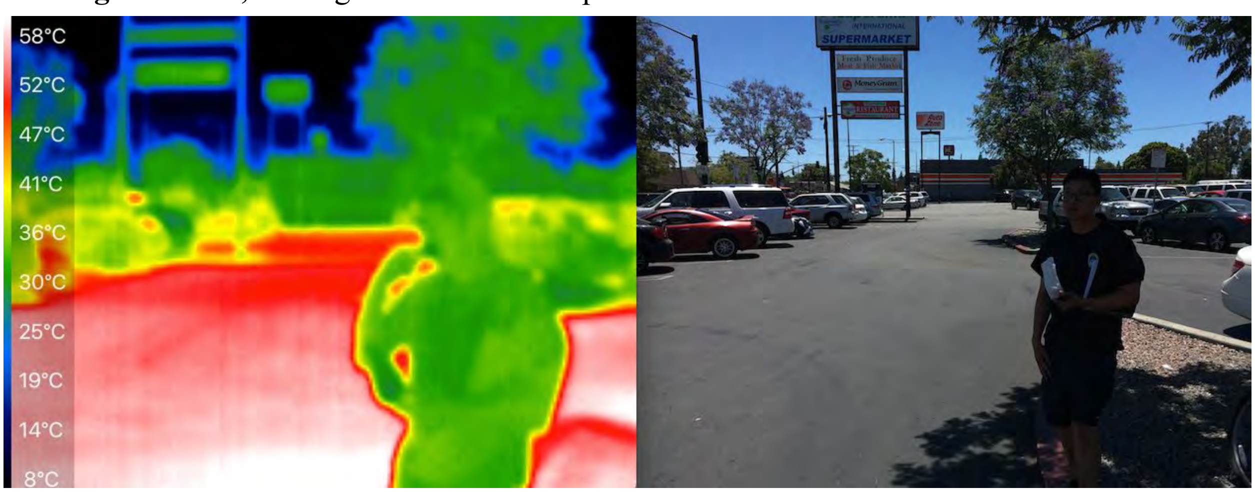
Shrub, Average Heat Event Temperature: 37.8 °C



Parking Lot, Average Heat Event Temperature: 39.2 °C

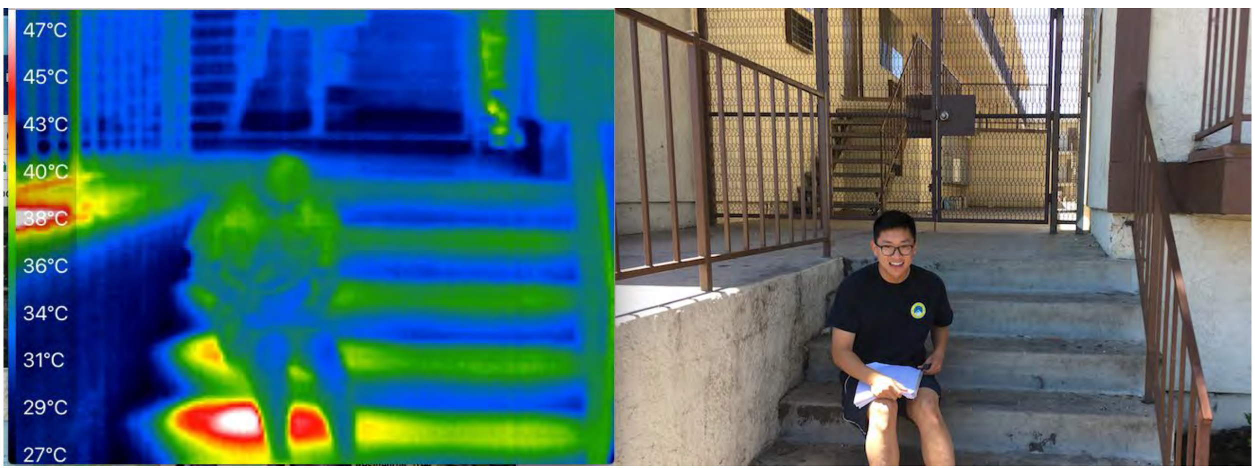


Parking Lot-Tree, Average Heat Event Temperature: 37.7 °C



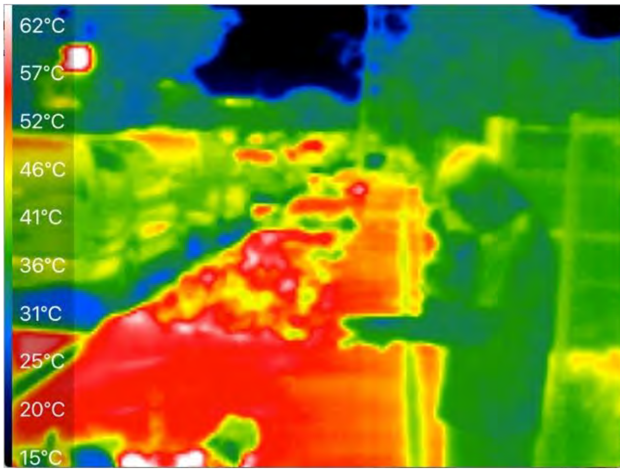
Bus stop, Average Heat Event Temperature: 35.3 °C

Residential, Average Heat Event Temperature: 34.5 °C



Residential-Tree, Average Heat Event Temperature: 33.5 °C

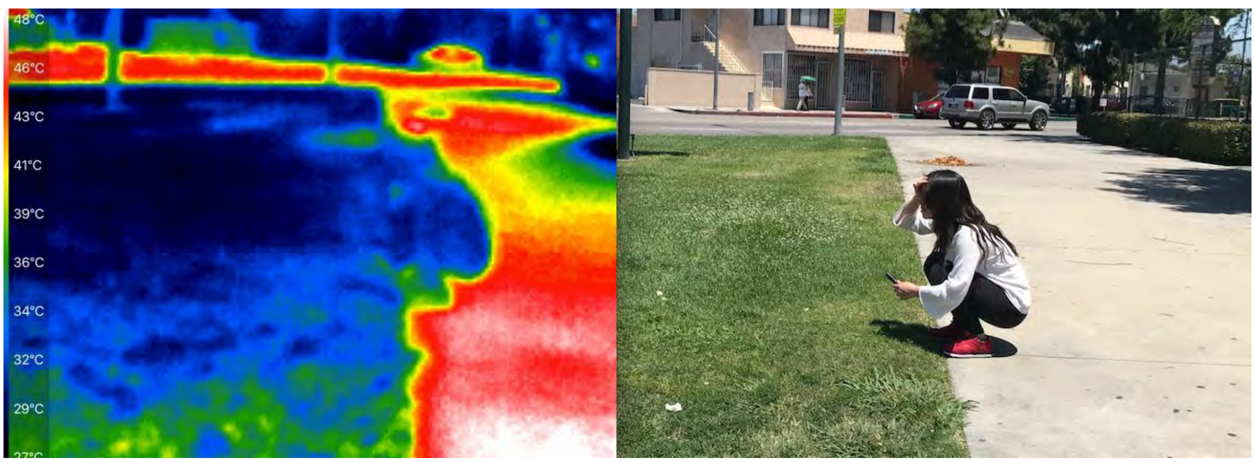
Sidewalk Average Heat Event Temperature: 37.0 °C



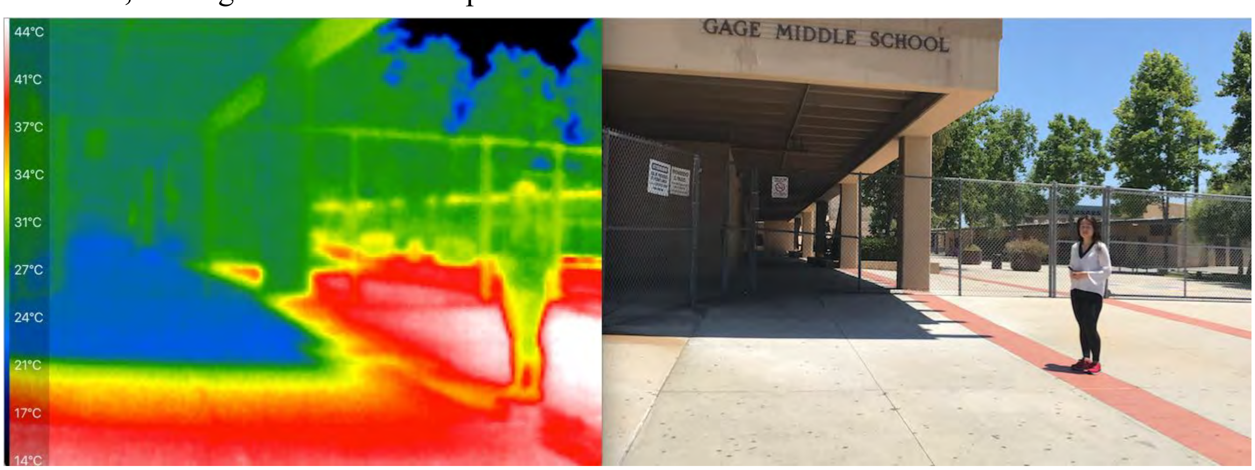
Huntington Park

Bus stop, Average Heat Event Temperature: 32.2 °C

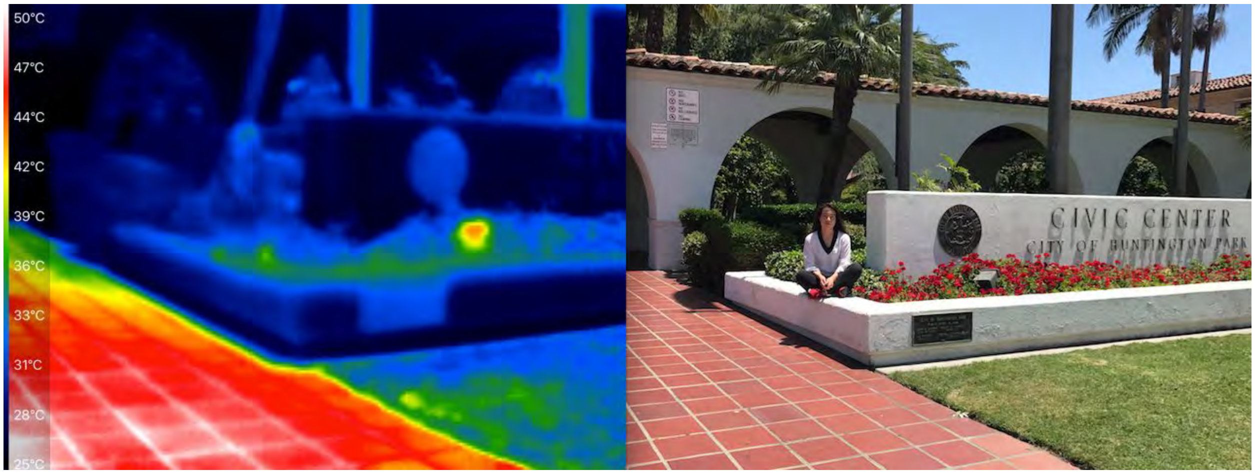
Grass, Average Heat Event Temperature: 34.2 °C



Sidewalk, Average Heat Event Temperature: 34.5 °C

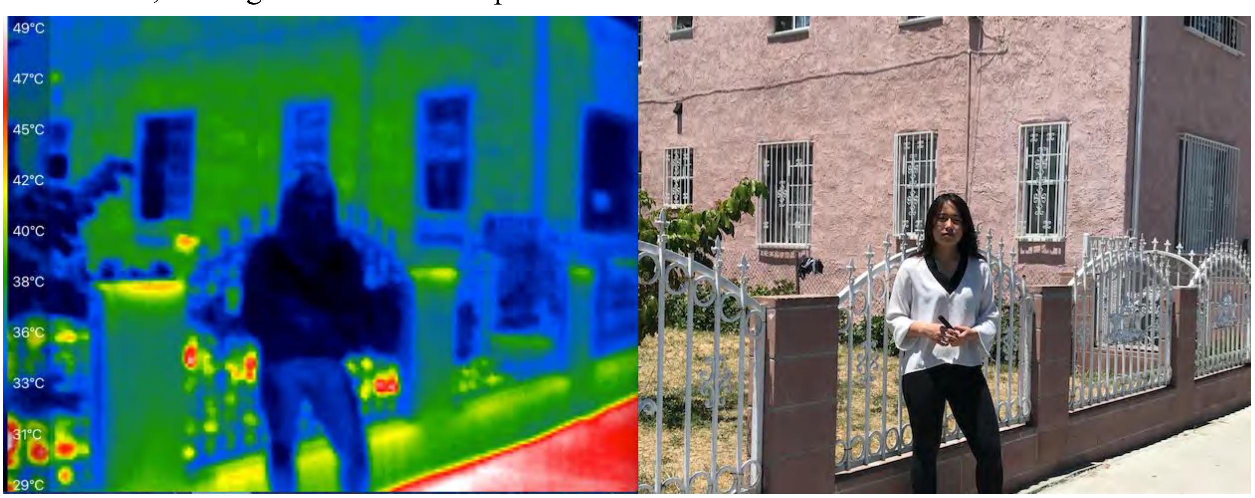


Shrubs, Average Heat Event Temperature: 34.3 °C

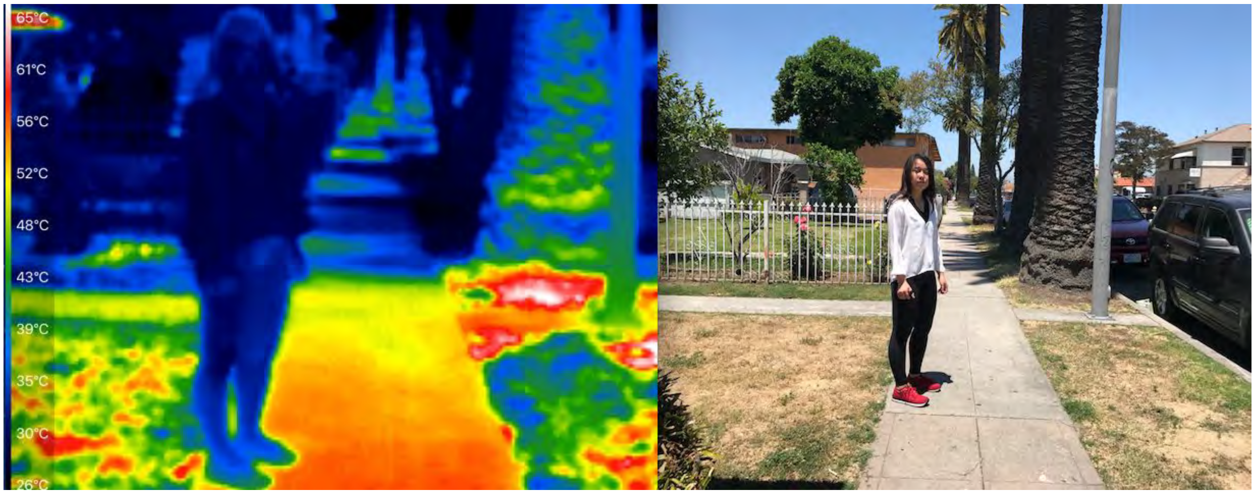


Tree, Average Heat Event Temperature: 33.2 °C

Residential, Average Heat Event Temperature: 35.3 °C



Sidewalk, Average Heat Event Temperature: 36.0 °C



Parked Car, Average Heat Event Temperature: 35.8 °C

Commercial Building, Average Heat Event Temperature: 35.5 °C

Parking Lot, Average Heat Event Temperature: 34.8 °C