Effects of trees, gardens, and trails on heat index and child health: Design and methods of the Green Schoolyards Project

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Abstract

Background: Low-income Latinx children in the United States are vulnerable to nature-deficit disorder, heat-related illness, and physical inactivity. We developed the Green Schoolyards Project to investigate how green features—trees, gardens, and nature trails—in school parks impact heat index (i.e., air temperature and relative humidity) within parks, and physical activity levels and socioemotional well-being of these children. Herein, we present baseline results of this project and its novel methods for a) observing children's interaction with green features and b) measuring heat index and children's behaviors in a natural setting.

Methods: During two September weeks (high temperature) and one November week (moderate temperature) in 2019, we examined three joint-use elementary school parks in Central Texas, United States, serving predominantly low-income Latinx families. To develop thermal profiles for each park, we installed 10 air temperature/relative humidity sensors per park, selecting sites based on land cover, land use, and even spatial coverage. We measured green features within a geographic information system. In a cross-sectional study, we used an adapted version of System for Observing Play and Recreation in Communities (SOPARC) to assess children's physical activity levels and interactions with green features. In a cohort study, we equipped 30 3rd and 30 4th grade students per school during recess with accelerometers and Global Positioning System devices, and surveyed these students regarding their connection to nature. Baseline analyses included inverse distance weighting for thermal profiles and summing observed counts of children interacting with trees.

Results: In September 2019, average daily heat index ranged 2.0°F among park sites, and maximum daily heat index ranged from 103.4°F (air temperature = 33.8°C; relative humidity = 55.2%) under tree canopy to 114.1°F (air temperature = 37.9°C; relative humidity = 45.2%) on an unshaded playground. 10.8% more girls and 25.4% more boys interacted with trees in September than in November.

Conclusions: We found extreme heat conditions at select sites within parks, and children positioning themselves under trees during periods of high heat index. These methods can be used by public health researchers and practitioners to inform the redesign of greenspaces in the face of climate change and health inequities.

Background

Children in modern times are experiencing "nature-deficit disorder," described as the human costs of alienation of nature (1), and are consequently missing the benefits of engaging with nature such as a stronger sense of place, improvements in physical and mental health, greater environmental knowledge, and pro-environment attitudes as an adult (2). In the United States (US), children spend three times as many hours on the computer or watching television as they do playing outdoors (3). Furthermore, access to nature is an environmental justice issue: individuals who are Latinx, low-income, and/or with low levels of education have less access to vegetation (4, 5).

These same populations lacking access to nature are also at risk for heat-related illnesses, such as heat exhaustion and heat stroke (6). Racial and ethnic minority children from low-income families disproportionately live in areas characterized by urban heat islands (7), the phenomenon in which cities experience higher temperatures than nearby areas due to high amounts of impervious materials, lack of vegetation, morphology, and waste heat from industrial processes (8).

Along with vulnerability to nature-deficit disorder and heat-related illness, racial and ethnic minority children from low-income families are less physically active than other groups (9, 10). Fewer than half of all US children are reaching recommended physical activity levels (11). This lack of physical activity poses a serious public health threat: children who are not sufficiently active are more likely to develop several chronic diseases, such as obesity and type 2 diabetes (12).

With children spending a significant portion of their time at school (13), public health practitioners have promoted child health through green schoolyards—"natural spaces (that) are used as outdoor classrooms to enhance learning outcomes and create daily wellness for the children they serve" (14). Although schoolyard greening has been shown to contribute to children's physical, mental, and social-emotional well-being (15–18), public health researchers have not fully explored the relations between green schoolyards, temperatures, and child health.

In response, we developed the Green Schoolyards Project to understand whether school parks can serve as a tool for urban heat island adaptation and health promotion in underserved communities at risk of disconnect from nature (and its associated health consequences) and heat-related illness. The specific aims of the Green Schoolyards Project are to examine how green features—trees, gardens, and nature trails—in joint-use elementary school parks impact: a) heat index within parks; b) physical activity levels of predominantly Latinx children from low-income families; and b) psychosocial and academic outcomes following park use (i.e., connection to nature, social-emotional learning skills, standardized test scores, and disciplinary behavior) of these children. Herein, we present baseline results of the Green Schoolyards Project, along with an overview of the research methods, which are novel and innovative in two major ways: a) direct observation of children's interaction with green features at multiple physical sites per park; and b) time-matching of objective measurements of heat index, student's geographic location, and student's physical activity levels in relation to location of green features. The importance of these methods is illustrated by our findings of extreme heat conditions at select sites within parks, and children positioning themselves under trees during periods of high heat index.

Methods

Research Design

The Green Schoolyards Project consisted of two separate studies: a) a serial cross-sectional study focused on physical sites within parks, and b) a prospective cohort study focused on students. The cross-sectional study was designed to examine the associations between heat index, children's physical activity, and interaction with green features for multiple sites (e.g., playground, track, and soccer field) per park on multiple times per day. The cohort study followed a selection of students from each school affiliated with these parks to assess the impact of green features—the amount of which differs per park—on heat index and student's physical activity levels during recess, along with their connection to nature, social-emotional learning skills, standardized test scores, and disciplinary behavior.

Conceptual Framework

The research design of the Green Schoolyards Project was based on the social-ecological model of health behavior, which states multiple levels of influence—individual, social, environmental, and policy—impact health behaviors (e.g., physical activity), and these influences interact across levels to impact behavior (19). Effective health interventions focus on behavior-specific influences, and intervene at multiple levels of influence. A principal goal of the project was to learn if green features moderate the relation between ambient heat and physical activity of children, which includes factors within the individual level (i.e., sex, age, race, and ethnicity); environmental level (i.e., green features and heat index); and policy level (i.e., policies that impact park temperatures and park use) of the socio-ecological model.

Project Sites

Three elementary school parks within a school district in Central Texas, US, were used for this study. The project was a comparative analysis between similar parks with different levels of green features. Three schools met our initial selection criteria: serving populations greater than 85% economically disadvantaged Latinx; located in zip codes with low Nature Factor scores; joint-use agreements between the school district and the city Parks and Recreation Department permitting the surrounding community to use parks after school hours; and equivalent park features (e.g., playgrounds, soccer fields, running tracks, and basketball courts).

The selection criterion of Nature Factor is defined as the sum of Nature Factor Ratings of all parks within a zip code (20). Nature Factor Rating is the sum of four park-level ratings: park acreage rating, Trust for the Public Land land use rating, National Recreation and Parks Association park status rating, and tree canopy rating (21). High values for Nature Factor Ratings (e.g., high park acreage, designed lands, open park status, and high levels of tree canopy) correspond to high Nature Factor scores (i.e., higher levels of nature present in that zip code). The three selected schools are in zip codes with Nature Factor scores of 121, 118, and 198, respectively, which are relatively low compared to those of other zip codes (n = 53; min. = 0; max = 712; mean = 150; standard deviation = 143).

The three school parks were characterized by different profiles of green features: the “intervention park” had added green features (i.e., trees, two gardens, and a nature trail); the “low-green park” had relatively low amounts of historical green features (i.e., trees); and the “high-green park” had relatively high amounts of historical green features (i.e., trees and a garden). The school of the intervention park participated in the Green School Parks pilot project, a district-parks department partnership in which green features were installed at elementary school parks. In August 2017, the intervention park received an outdoor classroom, a 3,000-gallon leaky water cistern, two rain gardens with a 1,208 m^2 drainage area, and a 76 meter-long nature trail. The community also planted over 100 trees in the park, in October 2017.

For each school park, we calculated tree canopy cover using i-Tree Canopy, a publicly available tool that uses random point sampling to estimate the percentage of tree canopy cover for a predefined area (22). Although trees at the intervention park were more abundant and evenly distributed than trees at the parks at the other schools, the tree canopy cover was only 8.5% (standard error = 1.97) because trees planted were saplings. The low-green park had 11.5% (standard error = 2.26) tree canopy cover, with most trees clustered in the far northwest corner. The high-green park had 22.5% (standard error = 2.95) tree canopy cover, with relatively large trees on the periphery of the park.

Project Period

We designed data collection to take place on 18 days over the fall semester in 2019, which will be duplicated in 2020 for a total of 36 study days. Each year, study days consist of two September weeks (i.e., five weekdays and one weekend day per week) and one November week (i.e., five weekdays and one weekend day). We selected September and November because these months have historically high and moderate temperature conditions, respectively: the weather station at the city’s major airport recorded monthly mean average air temperatures of 26.4 °C in September and 15.3 °C in November from 2009 to 2018 (23). Prior to undertaking any project activities, we received approval of project protocols by the institutional review board at The University of Texas Health Science Center at Houston (HSC-SPH-19-0502) and the school district. We also received informed consent from participants’ parents and written assent from study participants.

Measurement of Heat Index

We measured heat index—the combination term for air temperature and relative humidity that captures what the temperature feels like (24)—by semi-permanently installing 10 HOBO MX2302A external air temperature/relative humidity sensor data loggers (Onset Computer Corporation, MA) at each park. Previous studies have used comparable networks of in situ sensors to monitor microclimatic conditions of a given area (25–27). Measurement of near-surface air temperatures is advantageous over the use of land surface temperatures as a proxy for air temperatures, as research has shown land surface temperatures are not directly comparable to air temperatures (28, 29). In situ measurement of air temperatures has been found to be more useful for estimating short-term, actual temperature exposures than using land surface temperatures or the percentage of impervious surface (30). Designed for outdoor use, the MX2302A model collects air temperature (± 0.2 °C from 0 to 70 °C) and relative humidity data (± 2.5% from 10–90%), and is configured to wirelessly link with the free HOBOmobile app on a cell phone or tablet (31), permitting efficient collection of air temperature and relative humidity data by project members.

Before deploying HOBO sensors, we encased each sensor in an RS3-B solar radiation shield (Onset Computer Corporation, MA), which results in improved temperature measurement accuracy by protecting the sensor from absorption of incoming solar radiation and resultant heat gain. In another attempt to improve temperature measurement accuracy, we attached the radiation shield (encasing the external sensor) and data logger to a 2 × 2” piece of weather-treated lumber, which serves as a physical buffer minimizing heat transfer between the sensor and the installation surface in the park, such as a metal swing set pole (Fig. 1). We programmed the sensors to record air temperature and relative humidity every five minutes, consistent with previous studies (27, 32, 33).

Figure 1. HOBO MX2302A external air temperature/relative humidity sensor data logger on swing set at low-green park.

For each park, we selected 10 sites for HOBO sensors based on land cover (e.g., grass, pavement, and mulch); land use (e.g., soccer field, basketball court, and playground); comparability across parks; and even spatial coverage (Fig. 2). To include a highly impervious area for comparison within park sites, we installed one of the 10 sensors at each park’s parking lot, just outside park boundaries. To capture air temperature and relative humidity experienced by humans, we installed sensors at two meters above ground level, similar to previous studies (26, 27, 32). To promote community awareness of our project and deter vandalism, we attached a small laminated tag with a description of the sensor and our contact information to each sensor. Sensors were installed the day before a study week, and removed at the end of each study week.

Measurement of Green Features

We identified the location, type, and quantity of green features using four-band, 60 cm orthoimagery taken in November 2018 by the US Department of Agriculture’s National Agriculture Imagery Program (34). Within a geographic information system (ArcGIS 10.6.1, ESRI, Redlands, CA, USA), we digitized polygons of trees, gardens, and nature trails, an established technique deemed appropriate for the relatively small park areas (i.e., intervention = 21,448 m^2; low-green = 27,923 m^2; high-green = 16,187 m^2) (35).

Direct Observation of Parks

The cross-sectional study utilized the System for Observing Play and Recreation in Communities (SOPARC), a validated direct observation tool for assessing the conditions and users of park sites (36). Following SOPARC protocol, we divided each park into target areas intended for physical activity, such as basketball courts and soccer fields (Fig. 2). On study days during school (i.e., 7:00 and 12:00) and after school (i.e., 16:00 and 18:00), study staff—in pairs for interrater reliability—administered SOPARC by walking from target area to target area and recording what they observed.

We adapted SOPARC to measure physical activity levels of children aged 1–12 years old and these children’s interactions with green features. Although previous research has used direct observation to examine the influence of nature on children’s play (37), no research employs SOPARC to quantify the number of children’s interactions with different green features at multiple park sites. On study days for each target area, trained staff recorded target area conditions, scanned for the physical activity levels of female and male children, and then scanned for the number of female and male children interacting with green features (i.e., no interaction, under tree canopy or touching tree, interacting with garden, and on nature trail). Staff used the iSOPARC application on an electronic tablet for scan counts and recorded data on a data collection form (see **Additional File 1**).

Figure 2. HOBO sensors and SOPARC target areas at (**A**–**B**) intervention, (**C**–**D**) low-green, and (**E**–**F**) high-green parks.

Cohort Study Sample

For the cohort study, we recruited 40 3rd and 40 4th grade students per school over two years, to achieve a final sample size of 30 students per grade, after accounting for attrition. From mid-August 2019 through early September 2019, we recruited participants by convenience sampling. Participant incentives were a total of $35 US dollars/year worth of supermarket gift cards (i.e., $10 for each September study week and $15 for each November study week).

Measurement of Geographic Location and Physical Activity

On study days during recess (i.e., 30-minute period of unstructured play under teacher supervision), the cohort sample wore elastic belts around their waist equipped with a Qstarz BT-Q1000XT Global Positioning System (GPS) device (Qstarz Intl Co., Taipei, Taiwan) and an Actigraph wGT3X-BT accelerometer (ActiGraph LLC, FL) to measure geographic location and physical activity levels, over time (38, 39). We set sampling rates of 15 seconds for GPS devices and accelerometers (40, 41). For the separate recess periods per grade, belt distribution began five minutes before recess start, and belt collection occurred once teachers signaled recess end.

Time-Matching of Geographic Location, Physical Activity, and Heat Index

Data from GPS devices, accelerometers, and HOBO sensors will be time-matched, allowing us to know a student's location, student's physical activity intensity level, and heat index at that location at 15-second intervals throughout recess. The location of green features will be joined to the time-matched device data, within GIS. Although previous studies have matched children's geographic location and physical activity levels over time (38–41), this study enables assessment of a child's experienced heat index and physical activity level at any particular location.

Measurement of Outcomes Following Park Use and School Policies

For baseline data collection in November 2019, we collected data on the cohort sample and school policies from three sources. First, we administered aloud a written survey—in both English and Spanish language—to the cohort sample, asking them about their connection to nature using two adapted instruments: Inclusion of Nature with Self and Connection to Nature Index (see **Additional File 2**)(42–44). Second, the school district provided student-level data on sociodemographic characteristics, social-emotional learning skills (from a student climate survey), disciplinary behavior, and standardized test scores. Lastly, we distributed an annual survey—adapted from a previous study (45)—to ask school principals about policies impacting park access, greening at school parks, and student physical activity.

Statistical Analysis of Baseline Data

For baseline findings shared within, we performed the analysis over several steps. To develop a thermal profile for each park, we first calculated heat index—from air temperature and relative humidity data recorded by HOBO sensors—using a set of validated equations utilized by the US National Weather Service (46, 47). Heat index is measured in degrees Fahrenheit, rather than Celsius (48). Within GIS, we used inverse distance weighting to create a spatially continuous thermal profile for each park. A common interpolation method in urban heat island measurement (49), inverse distance weighting permits estimation of unsampled heat index values between HOBO sensors by averaging the values of sampled heat index values from sensors surrounding each prediction location. We used SOPARC data to understand how children interact with trees during time periods with different temperature conditions, summing observed counts of children under tree canopy or touching trees by sex of child, park, and study period.

Results

Thermal Profiles of School Parks

Average daily heat index was 87.4°F in September and 62.4°F in November across the three parks, with average daily heat index ranging from 86.8°F to 88.8°F from September 16–30th, in 2019 (Fig. 3). The minimum and maximum values of this range originated from the intervention park at two sites 141ft apart: a playground under heavy tree canopy (Target Area 18) and a unshaded playground (Target Area 9), respectively (Fig. 2).

In September 2019 at the intervention park, the canopied playground reached a maximum heat index of 104.3°F (air temperature = 34.6 °C; relative humidity = 51.0%), whereas the unshaded playground reached 114.1°F (air temperature = 37.9 °C; relative humidity = 45.2%). At the low-green park, the lowest maximum heat index was 103.4°F (air temperature = 33.8 °C; relative humidity = 55.2%) under heavy tree canopy (Target Area 14), and the highest was 106.9°F (air temperature = 35.8 °C; relative humidity = 47.4%) at an unshaded playground (Target Area 13). At the high-green park, the lowest maximum heat index was 104.2°F (air temperature = 33.8 °C; relative humidity = 55.8%) at a basketball court under an artificial shade structure (Target Area 9), and the highest was 109.4°F (air temperature = 35.9 °C; relative humidity = 50.5%) at an unshaded playground (Target Area 14).

Figure 3. Thermal profiles for (**A**) intervention, (**B**) low-green, and (**C**) high-green parks, September 16–30th 2019.

Children's Interaction with Green Features

When conducting SOPARC scans for the number of children interacting with green features, we observed a total of 1,229 children in target areas with trees, three children in target areas with gardens, and zero children in target areas with nature trails, during 12 days in September and six days in November 2019. In target areas with trees (Table 1), children observed at the low-green park constituted 67.1% of all children observed in September and 65.4% of all children observed in November. Target areas with trees were frequented by a slightly larger percentage of female children than male children in both September (52.4% female) and November (51.8% female). Across the three parks, these target areas had 10.8% more female children and 25.4% more male children under tree canopy or touching trees in September than in November 2019. However, a lower percentage of male and female children at the high-green park interacted with trees in September than in November. Across the three parks, we observed no children interacting with gardens or on nature trails during study days in September and November 2019.

Table 1
Children's interaction with trees at school parks on study days using SOPARC (September, November 2019).

School Park	Study Period (2019)	Children Under Tree Canopy or Touching Trees[1]		Total Children Observed[1]	
		Female (%)	**Male (%)**	**Female (#)**	**Male (#)**
Intervention	September	59.7	65.7	72	67
	November	50.0	53.7	30	41
Low-Green	September	71.4	77.6	273	228
	November	59.8	44.7	184	132
High-Green	September	19.6	13.3	46	60
	November	63.2	64.5	36	60
Total	September	63.2	64.5	391	355
	November	52.4	39.1	250	233

[1]Observations are for target areas with trees present within its boundaries.

Discussion

Methodology for Climate and Health Solutions

We provided baseline findings from the Green Schoolyards Project as evidence for the utility of the methods in understanding how green features can moderate place-based climate change and health inequities affecting children. Public health researchers and practitioners can use these methods as a model for exploring how joint-use parks with green features can serve as climate and health solutions for underserved communities, in the wake of current climate change and health inequities impacting cities (7). Understanding how green features in school parks impact heat index and child health is essential due to projected increases in a) urban temperatures from population-driven development; b) global temperatures from greenhouse gas emissions; and c) the intensity, frequency, and duration of extreme heat events from climate change (50).

From thermal profiles of each park (Fig. 3), we found a two-degree range in average daily heat index (86.8–88.8°F) in September 2019 across the three parks, which is a change detectable by humans (51). Park sites with heavy tree canopy and artificial shade structures exhibited the lowest heat index values, and unshaded playgrounds exhibited the highest heat index values. These results corroborate those of a previous study that examined the temperatures of surface materials in parks in Phoenix, Arizona, in which researchers found tree canopy and artificial shade structures were associated with significant reductions in surface temperatures, and playground structures exhibited the highest surface temperatures (52). In September at the intervention park, we found a 9.8°F difference in maximum heat index between a canopied playground and an unshaded playground—the difference between "Extreme Caution" and "Danger" levels for likelihood of extreme heat disorders with prolonged exposure or strenuous activity, as defined by the US National Weather Service (53).

From using SOPARC to understand children's interaction with green features, we found more children were interacting with trees in September than in November across the three parks (Table 1). This may suggest children were actively seeking trees—a proven heat management strategy (54, 55)—during high heat index for thermal comfort. Yet this finding was reversed when examining the high-green park independently, which may be related to children's preference for a playground characterized by sparse canopy cover (i.e., 53.8% of all children observed), and their unwillingness to travel to large trees on the park's periphery during high heat index. Our finding that no children interacted with gardens or used nature trails may be due to these features being located far from play elements (e.g., slides, ladders, and swings), which have been shown to be associated with more users and more moderate-to-vigorous physical activity (56). In addition, installation of green features in a park may not induce the use of these spaces: researchers have found that living near sidewalk improvements was not associated with accelerometer-derived physical activity (57). Lastly, the gardens at the parks were rain gardens, which may not be aesthetically pleasing enough or functional for children, unlike vegetable and fruit gardens. Children have been found to engage in more physical activity during outdoor, garden-based lessons than during indoor, classroom-based lessons (58).

Strengths and Limitations

The methods presented herein are unique for adapting a direct observation tool to measure children's interaction with green features, and for actively documenting heat index and children's behaviors in a natural setting (i.e., recess period during a typical school day). Other strengths included the use of validated tools for the objective measurement of heat index (i.e., HOBO sensors), conditions and users of park sites (i.e., SOPARC), children's physical activity levels (i.e., accelerometers), and children's geographic location (i.e., GPS devices). In addition, we paired subjective and objective measures of children's connection to nature, an improvement over a single measure. When responding to survey items about their connection to nature, the cohort sample may be prone to social desirability bias, potentially leading to invalid estimates and poor data quality (59). This self-reported measure can be compared to each survey respondent's proximity to green features during recess, measured by their geographic location from GPS devices and the digitized polygons of green features within GIS.

One limitation of the Green Schoolyards Project was the uneven spatial distribution of HOBO sensors at each park, which could have reduced the accuracy of air temperature and relative humidity values in the thermal profile for each park. In inverse distance weighting interpolation, an uneven spatial distribution of observational data points results in less accurate predictions between observational data points (60). We found that achieving an even spatial coverage of sites for HOBO sensors at each park was difficult in practice. Installation at certain sites—in particular soccer fields—would obstruct use of those sites and/or sites lacked a surface for us to attach a sensor at two-meter height. Additional reasons for uneven spatial coverage included the potential for sensor damage, vandalism, and theft at each prospective site. Future studies can develop more accurate thermal profiles by installing HOBO sensors with more even spatial coverage, supplementing the data recorded by installed HOBO sensors with periodic handheld measurements between installation sites, and/or modeling air temperatures from a combination of air temperature and land surface temperature inputs (61).

We experienced two limitations with the use of SOPARC. For observations occurring on study days during school (i.e., 7:00 and 12:00), the number of children present at each park was directly linked to the schedule of the school and teachers, which resulted in significant differences in the number of children observed during school hours across school parks. If a recess period happened to coincide with an observation period, then more children were observed than if there was no overlap between observation and recess period. Each school had different schedules for recess across classes and grades (i.e., pre-kindergarten through 5th grade), and recess periods were sometimes shared among multiple classes and grades. Teachers were in control of the length of recess, and the start and end times of recess often fluctuated. As a solution, researchers can work with school staff to understand the recess schedule, and assign SOPARC observation periods accordingly.

A second limitation of SOPARC was that we did not observe children's physical activity and interaction with green features simultaneously. Because these two behaviors were observed on different scans, the female and male children observed during the scans for physical activity were not necessarily the same children observed during the scans for interaction with green features. In future work, we will test the use of a single scan to measure both physical activity and interaction with green features, to understand the physical activity levels of children while interacting with green features.

Conclusions

We designed the Green Schoolyards Project to determine the relations between green features and heat index at joint-use school parks and the health of children who are vulnerable to nature-deficit disorder, heat-related illness, and physical inactivity. From baseline results, we found extreme heat index conditions at school parks, significant differences in heat index across park sites, and more children interacting with trees during periods of high heat index than periods of moderate heat index. The methods presented herein can be adopted by projects in other cities that are exploring how to redesign urban greenspaces to adjust to high heat conditions and eliminate health inequities in underserved communities. City officials can use findings from implementing these methods to inform the funding of green feature enhancements at parks in areas characterized by urban heat islands and poor health outcomes. In future analyses of the Green Schoolyards Project, we will examine how green features and heat index at school parks affect children's physical activity levels, connection to nature, social-emotional learning skills, standardized test scores, and disciplinary behavior. If we find green features to decrease heat index within parks; increase children's physical activity levels; and/or exhibit positive associations with children's social and emotional well-being; then we can recommend future installments of green features in school parks—especially those located in under-resourced areas—for child health in a warming world.

Abbreviations

GIS: Geographic Information System

GPS: Global Positioning System

HOBO: Not an abbreviation/accronym

SOPARC: System for Observing Play and Recreation in Communities

US: United States

Declarations

Ethics Approval and Consent to Participate:

Prior to undertaking any project activities, we received approval of project protocols by the institutional review board at The University of Texas Health Science Center at Houston (HSC-SPH-19-0502) and the school district. We received informed consent from participants' parents and written assent from study participants.

Consent for Publication:

Not applicable

Availability of Data and Materials:

The datasets used and analyzed during the current study are available from the corresponding author on reasonable request.

Competing Interests:

The authors declare that they have no competing interests.

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Authors' Contributions:

KL contributed to conceptualization, methodology, formal analysis, investigation, writing of the original manuscript draft, development of visual materials, project administration, and funding acquisition. MA contributed to conceptualization, investigation, reviewing and editing of the manuscript draft, project administration, and funding acquisition. DH and HK both contributed to conceptualization, reviewing and editing of the manuscript draft, and supervision. All authors read and approved the final manuscript.

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Figures

Figure 1

HOBO MX2302A external air temperature/relative humidity sensor data logger on swing set at low-green park.

Figure 2

HOBO sensors and SOPARC target areas at (A–B) intervention, (C–D) low-green, and (E–F) high-green parks.

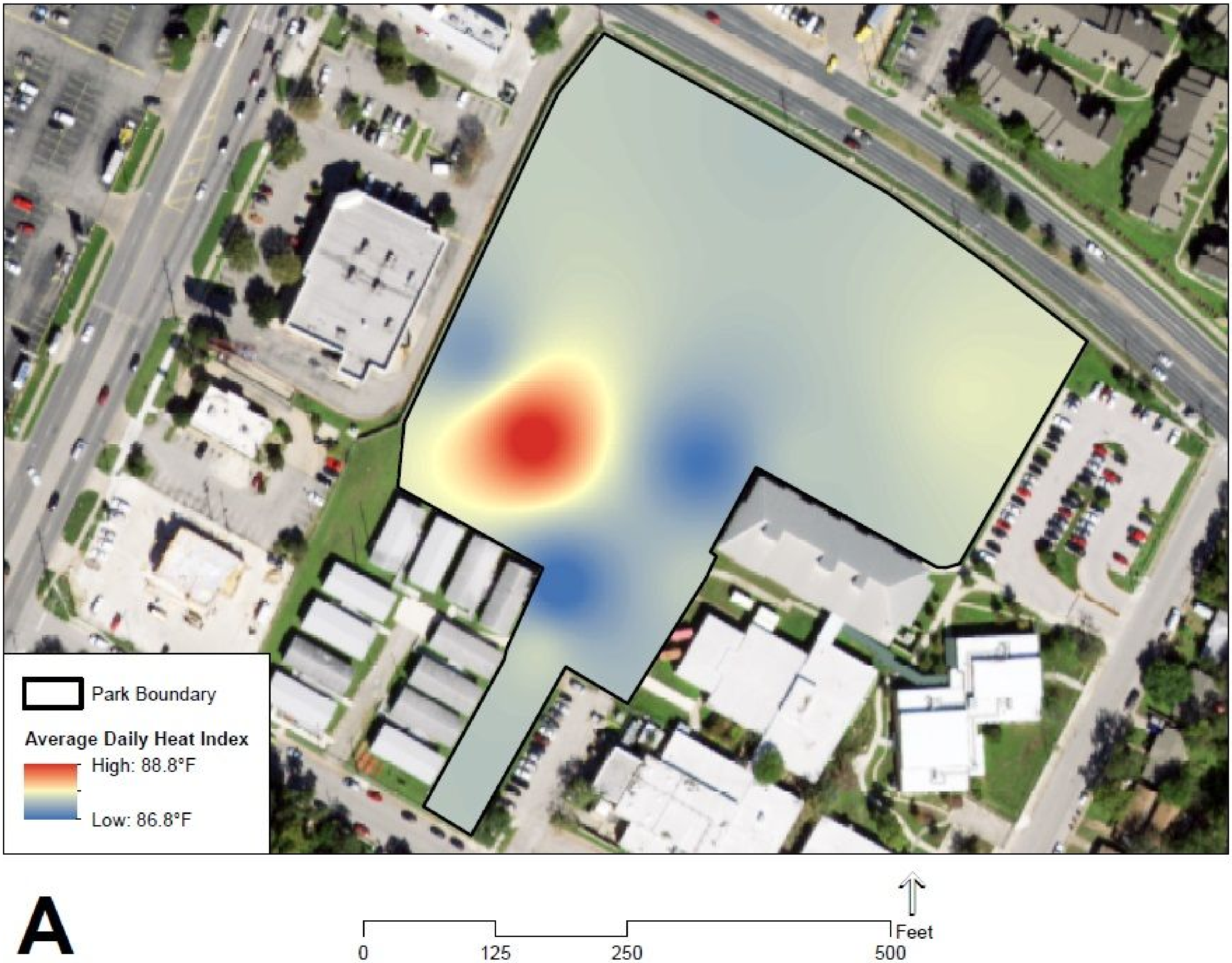

Figure 3

Thermal profiles for (A) intervention, (B) low-green, and (C) high-green parks, September 16–30th 2019.

Supplementary Files

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- AdditionalFile1.pdf
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