HERO: Urban Forestry Summer 2020

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& William Sanders

dcr Massachusetts

GREENING THE GATEWAY CITIES
MA Urban Canopy Project

George Perkins Marsh Institute

HERO

CLARK UNIVERSITY
FIAT LUX
MDCCCLXXXVII

Meet the Research Team

Undergraduate Research Cohort:

Valeria Chavez, Alvaro Esparza, Anna Massinger, Galen Oettel & William Sanders

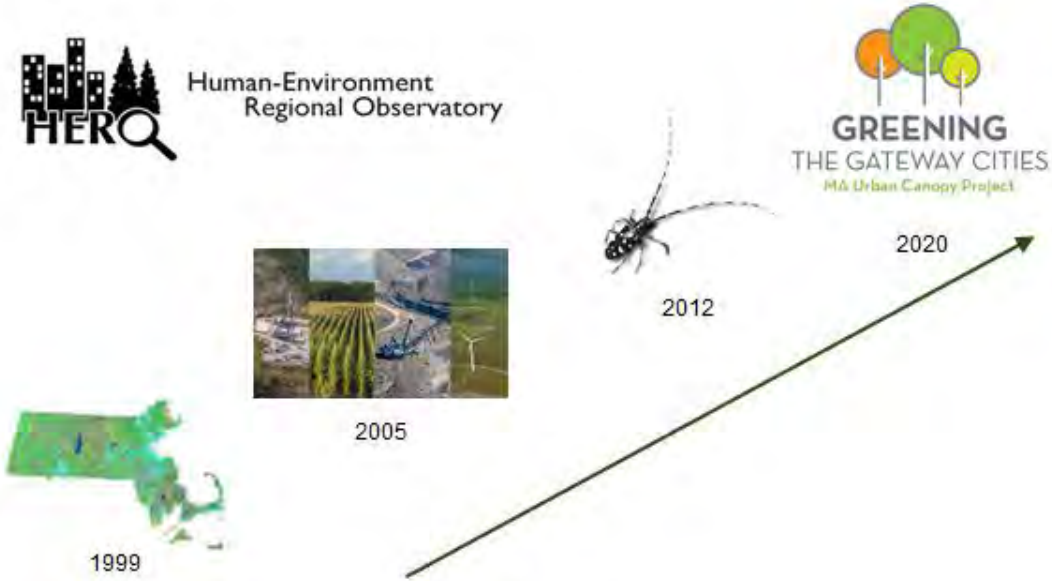
Graduate Mentors:

Marc Healy & Nicholas Geron

Directors:

John Rogan & Deborah Martin

Human-Environment Regional Observatory (HERO)



Summer 2020

- Urban Forestry in the Hadwen Arboretum
- HOBO Sensor Analysis in Gateway Cities

Urban Forestry in the Hadwen Arboretum

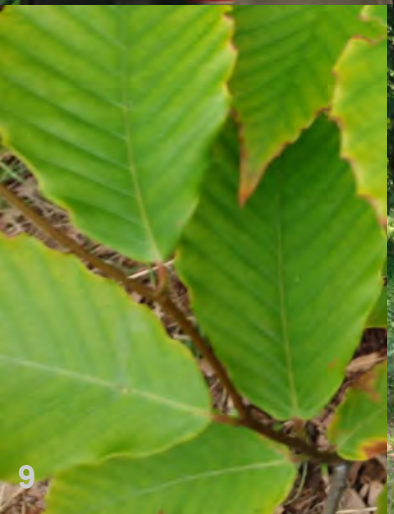
May 28th: removing Japanese knotweed

June 2nd:
Clearing and mulching the Magnolia Trail

June 12th - 16th:
Preparing for tree planting

June 17th:
Tree planting at the Arboretum with Worcester Tree Initiative [at Tower Hill Botanical Garden]

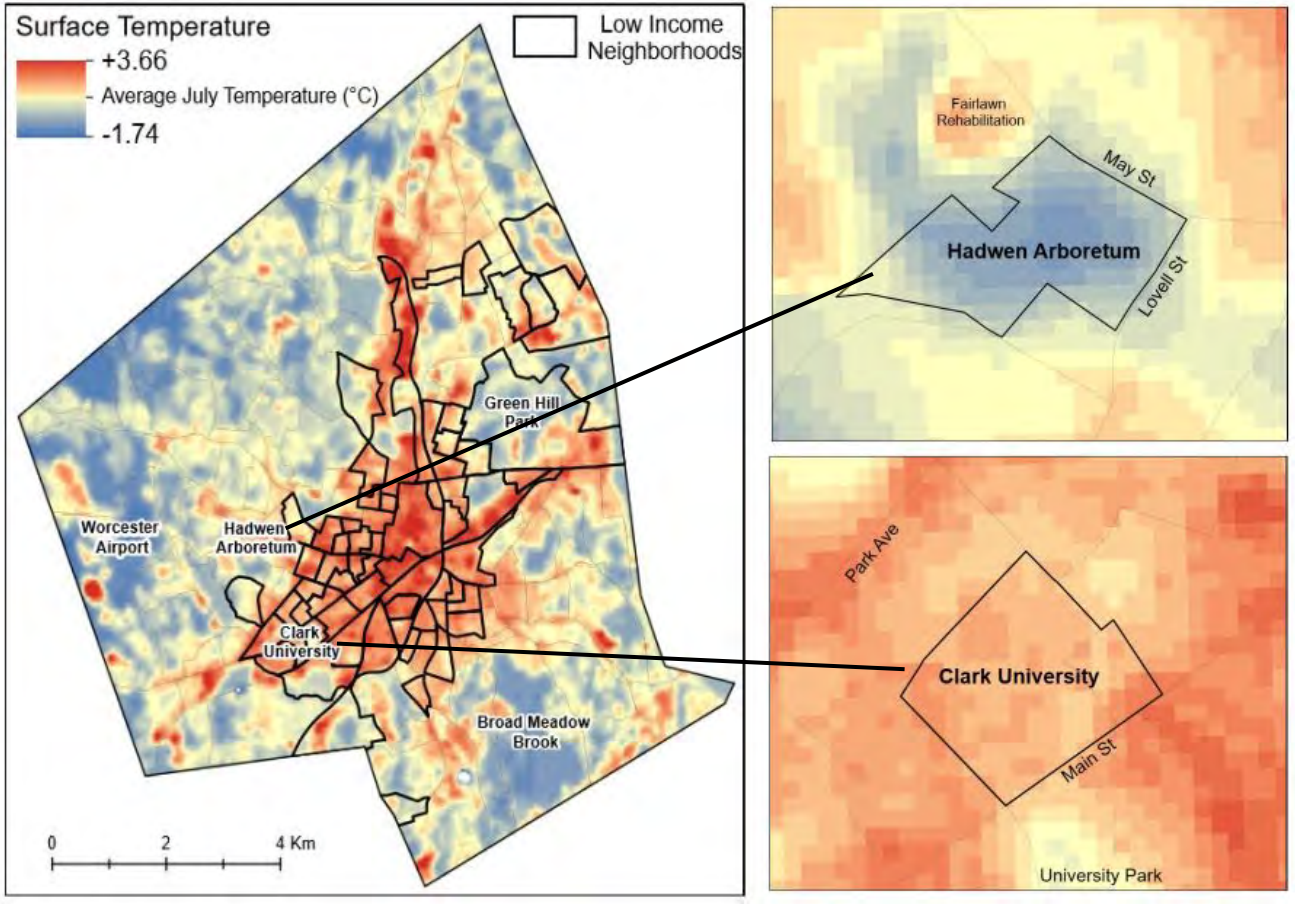
June 26th - July 2nd:
Watering and measuring newly planted trees



Life-History Information of Planted Trees

Count	Vigor	Species	Tree ID #
5	1	Serviceberry	1006, 1009, 1010, 1012, 1014
2	1	Dogwood	1002, 1005
2	1	Eastern redbud	1004, 1007
1	2	American beech	1001
1	1	American sweetgum	1008
1	1	Blue spruce	**1000**
1	2	American Hornbeam	1013
1	1	Honey locust	1003
1	1	Kentucky coffeetree	1011

Land-Surface Temperature Differences



Arboretum Takeaways

- Community benefits
  - Accessibility: restoring worn down trails and overgrown vistas
  - Potential cooling of surrounding areas
- Challenges
  - Choosing planting locations (right tree, right place)
  - Tree care during heat waves
  - Persistence of invasive species
- Plan for the future
  - Community tours
  - Interactive events to foster local involvement
  - Continued maintenance

Photo courtesy of Cynthia Sellers, HERO Fellow ‘19

HOBO Temperature Sensor Analysis

(**H**onest **O**bserver **B**y **O**nset)

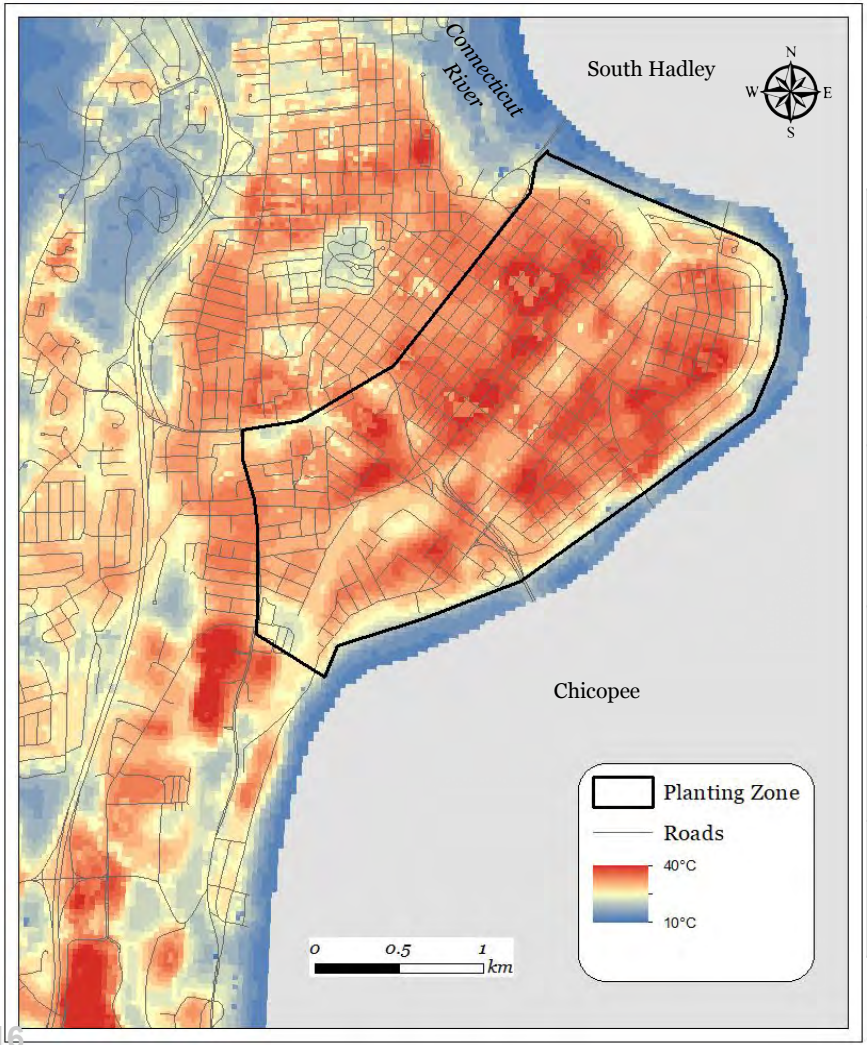
Study Area


Holyoke
Chelsea
Fall River
Greening the Gateway Cities
Study Area Cities
0
25
50
km
N
W
E
S

Demographic Information

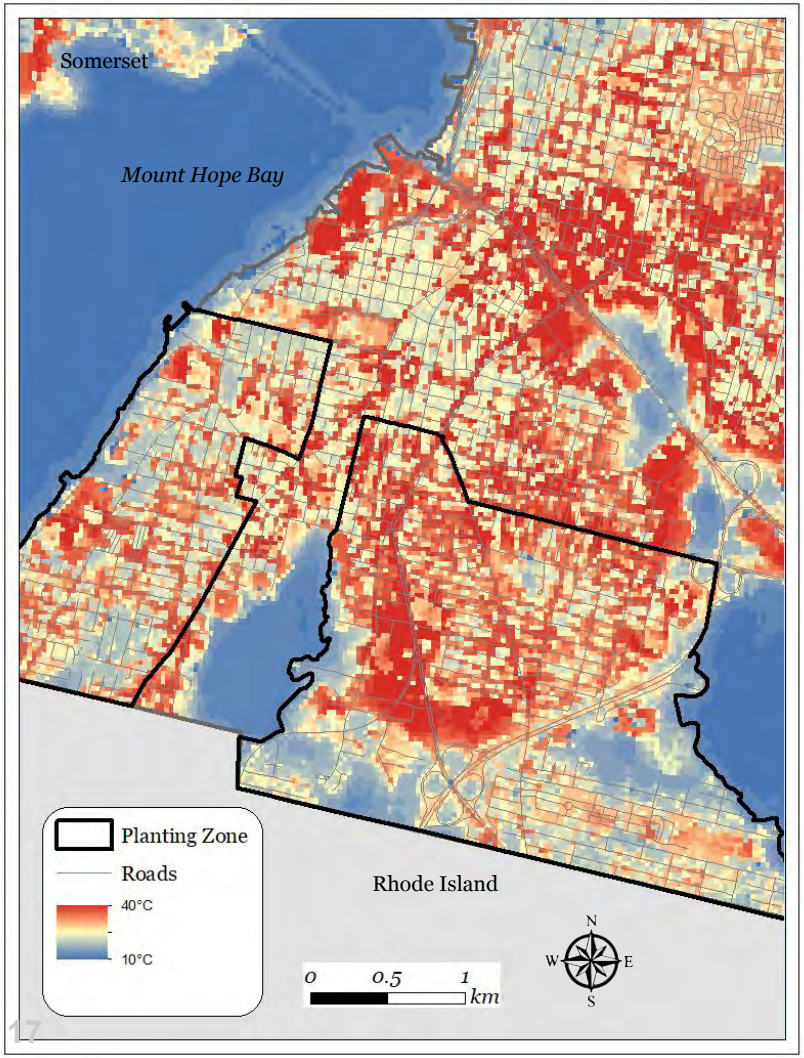
	Holyoke	Fall River	Chelsea	Massachusetts
Population	40,117	89,541	39,852	6,892,503
Median Household Income	$37,372	$41,585	$53,280	$79,054
Families Below Poverty Line (%)	29.7%	19.4%	18.8%	10.4%
Population Demographic Distribution	White - 41.9% Hispanic/Latinx - 52.1% Black/African American - 4.5% Asian - 1.3%	White - 76.9% Hispanic/Latinx - 10.4% Black/African American - 5.7% Asian - 2.3%	White - 21.9% Hispanic/Latinx - 66.9% Black/African American - 6.9% Asian - 3.2%	White - 71.4% Hispanic/Latinx - 12.3% Black/African American - 8.9% Asian - 7.1% Indigenous - 0.5%
Educational Attainment of those age 25 years+ - B.A. or Higher	23.4%	15.1%	17.5%	42.9%
Foreign-Born Persons (%)	5.8%	20.8%	45.5%	16.5%

2018 American Community Survey 5-Year Estimates



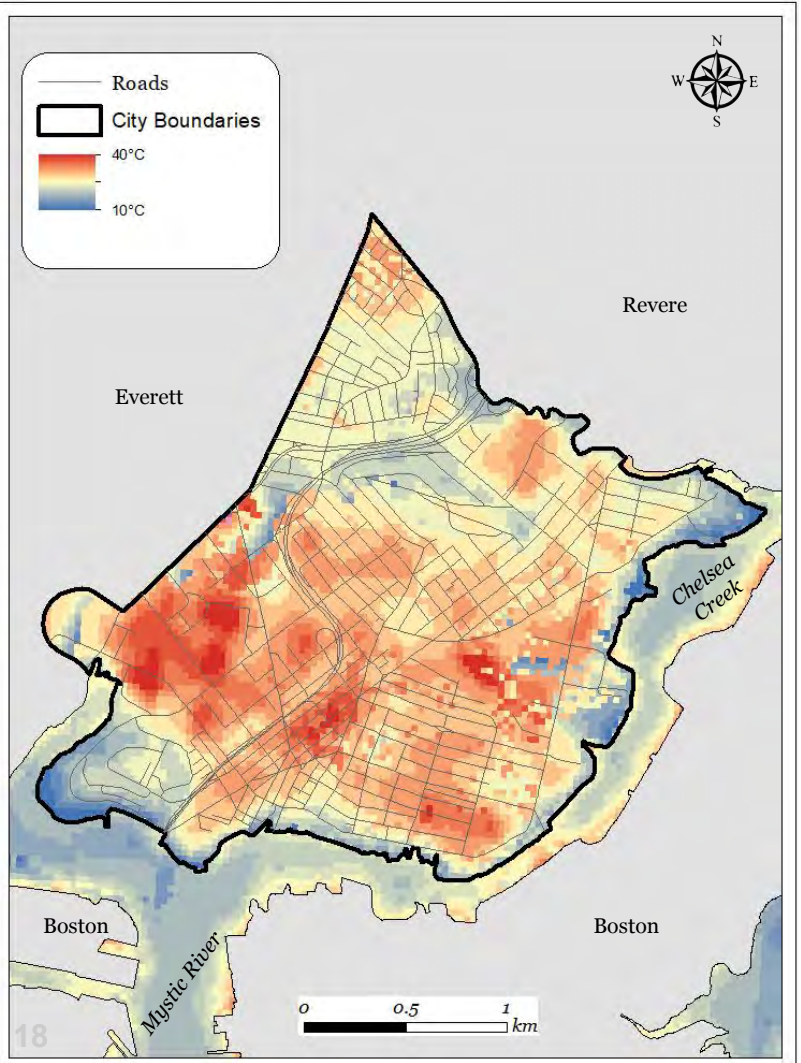
Holyoke

Total Population	40,117
Total Area	55.17 Sq km
% of Impervious Cover	62%
% of Green Cover (Tree canopy & grass)	38%
Number of DCR trees planted	1,819



Fall River

Total Population	89,541
Total Area	104.38 Sq km
% of Impervious Cover	44.7%
% of Green Cover (Tree canopy & grass)	55.3%
Number of DCR trees planted	2706



Chelsea

Total Population	39,852
Total Area	6.47 Sq km
% of Impervious Cover	75%
% Green Cover (Tree canopy & grass)	25%
Number of DCR trees planted	2159

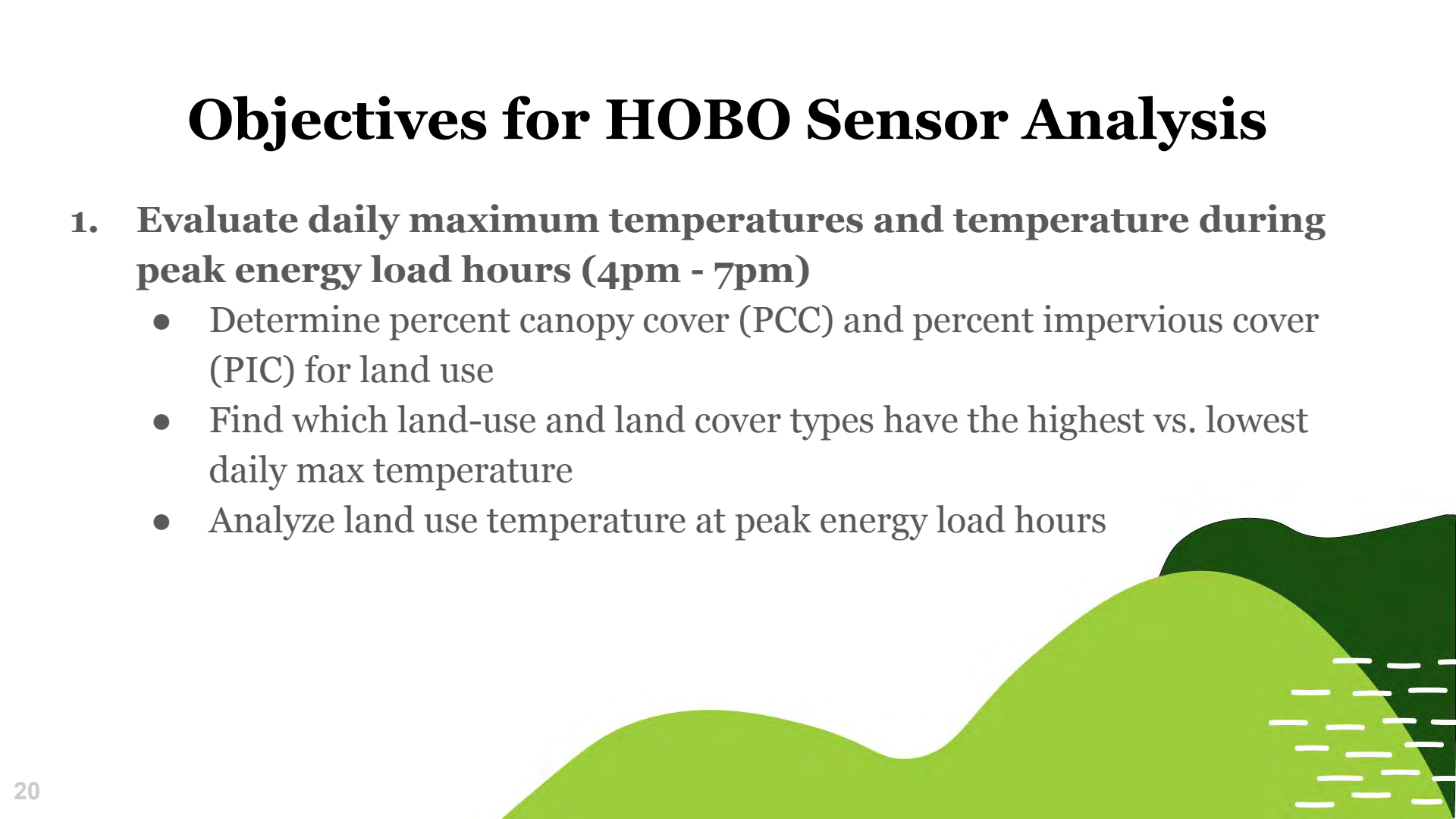
Research Questions for HOBO Sensor Analysis

1. What are the daily maximum temperatures and temperatures during peak energy load hours (4pm - 7pm) in Gateway Cities?

2. How do the trees planted by the Greening the Gateway Cities Program impact temperatures during peak energy load hours?

Objectives for HOBO Sensor Analysis

1. **Evaluate daily maximum temperatures and temperature during peak energy load hours (4pm - 7pm)**
    - Determine percent canopy cover (PCC) and percent impervious cover (PIC) for land use
    - Find which land-use and land cover types have the highest vs. lowest daily max temperature
    - Analyze land use temperature at peak energy load hours

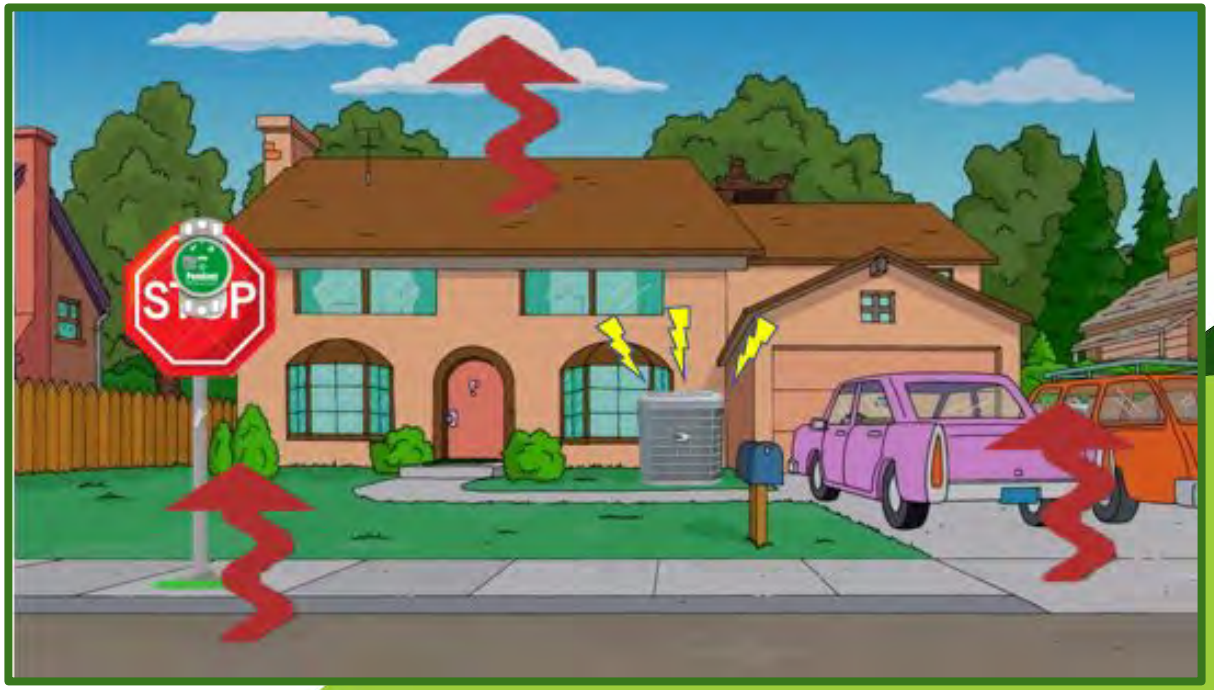


Objectives for HOBO Sensor Analysis

2. **Determine the effect of trees planted by DCR on residential temperature**
    - Model effects of PCC, PIC, number of trees planted on temperature, and distance to water
    - Compare temperatures at peak energy load hours
    - Compare residential temperatures at peak energy load hours between 2016 and 2019

Hypotheses

HOBO sensors in areas with more trees planted will record lower max temperatures and more rapid cooling during peak energy hours than sensors in areas with lower canopy cover.



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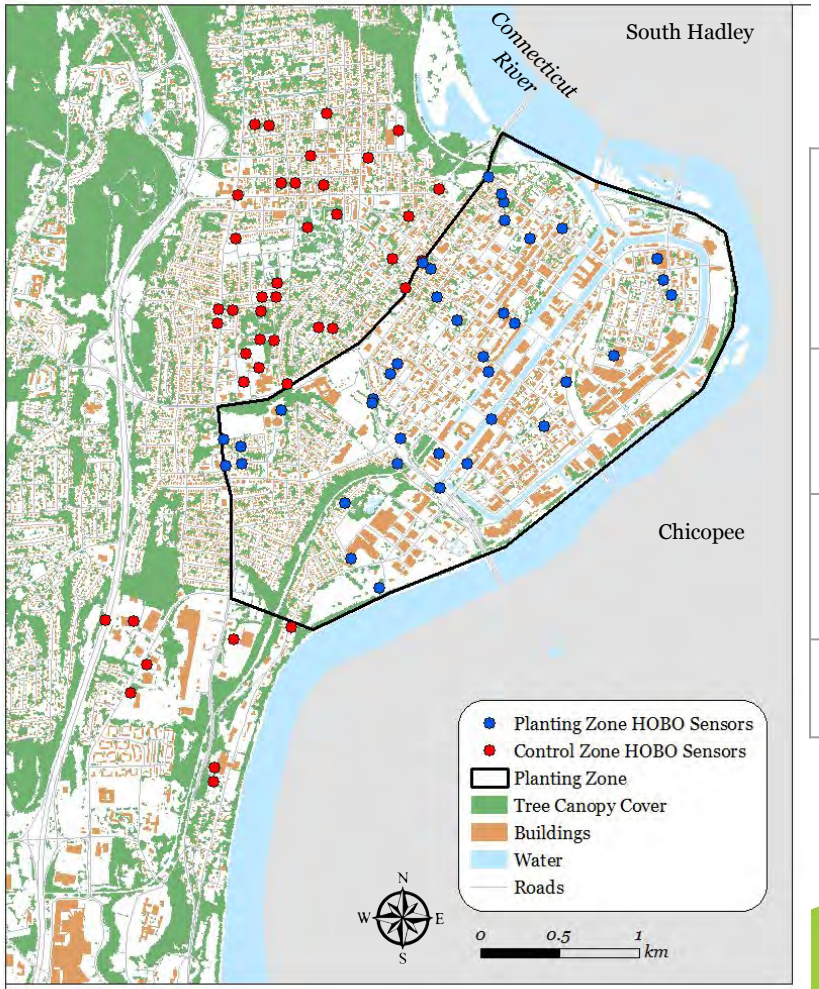
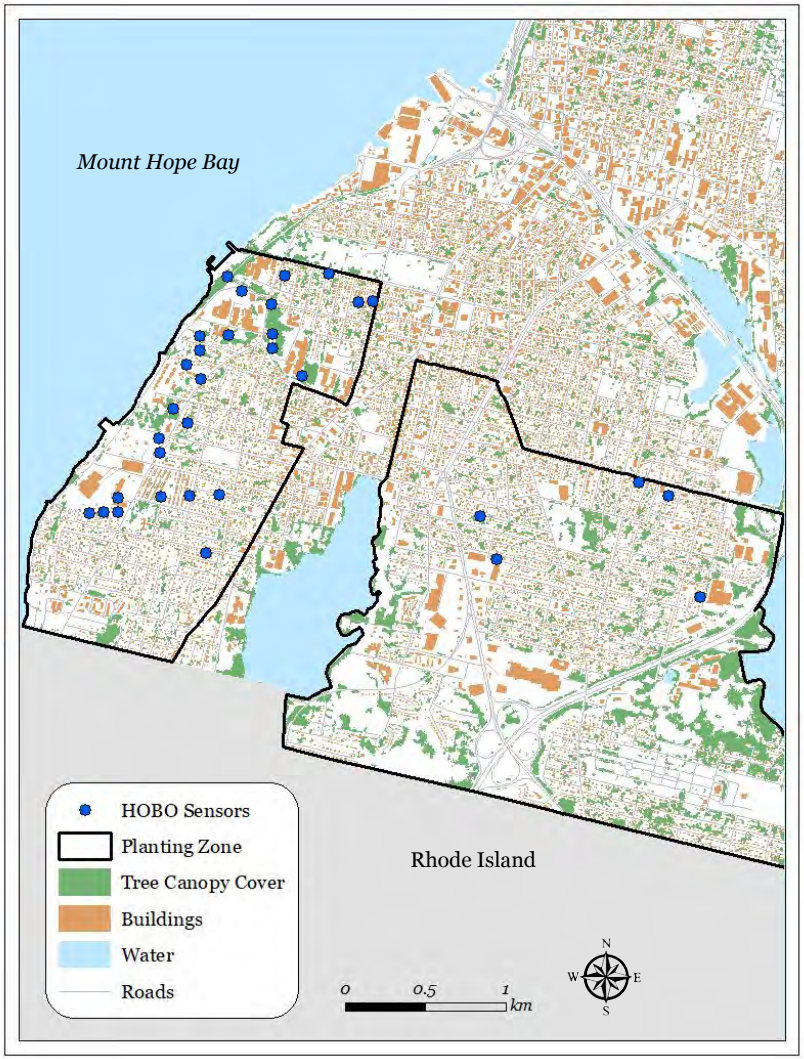


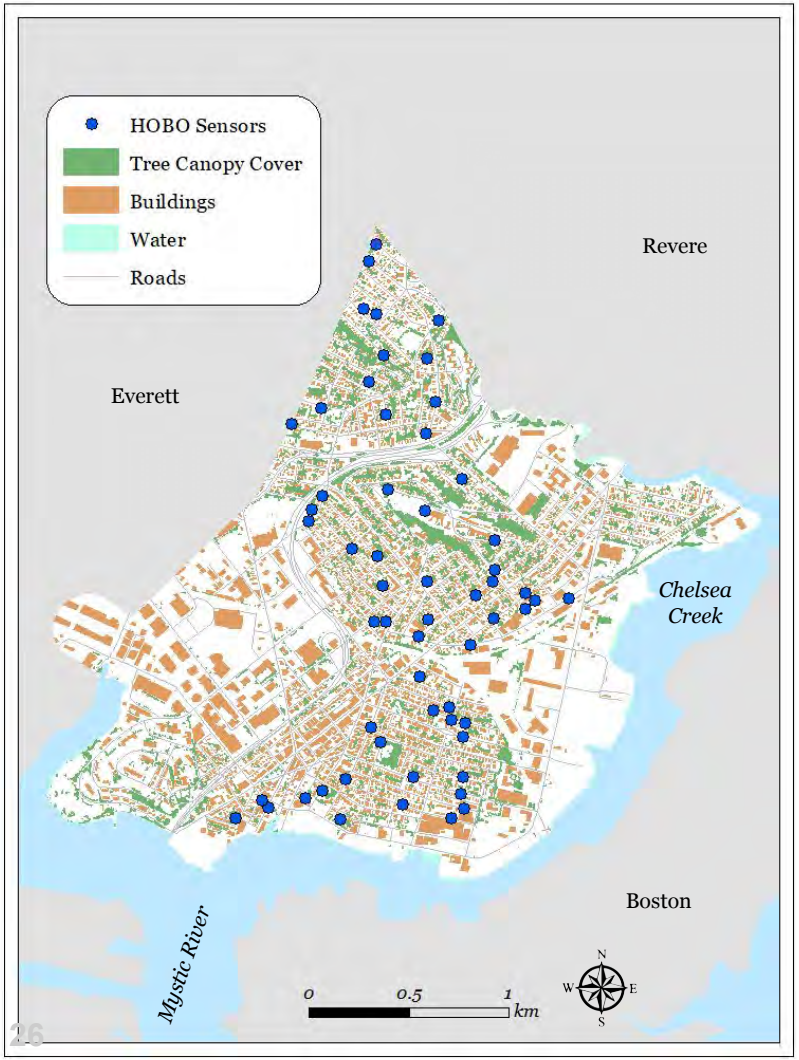
Holyoke HOBO Sensor Data

Sensor Type	Total	Used in Analysis	Active Through 2016 - 2019	Active in 2017	Active Only First & Last Year (2016 & 2019)
Planting Zone	45	38	27	37	26
Control Zone	82	37	0	33	5
Total	127	75	27	70	29



Fall River
HOBO Sensor Data

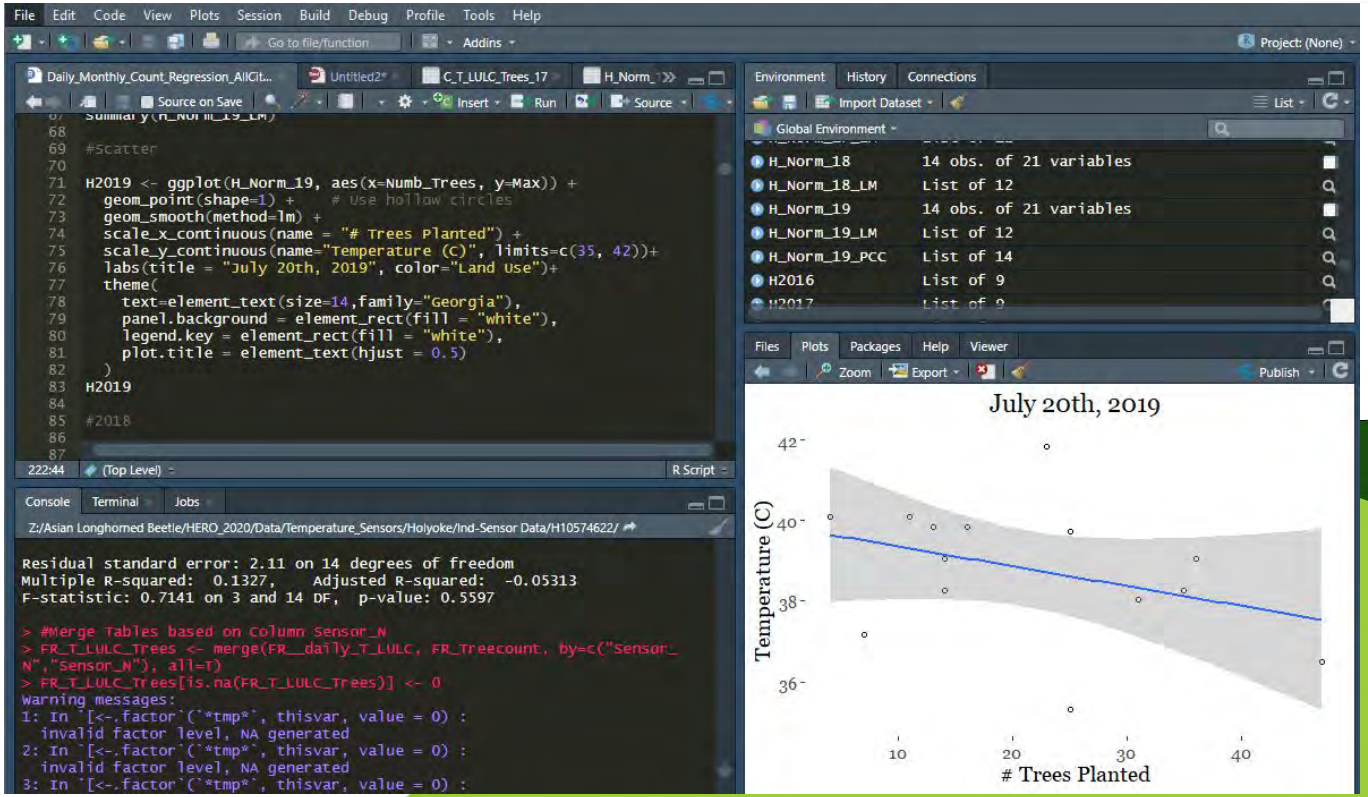
Sensor Type	Total	Used in Analysis	Active Through 2016 - 2019	Active in 2017	Active Through 2016 - 2018
Planting Zone	72	32	1	31	11



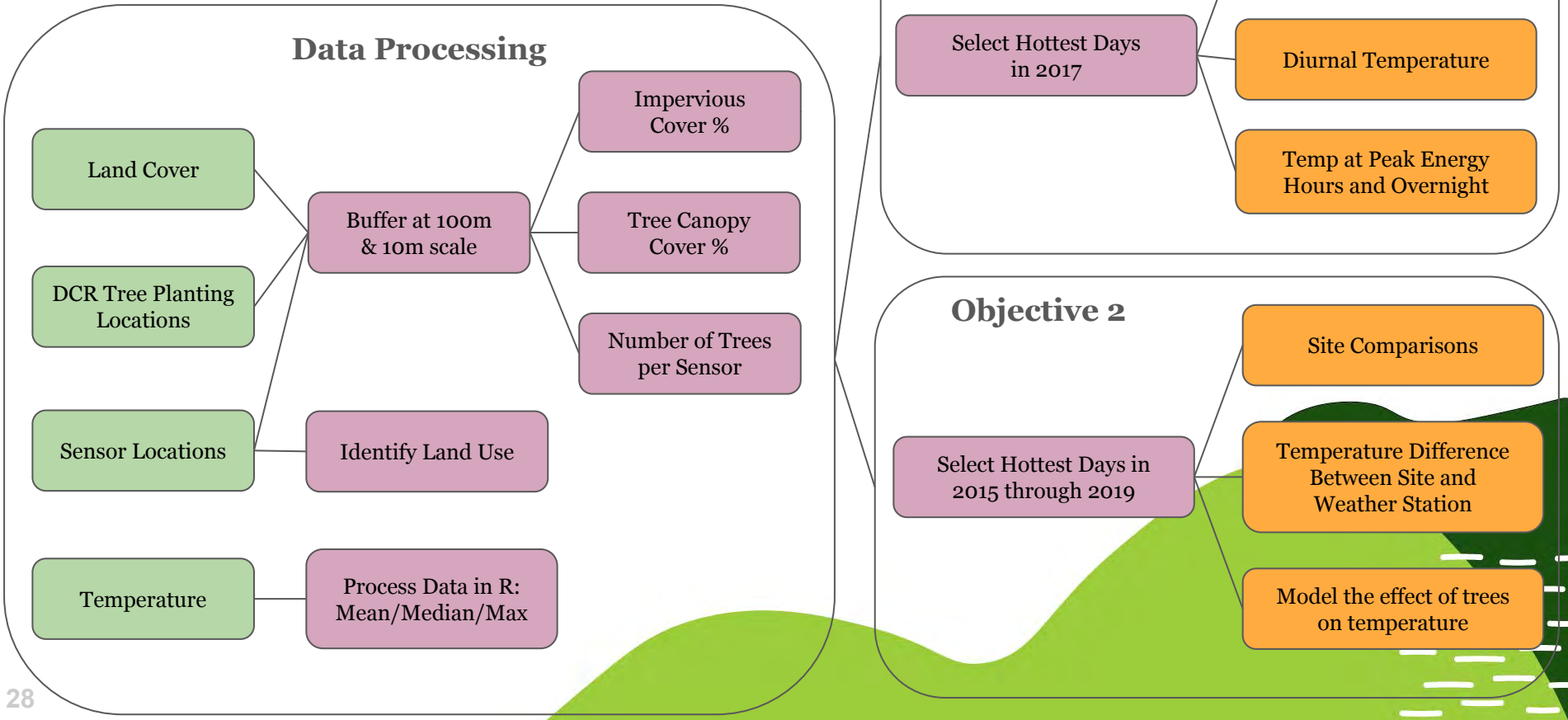
Chelsea HOBO Sensor Data

Sensor Type	Total	Used in Analysis	Active Through 2016 - 2019	Active in 2017	Active Only First & Last Year (2015 & 2019)
Planting Zone	63	54	22	42	33

Approach: Methods of Analysis



Approach


Data Processing
Land Cover
DCR Tree Planting Locations
Sensor Locations
Temperature
Buffer at 100m & 10m scale
Identify Land Use
Process Data in R: Mean/Median/Max
Impervious Cover %
Tree Canopy Cover %
Number of Trees per Sensor
Objective 1
Select Hottest Days in 2017
Daily Max Temp by Land Use
Diurnal Temperature
Temp at Peak Energy Hours and Overnight
Objective 2
Select Hottest Days in 2015 through 2019
Site Comparisons
Temperature Difference Between Site and Weather Station
Model the effect of trees on temperature

Land Use Classification

Commercial (COMM)

Institutional (INST)

Maintained Park (MP)

Multi-Family Residential (MFR)

Single Family Residential (SFR)

Vacant (V)

We define land use as the characterization of the land based on what is built on it and what can be used there.

Sources: MassGIS & NAIP

Land Cover Classification

Impervious

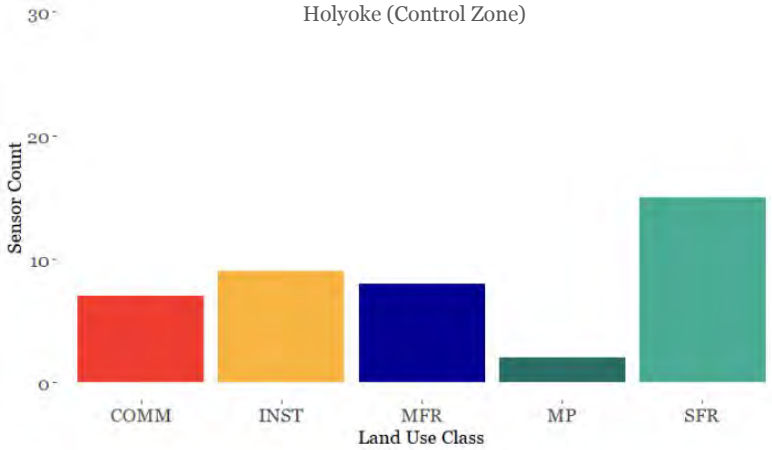
Urban Forest

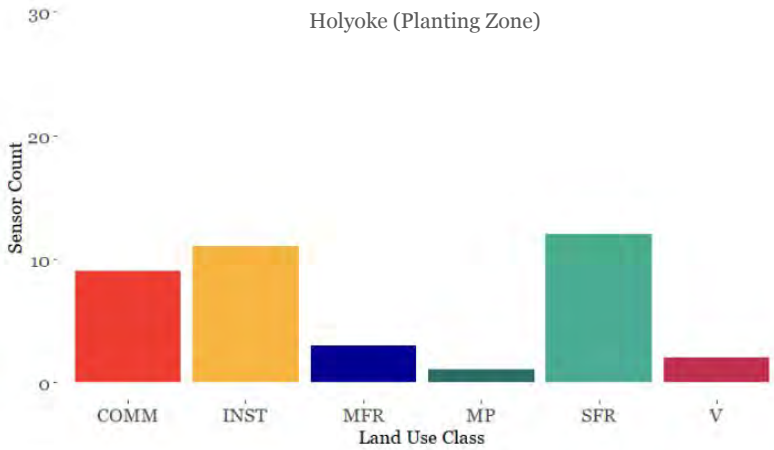
Developed Open Space

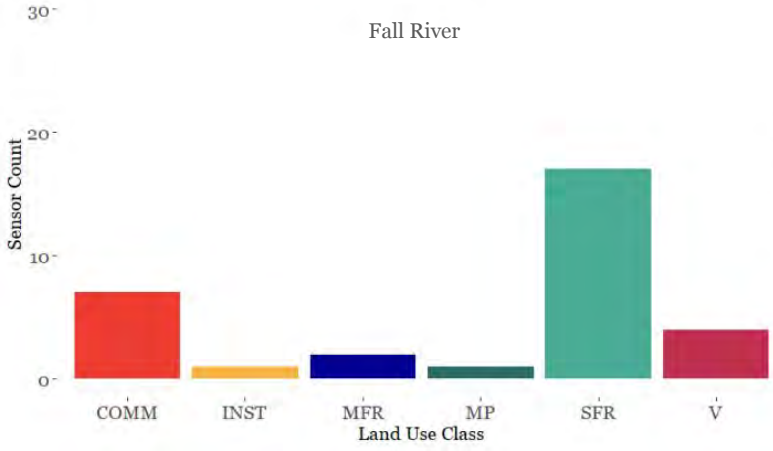
The characterization of the land based on the physical land type.

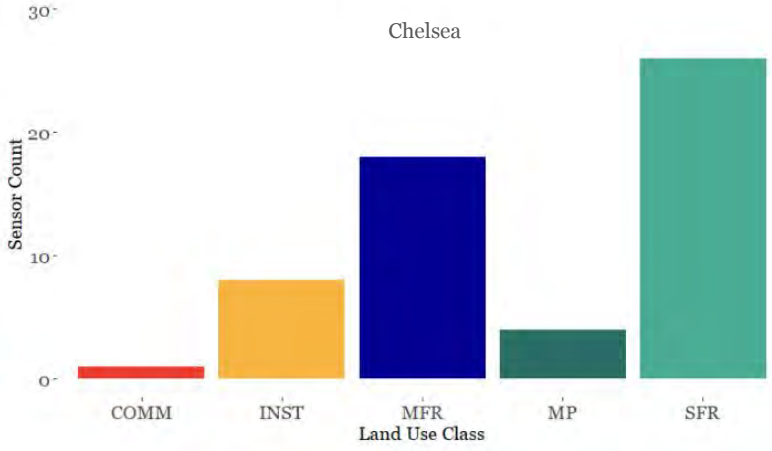
Sources: MassGIS & NAIP

Sensor Distribution by Land Use

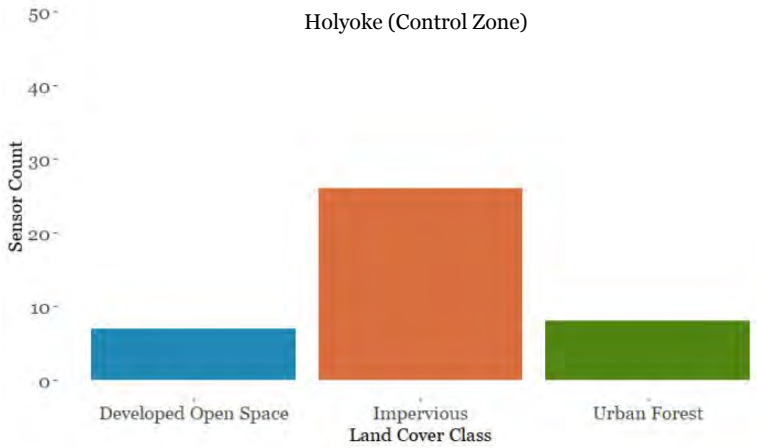


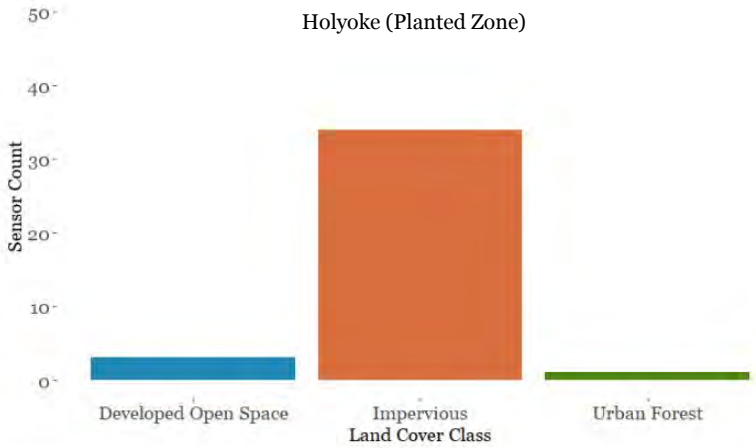


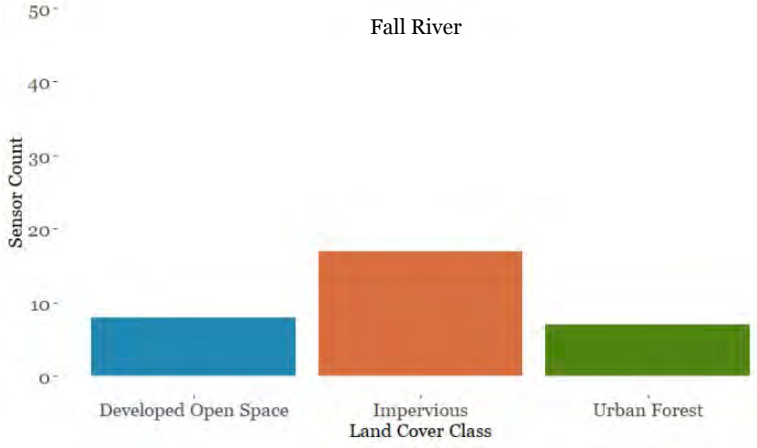


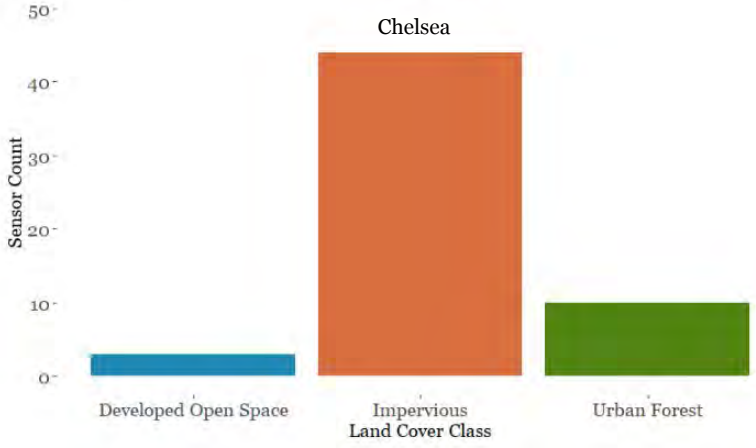


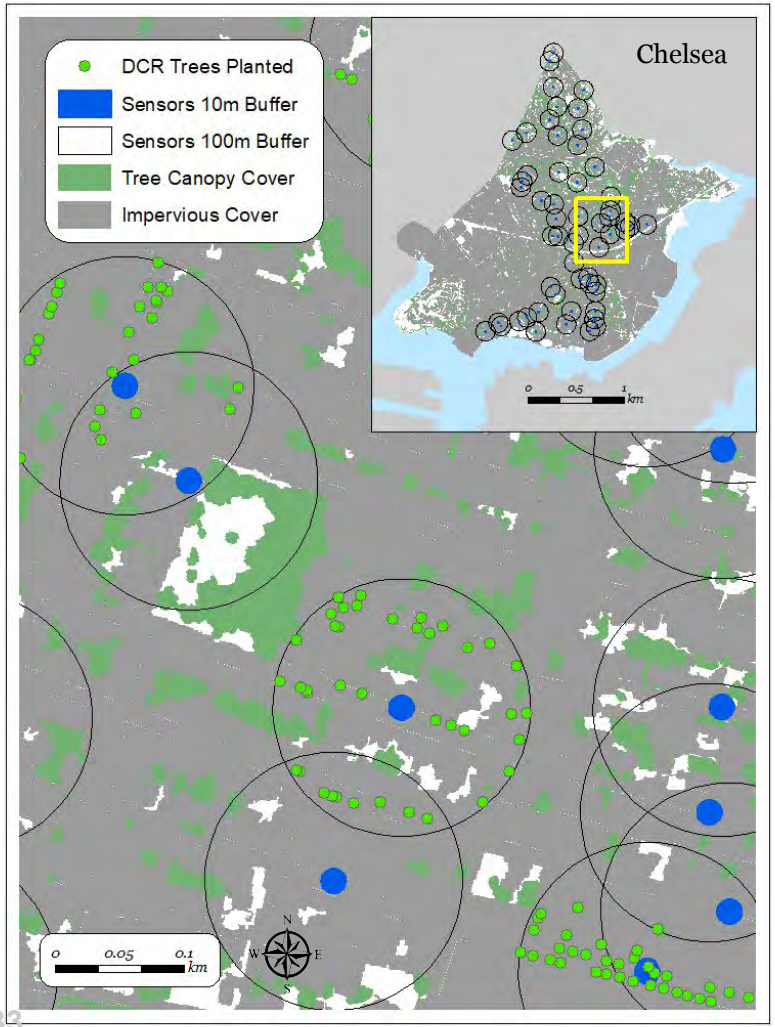
Sensor Distribution by Land Cover











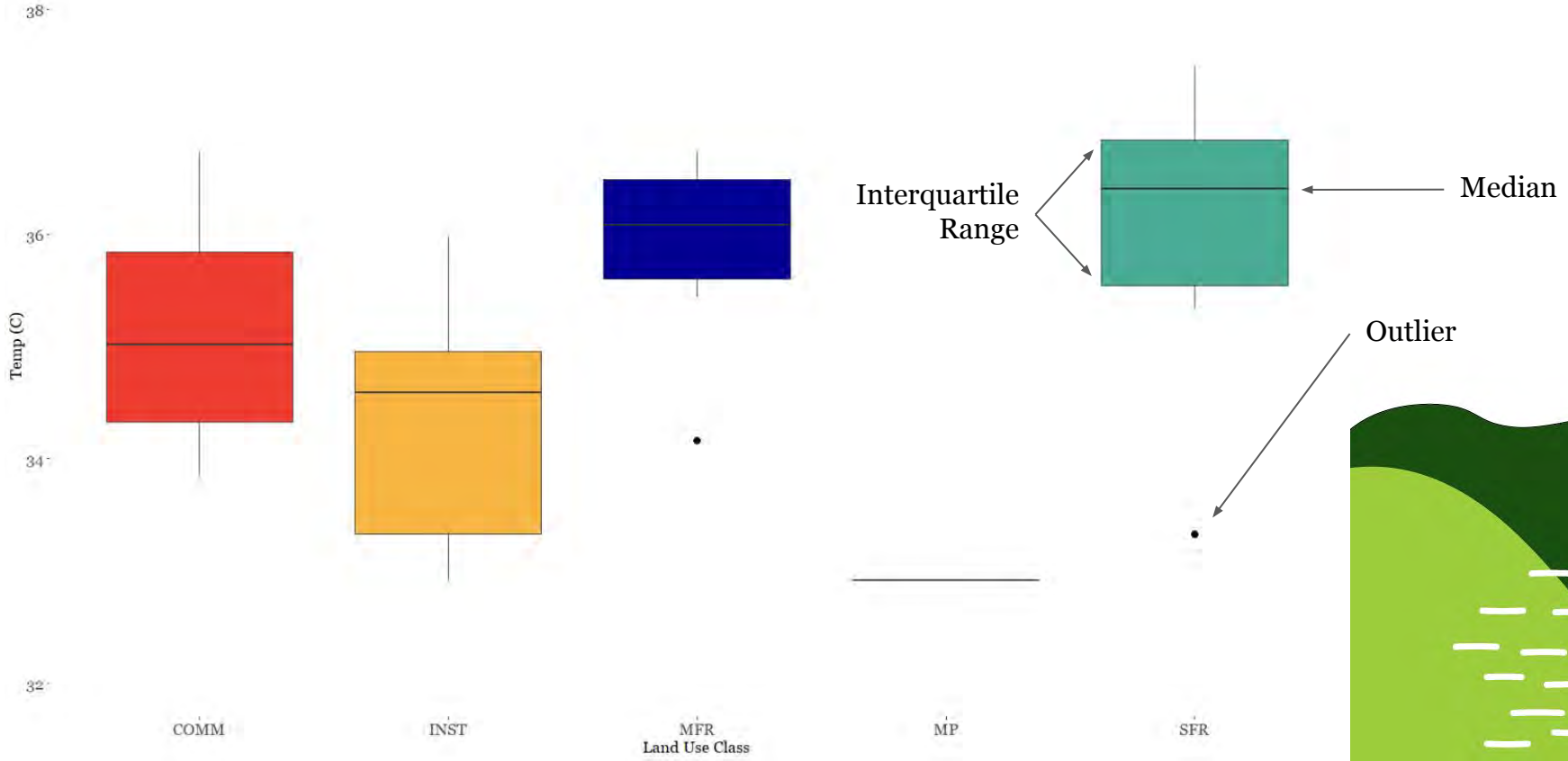
HOBO Sensor Buffers at 10m & 100m

10m radius shows land cover composition at the local scale.

100m radius shows land cover composition and number of DCR trees planted at the neighborhood scale

(Ziter et al., 2019)

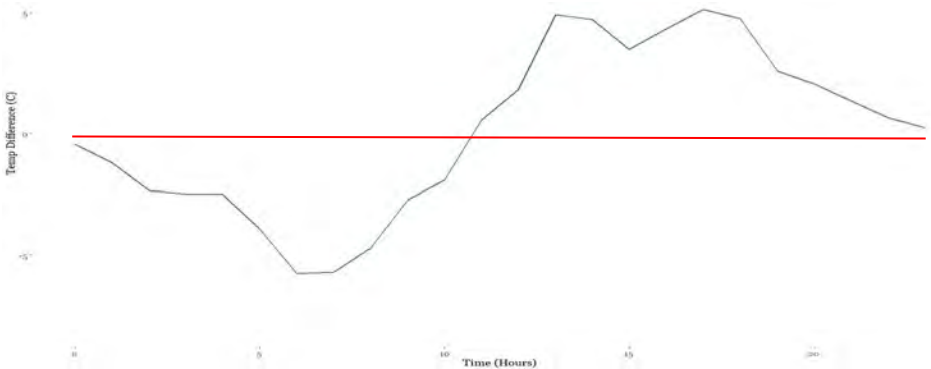
Creating Boxplots



HOBO Sensors and Local Weather Stations

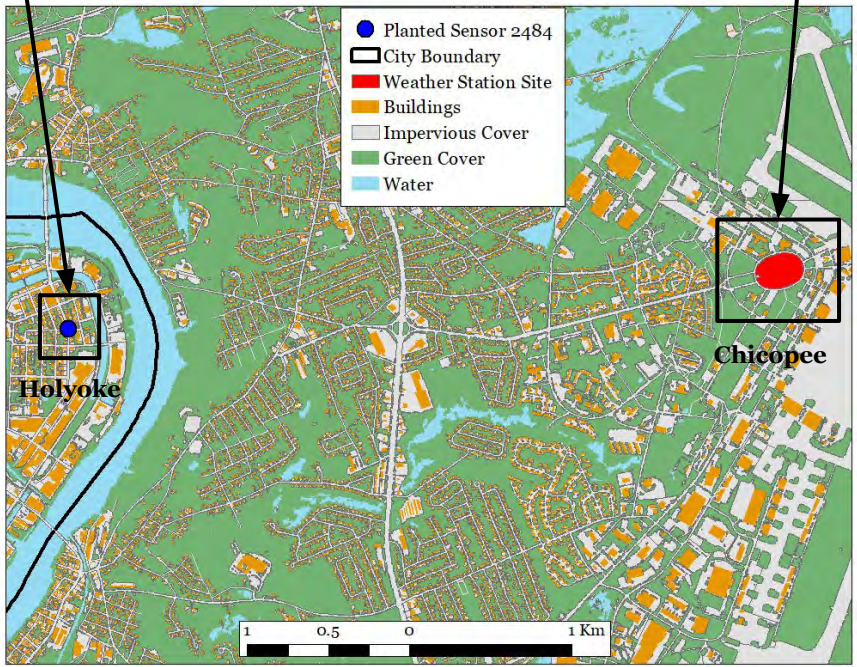
	Average Difference (2016)
Holyoke	0.20 °C
Fall River	-0.10 °C
Chelsea	1.95 °C

Zero-line —— Temperature Difference ——



Westover Air Reserve Base

Planted Sensor



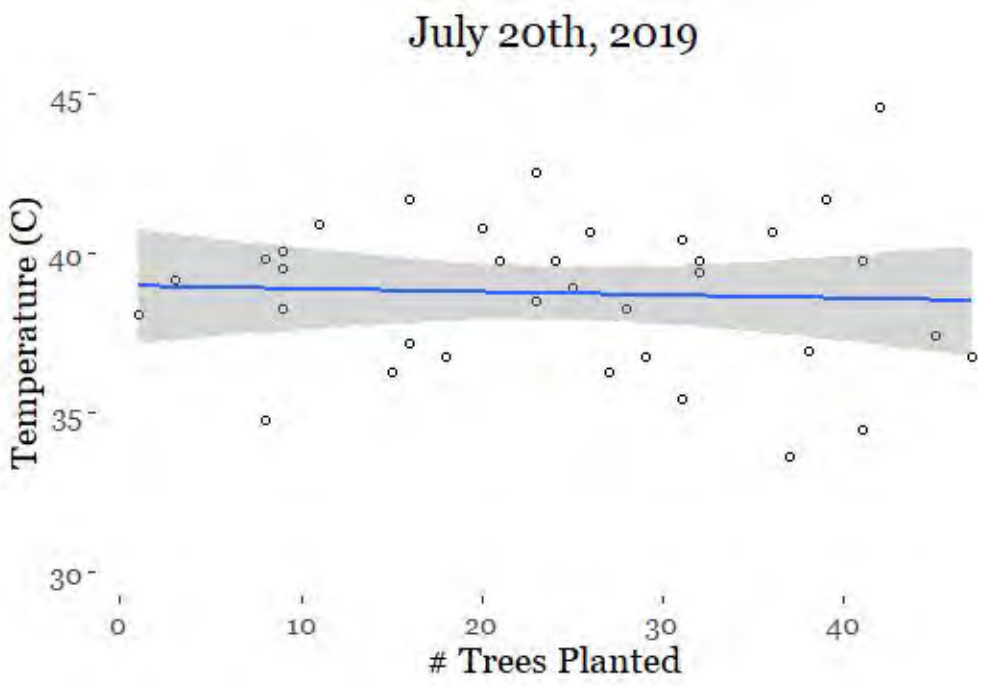
Model Building

Statistical Analysis

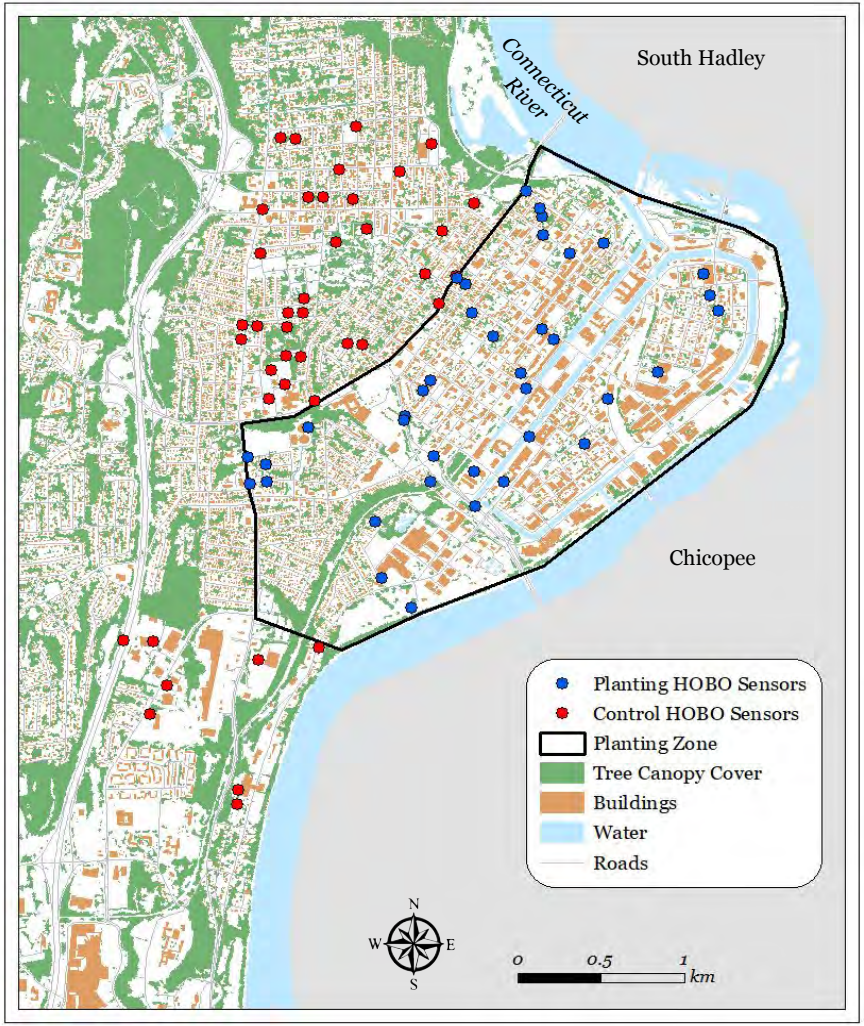
- What is significance?
- What is an R^2 value?

Regressions

- Select for Residential (MFR & SFR)



Independent Variable	Dependent Variable
• Canopy Cover % • Impervious Cover % • # of Trees Planted	• Maximum Temperature



Holyoke

Control & Planting Zones

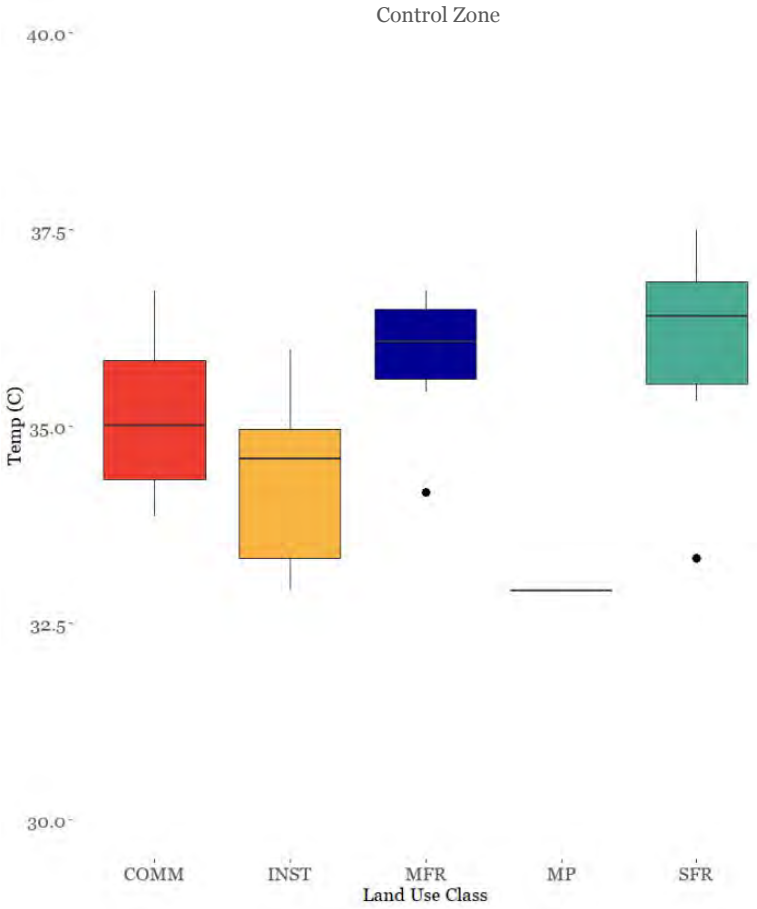
Holyoke

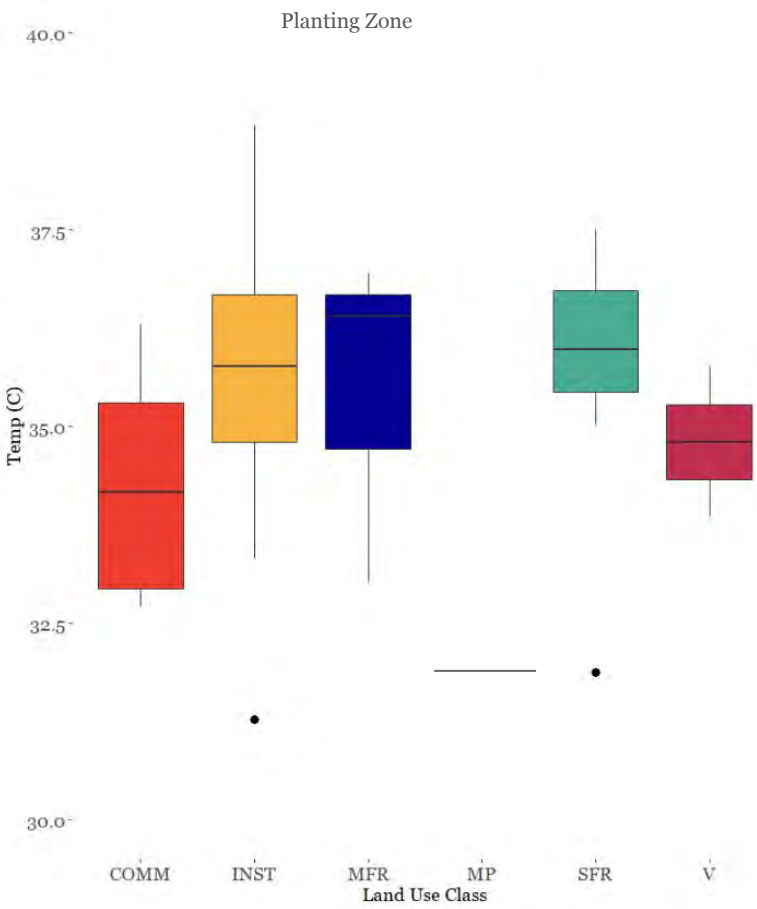
Objective 1:

Evaluate daily maximum temperatures and temperature during peak energy load hours (4pm - 7pm)

Holyoke

Maximum Temperature on August 22nd, 2017

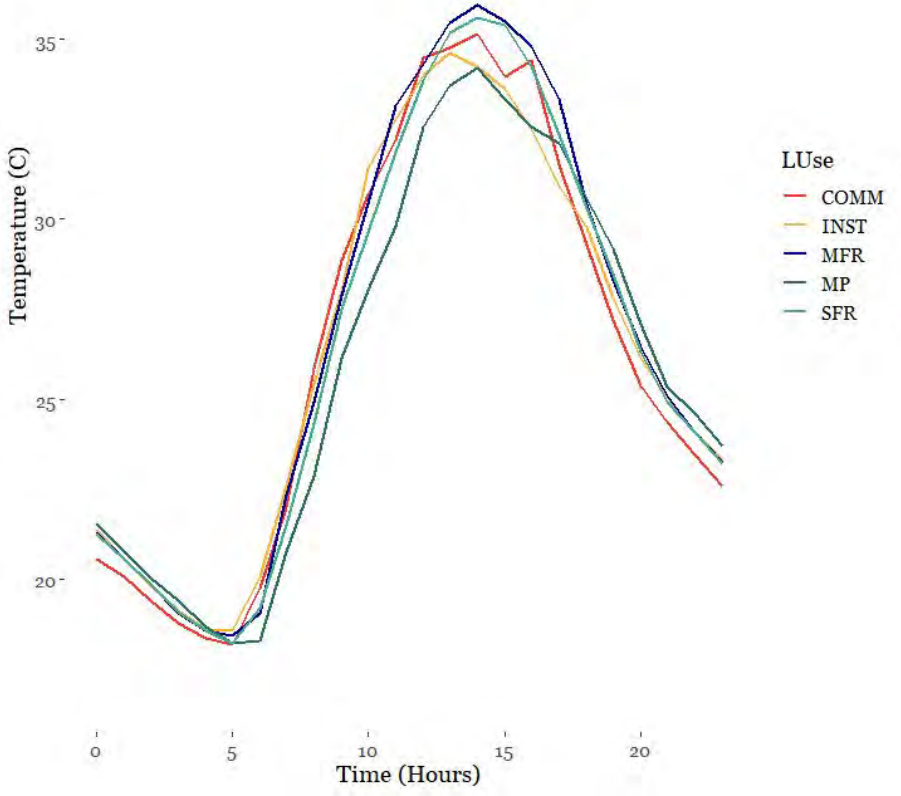




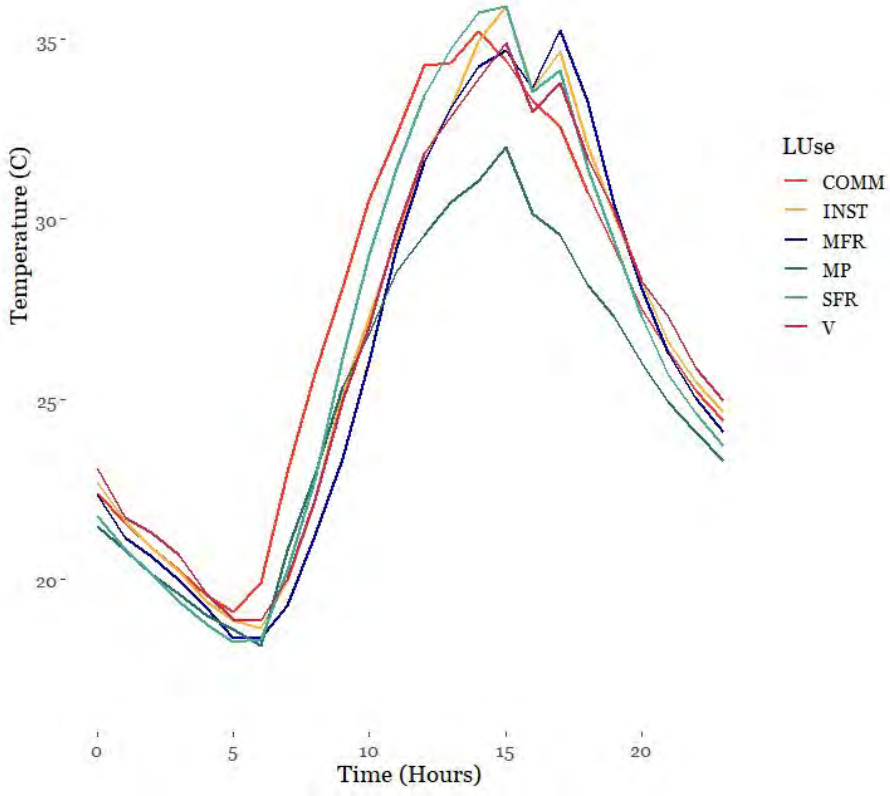
Holyoke

Diurnal Temperature on August 22nd, 2017

Control Zone



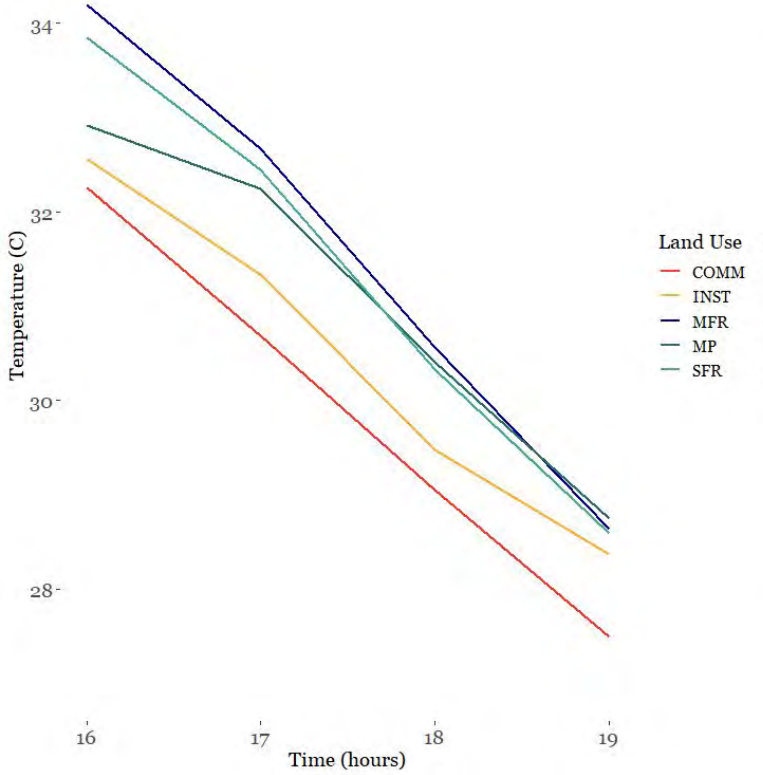
Planting Zone



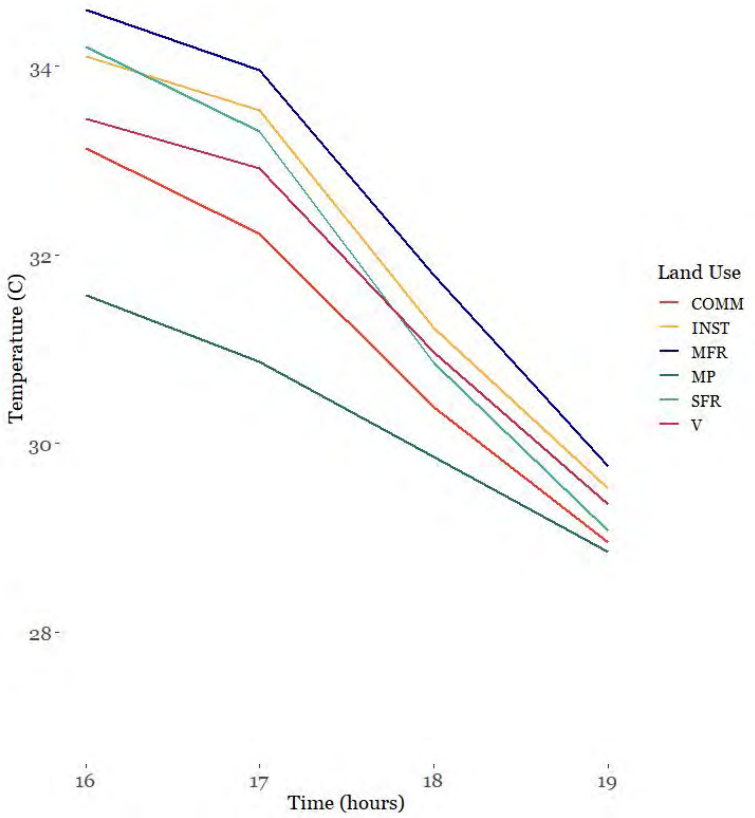
Holyoke

Temperature During Peak Load Hours on August 22nd, 2017

Peak Load Hours (Control Zone)



Peak Load Hours (Planting Zone)



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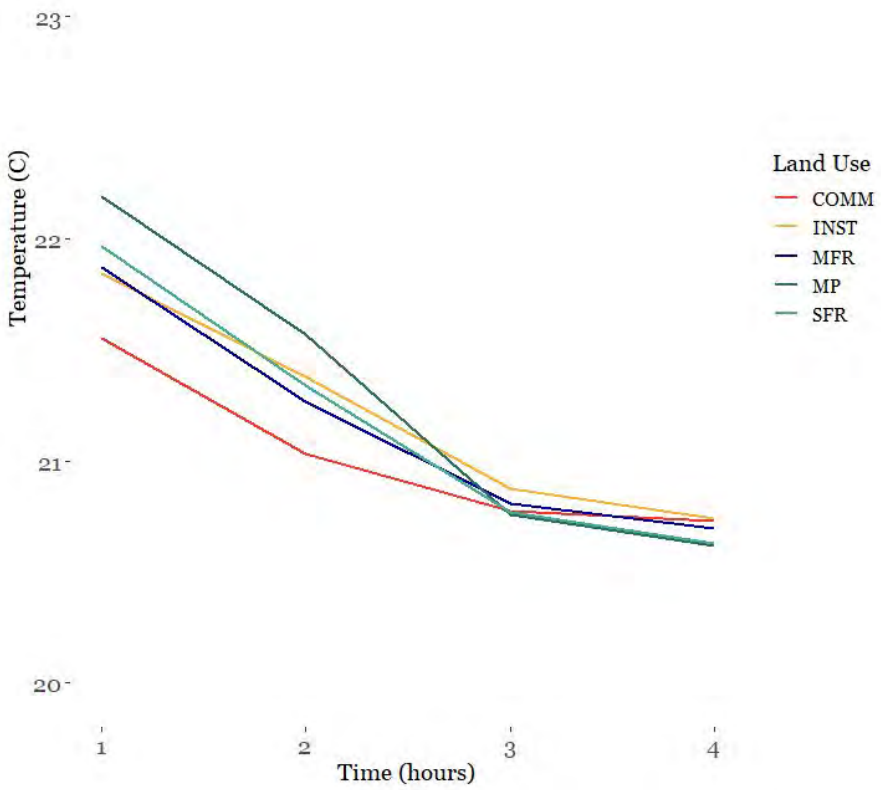
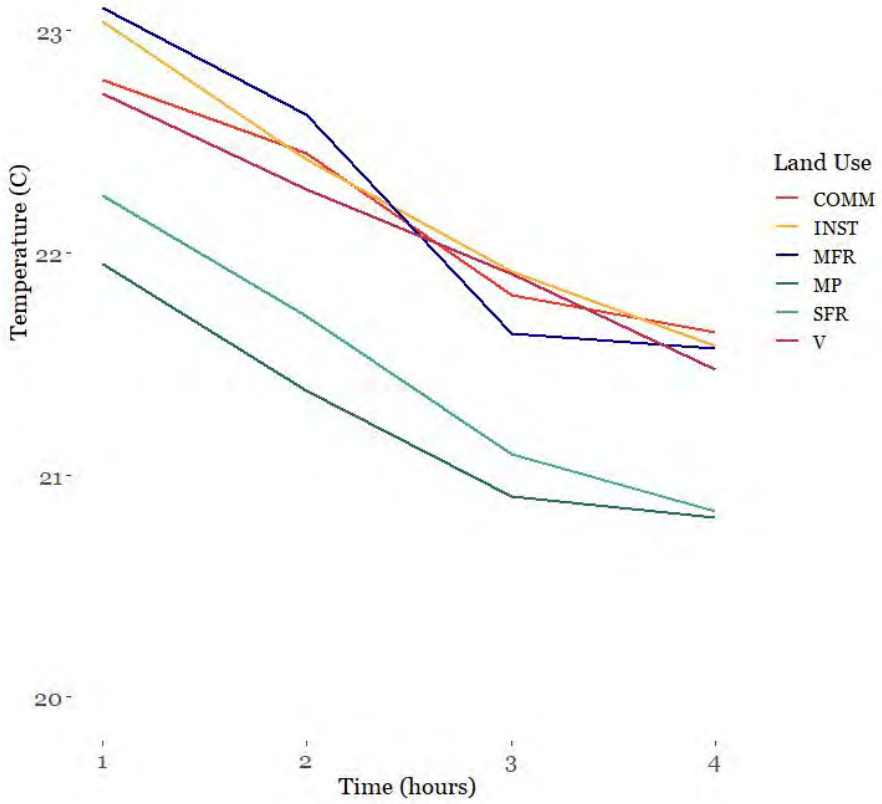
Holyoke

Temperature During Overnight Hours on August 22nd, 2017

Overnight Hours (Control Zone)



Overnight Hours (Planting Zone)



Holyoke

Objective 2:

Determine the effect of trees planted by DCR on temperature in residential areas

Holyoke

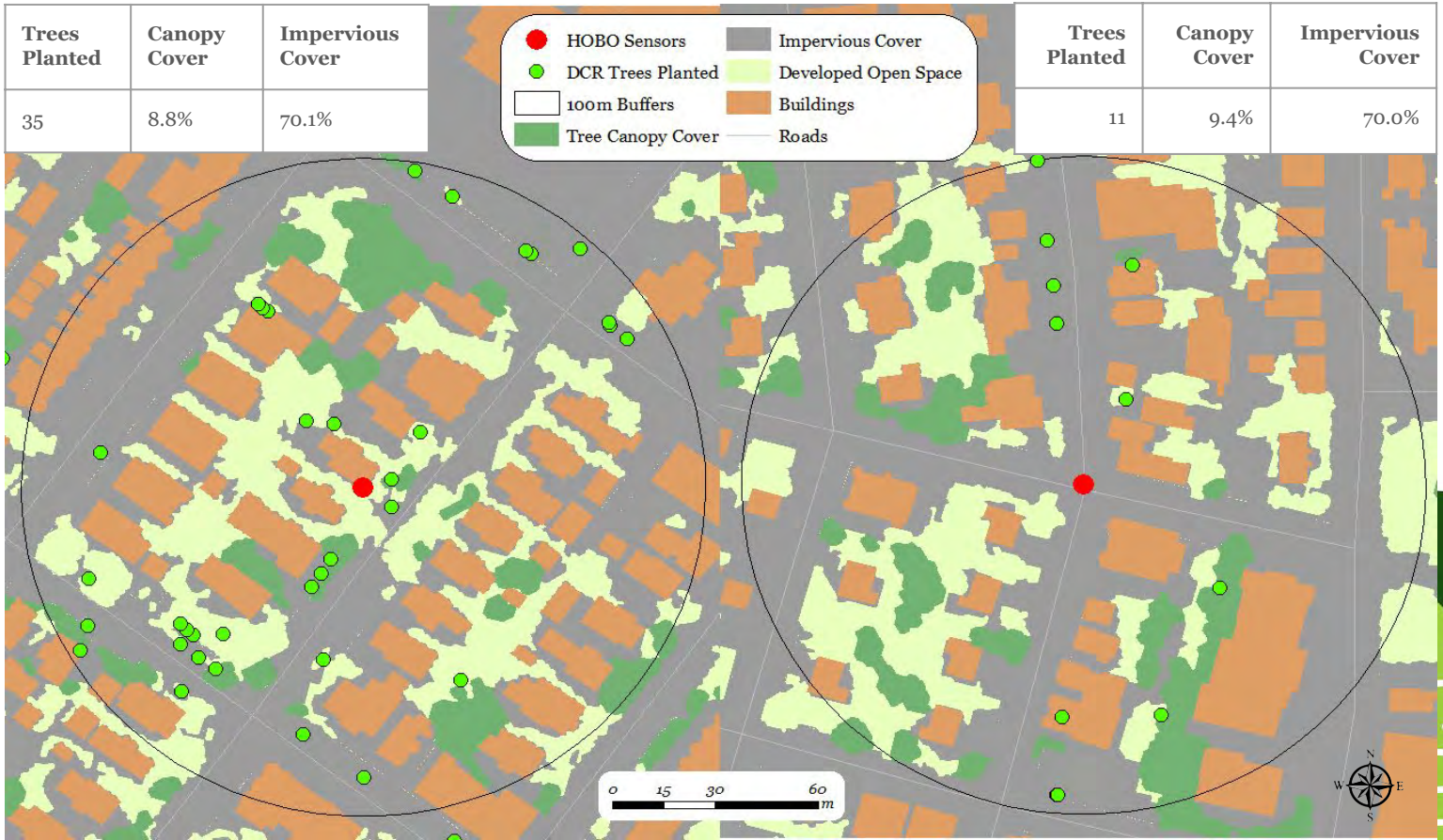
Single Family Residential Sensors

Site with More Planting

Trees Planted	Canopy Cover	Impervious Cover
35	8.8%	70.1%

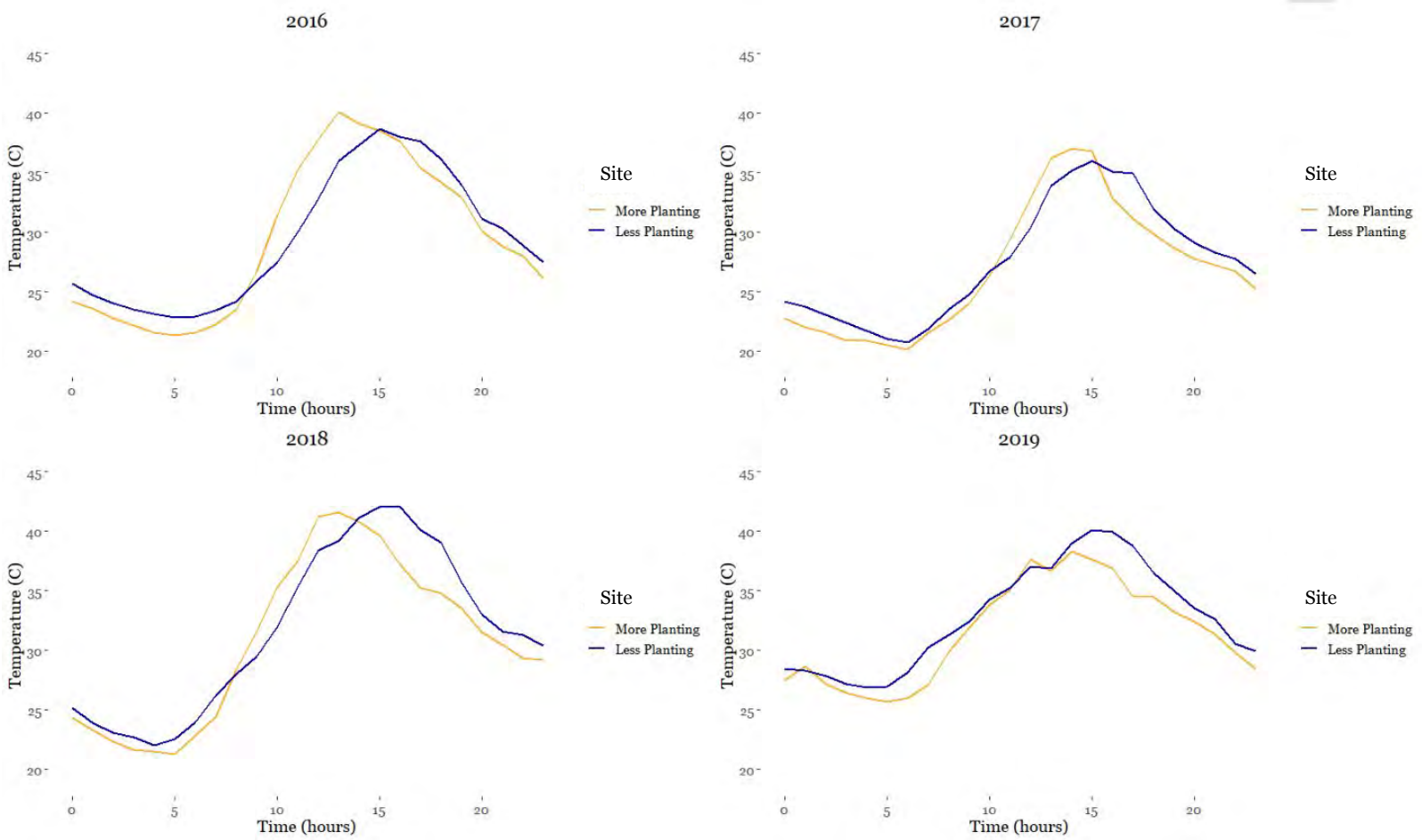
Site with Less Planting

Trees Planted	Canopy Cover	Impervious Cover
11	9.4%	70.0%



Holyoke

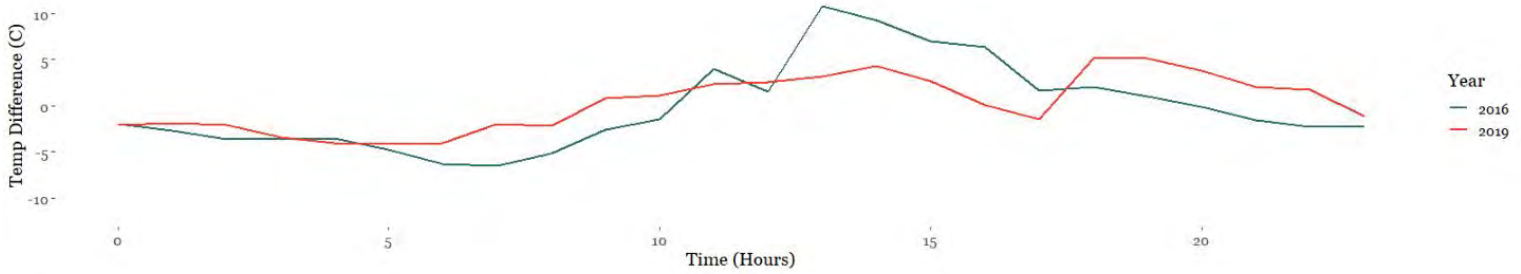
Comparison by Diurnal Temperature



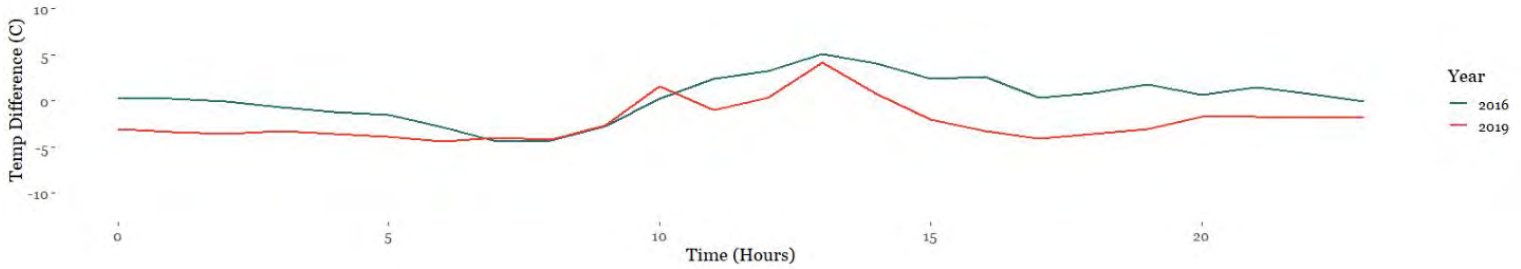
Holyoke

Comparison to Local Weather Station Site with More Planting

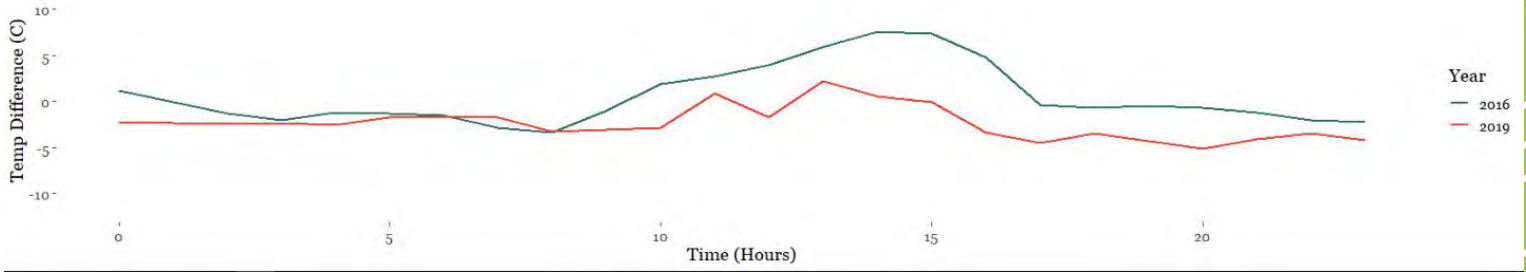
June 22nd



July 22nd



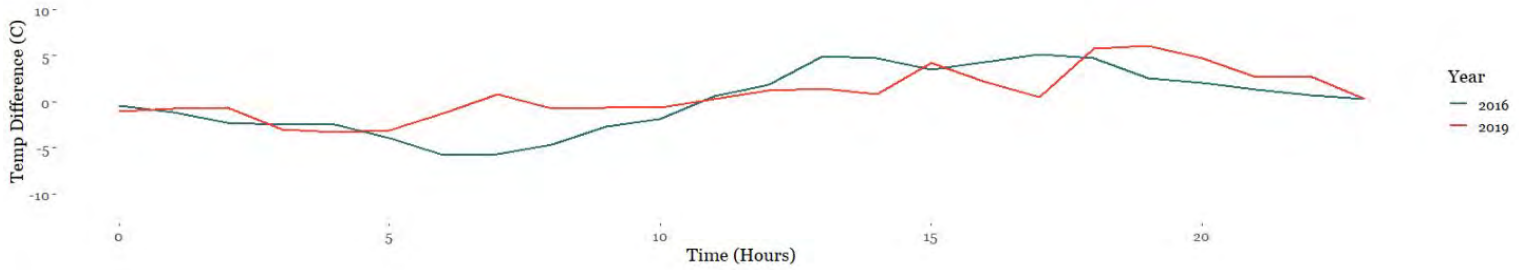
August 22nd



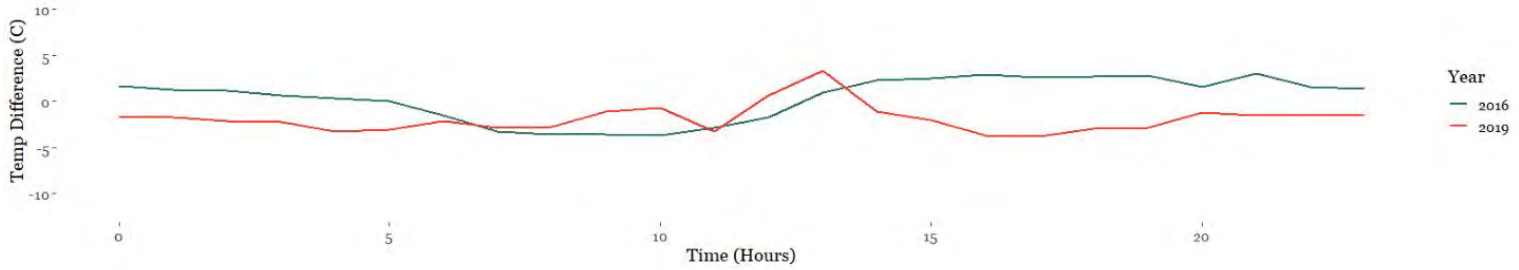
Holyoke

Comparison to Local Weather Station
Site with Less Planting

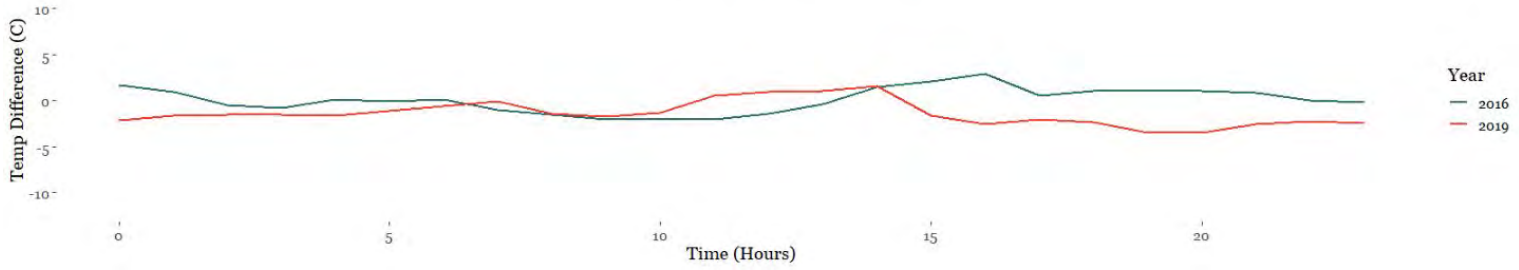
June 22nd



July 22nd

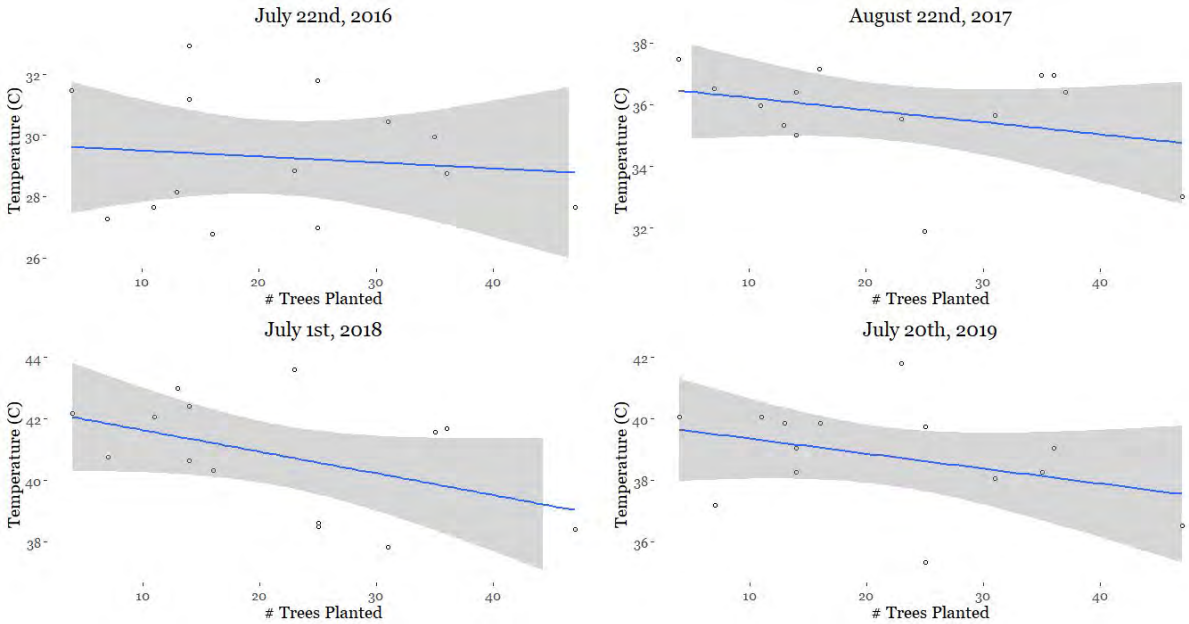


August 22nd



Holyoke

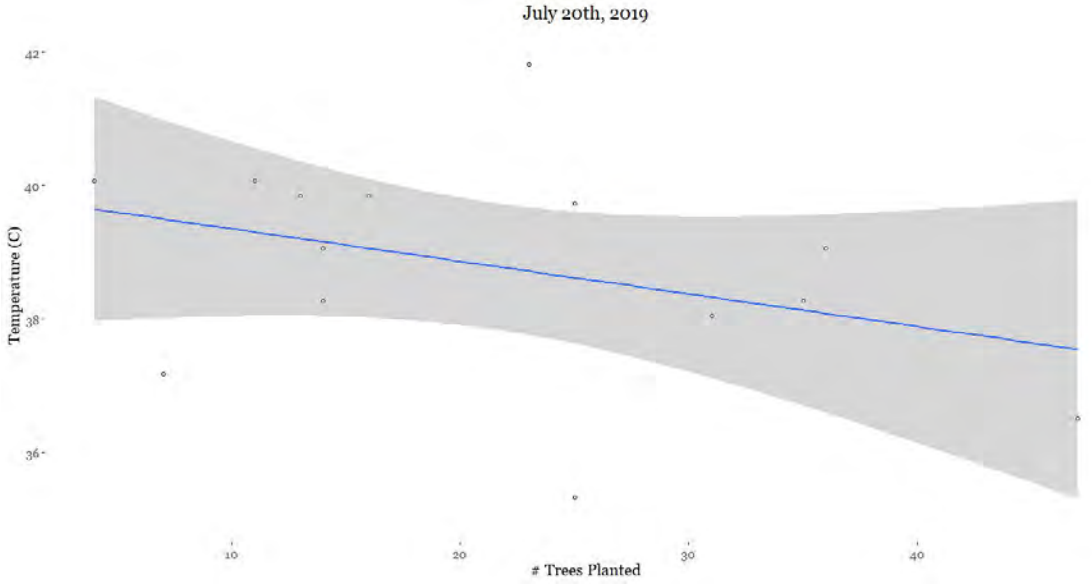
Modeling Shift in Temperature for SFR and MFR Locations



	2016	2017	2018	2019
Adjusted R^2	-0.3306	0.095	0.095	0.497
Model p-value	0.9641	0.2851	0.2853	0.01925

Holyoke

Modeling Effect of Tree Planting on Temperature



July 20th, 2019: R^2 = 0.497, P-Value = 0.019	Coefficients	P-value
# of Trees Planted	-0.06733	0.06403
Canopy Cover %	0.29757	0.01681
Impervious Surface %	0.21896	0.00653

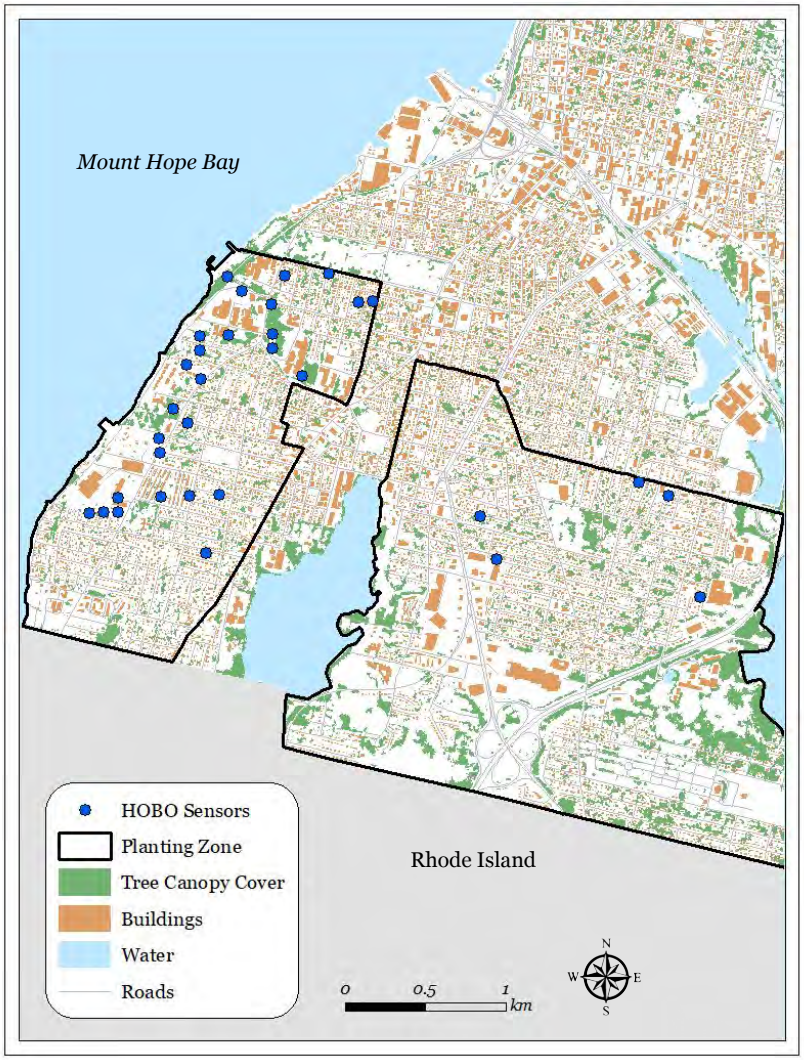
Holyoke Summary

Objective 1

- MFR was the warmest land use during peak load hours on the hottest day of 2017
- The planting zone experienced a lower degree of cooling during peak load hours and was warmer overnight in 2017

Objective 2

- The difference between the more planting site and a nearby weather station was 3°C lower in 2019 than it was on the same day 2016
- For every tree planted in residential land uses, there is a statistically significant decrease in temperature of 0.07°C



Fall River

Planting Zone

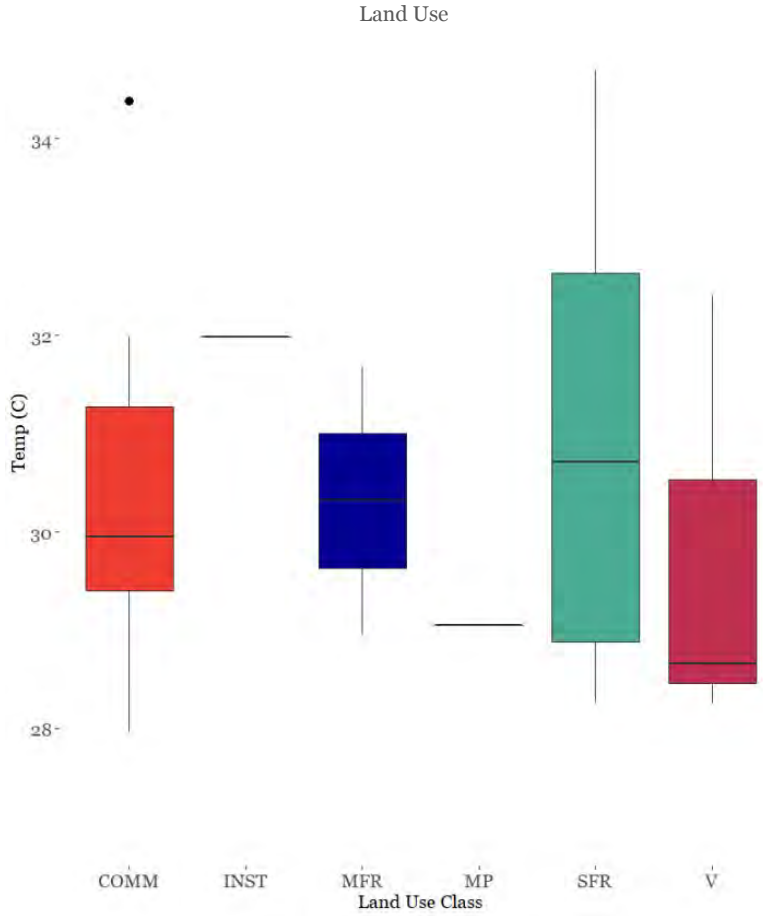
Fall River

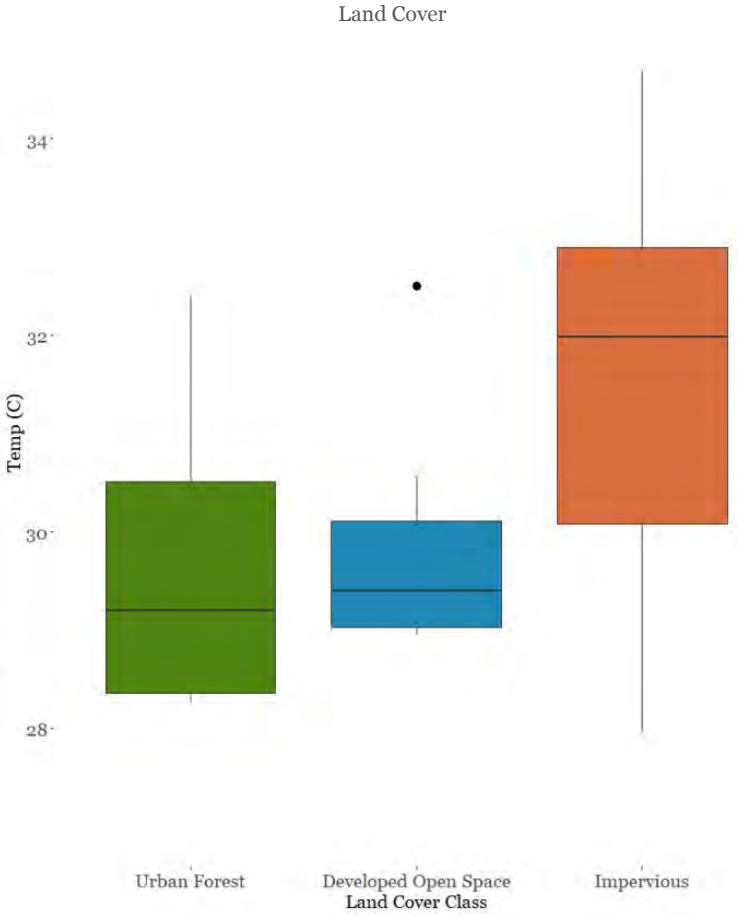
Objective 1:

Evaluate daily maximum temperatures and temperature during peak energy load hours (4pm - 7pm)

Fall River

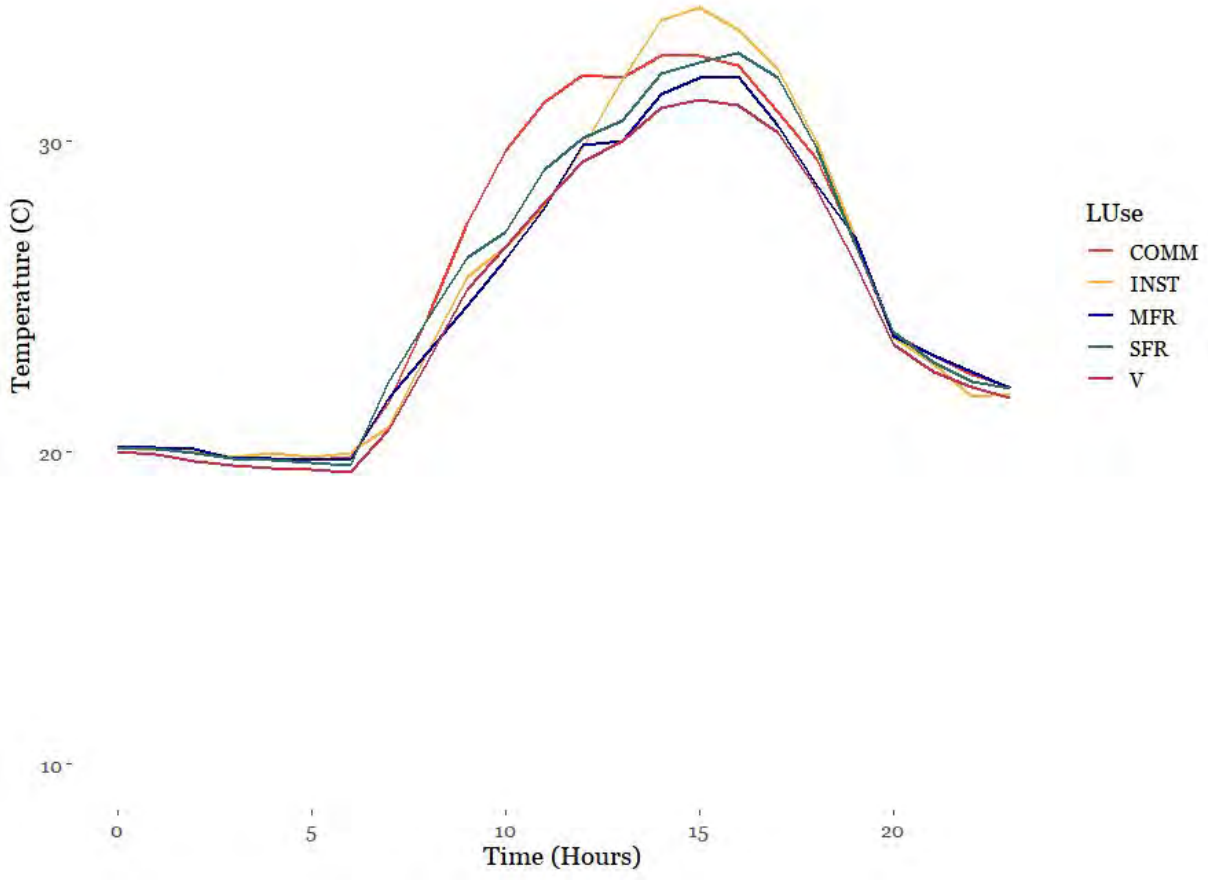
Maximum Temperature on August 22nd, 2017





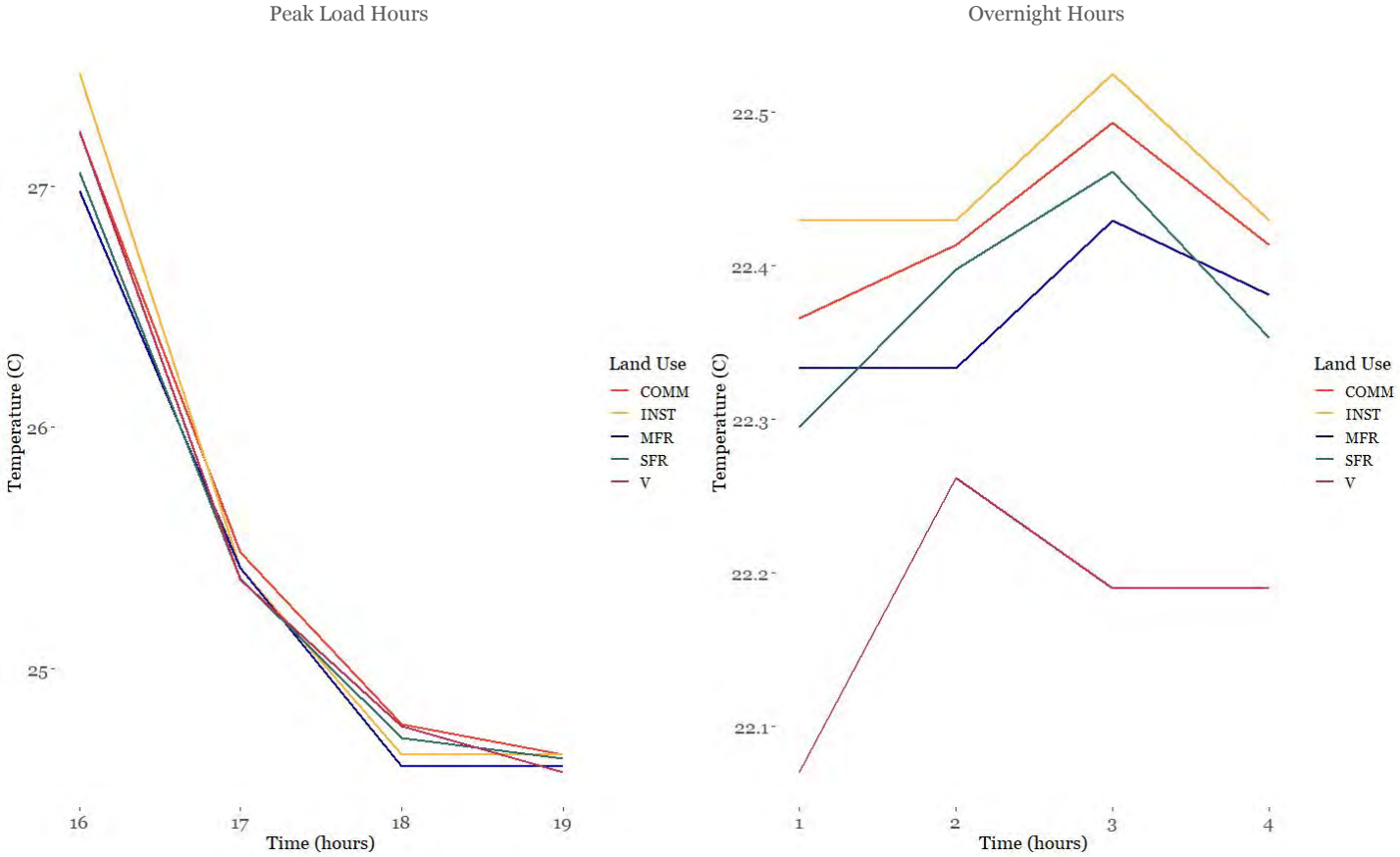
Fall River

Diurnal Temperature on August 22nd, 2017



Fall River

Temperature During Peak Load & Overnight Hours on August 22nd, 2017



Fall River

Objective 2:

Determine the effect of trees planted by DCR on temperature in residential areas

Fall River

Single Family Residential Sensors

Site with More Planting

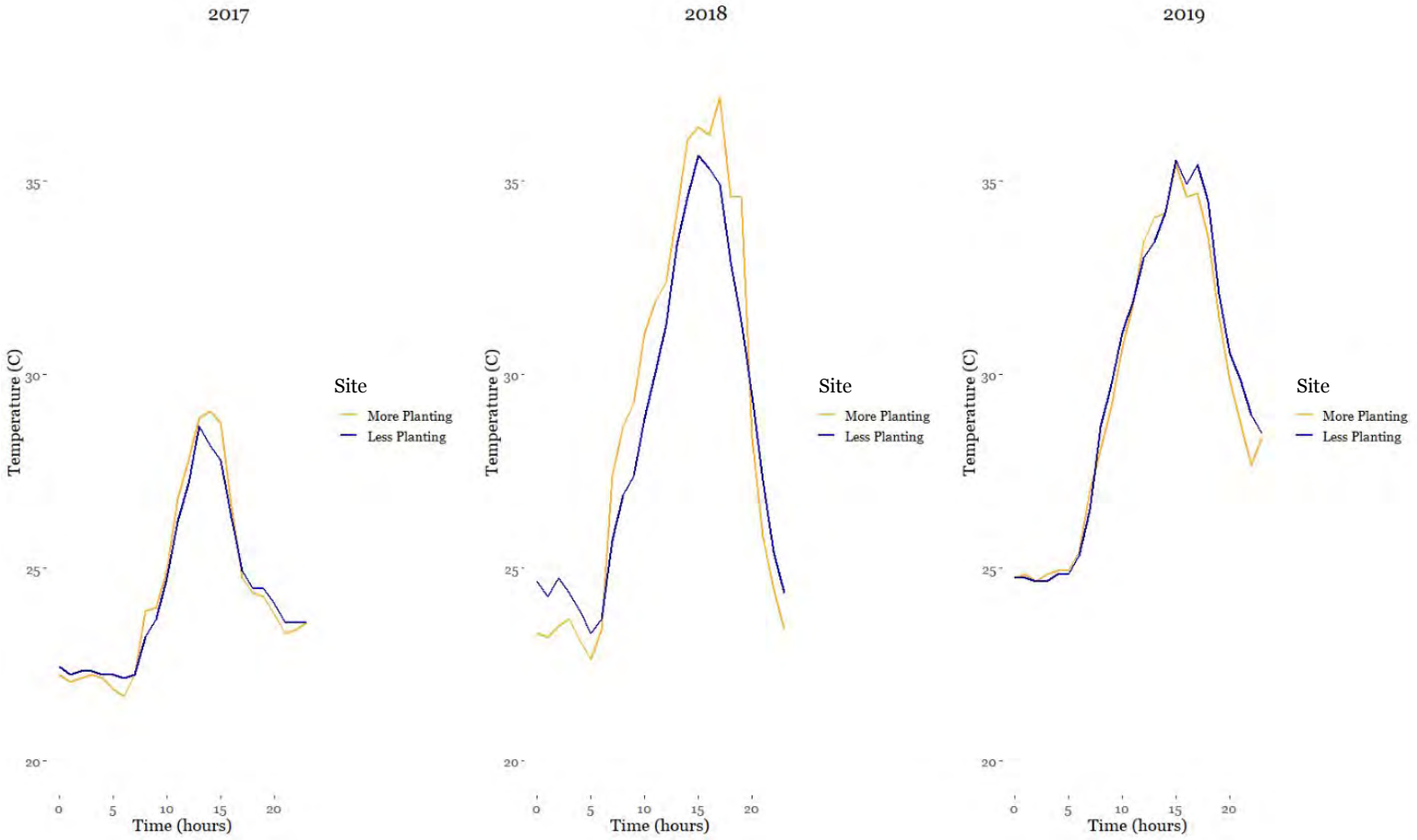
Trees Planted	Canopy Cover	Impervious Cover
38	7.9%	48.4%

Site with Less Planting

Trees Planted	Canopy Cover	Impervious Cover
1	5.1%	56.3%

Fall River

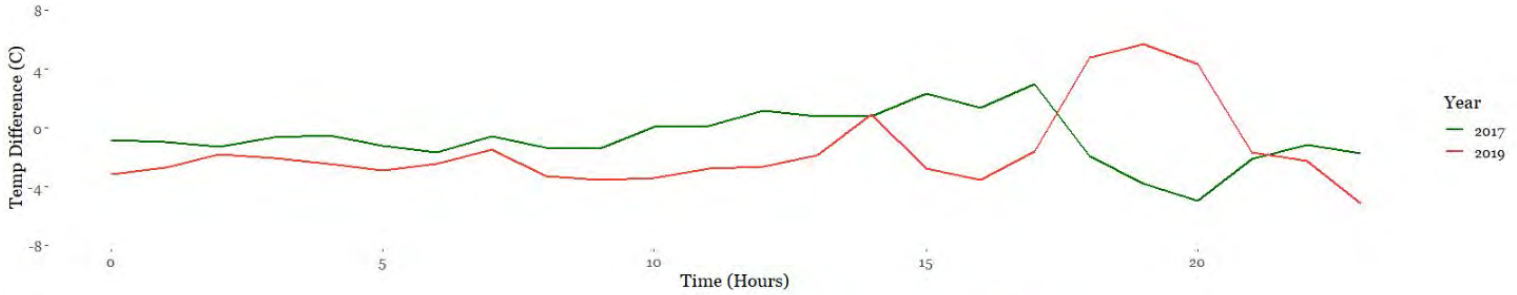
Comparison by Diurnal Temperature



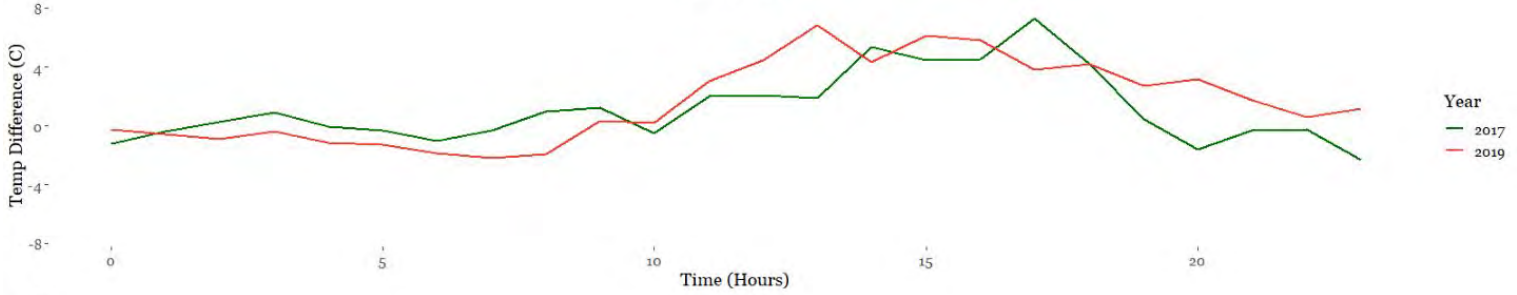
Fall River

Comparison to Local Weather Station
Site with More Planting

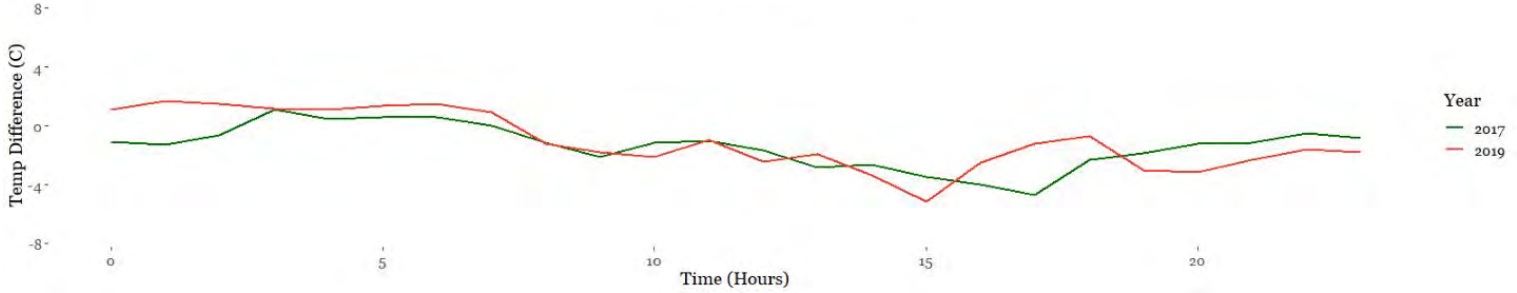
June 22nd



July 22nd



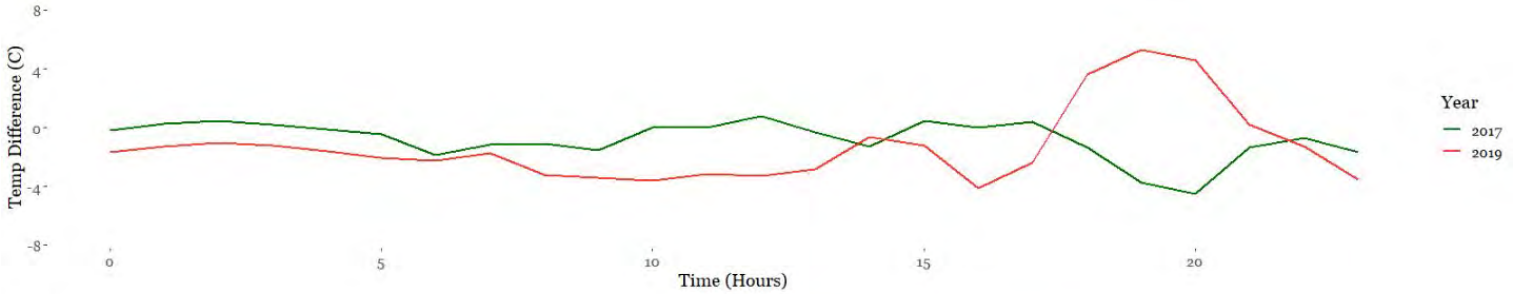
August 22nd



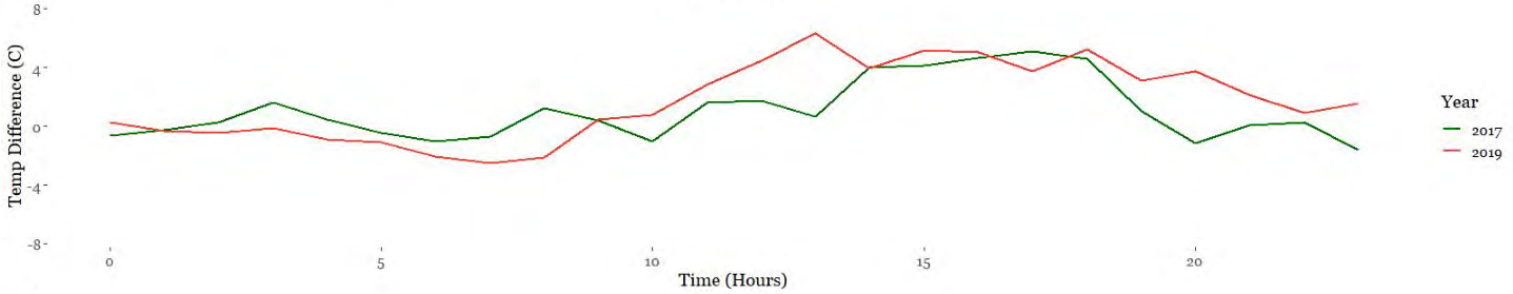
Fall River

Comparison to Local Weather Station
Site with Less Planting

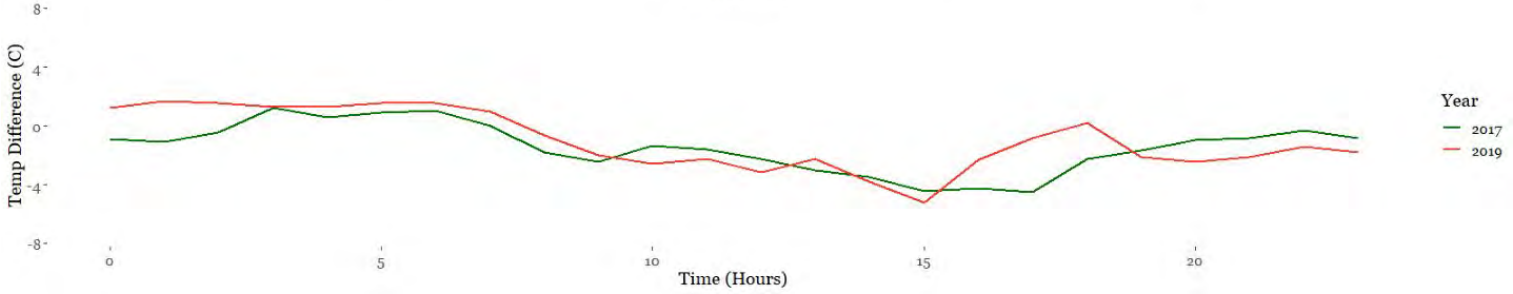
June 22nd



July 22nd



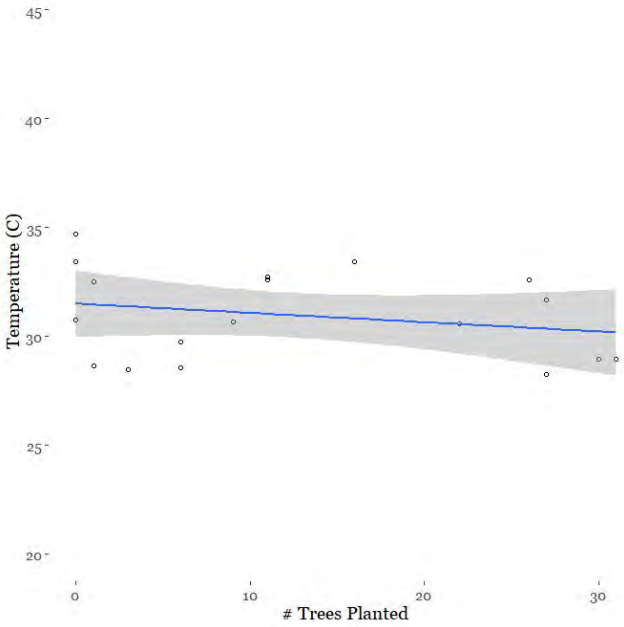
August 22nd



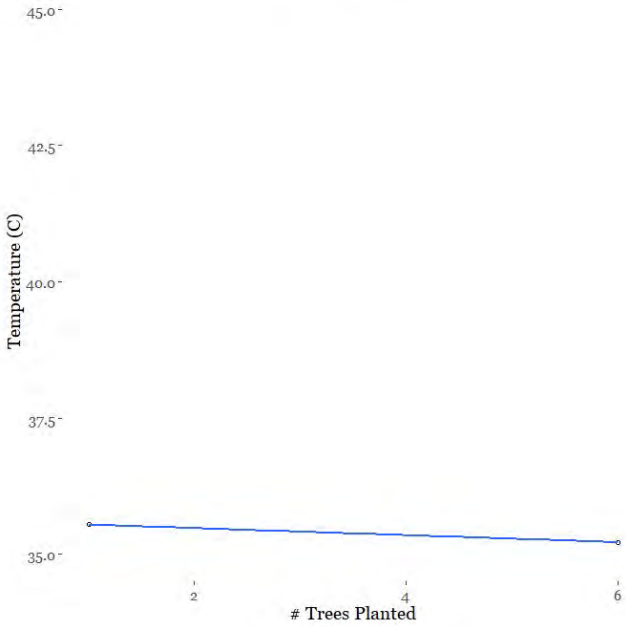
Fall River

Modeling Effect of Tree Planting on Temperature

August 22nd, 2017



July 20, 2019



	2017	2019
Adjusted R^2	-0.053	N/A
Model p-value	0.5597	N/A

Fall River

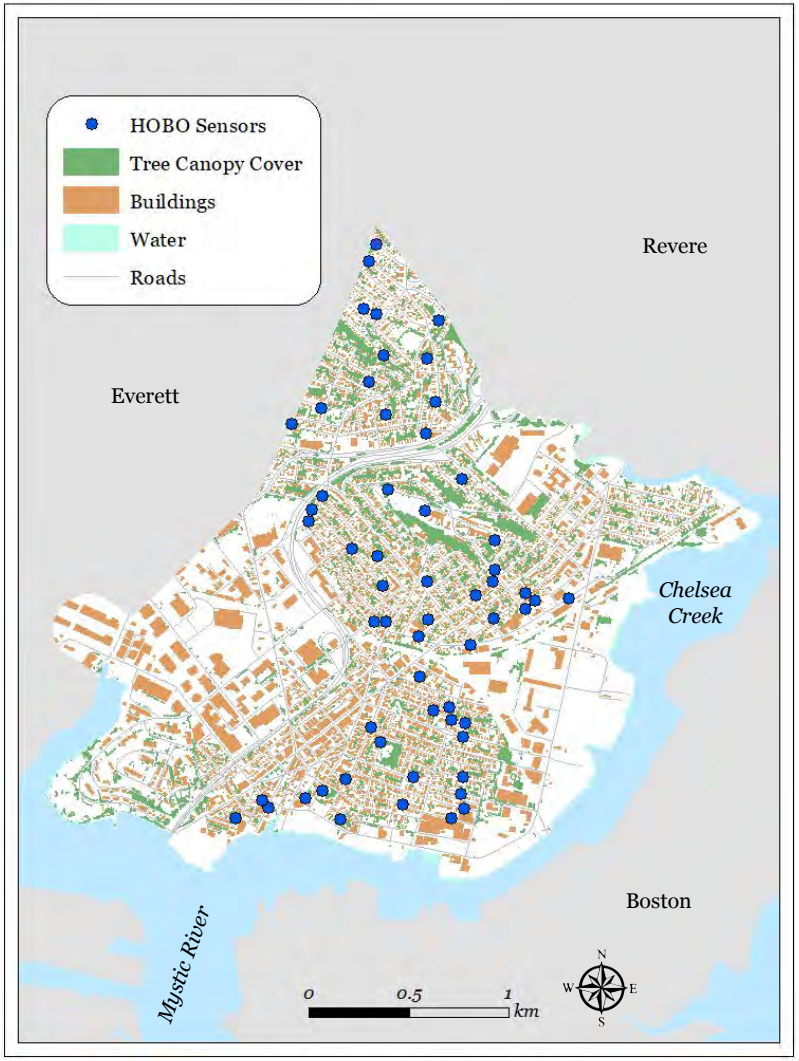
Fall River Summary

Objective 1

- Residential areas have a similar temperature profile to Commercial and Institutional areas with high percentage of impervious cover

Objective 2

- The site with more trees planted was warmer than the site with less trees planted on the hottest day of 2017, but became slightly cooler by the same day of 2019
- The difference between the site with more planting and the nearby weather station remained the same from 2017 to 2019



Chelsea

Planting Zone

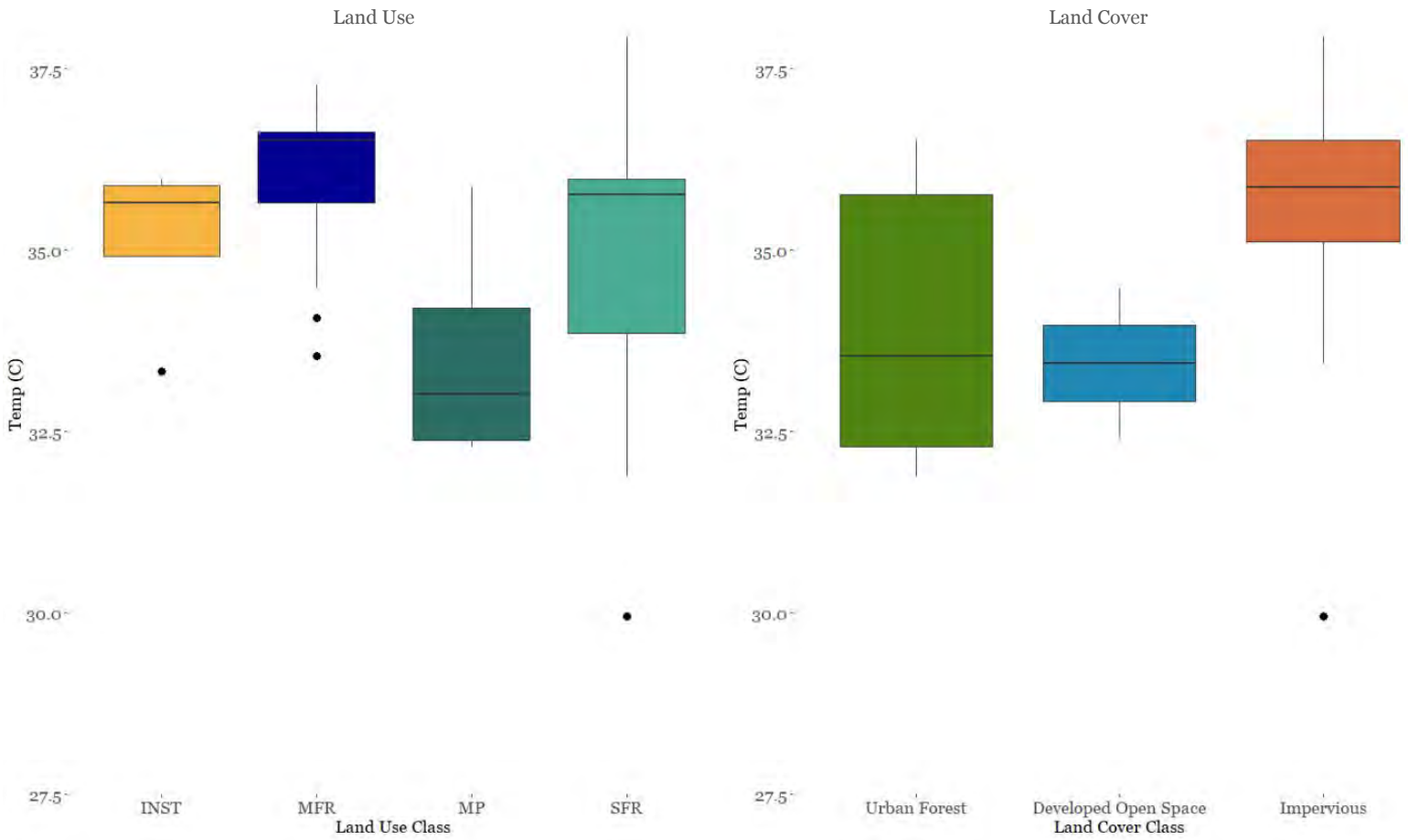
Chelsea

Objective 1:

Evaluate daily maximum temperatures and temperature during peak energy load hours (4pm - 7pm)

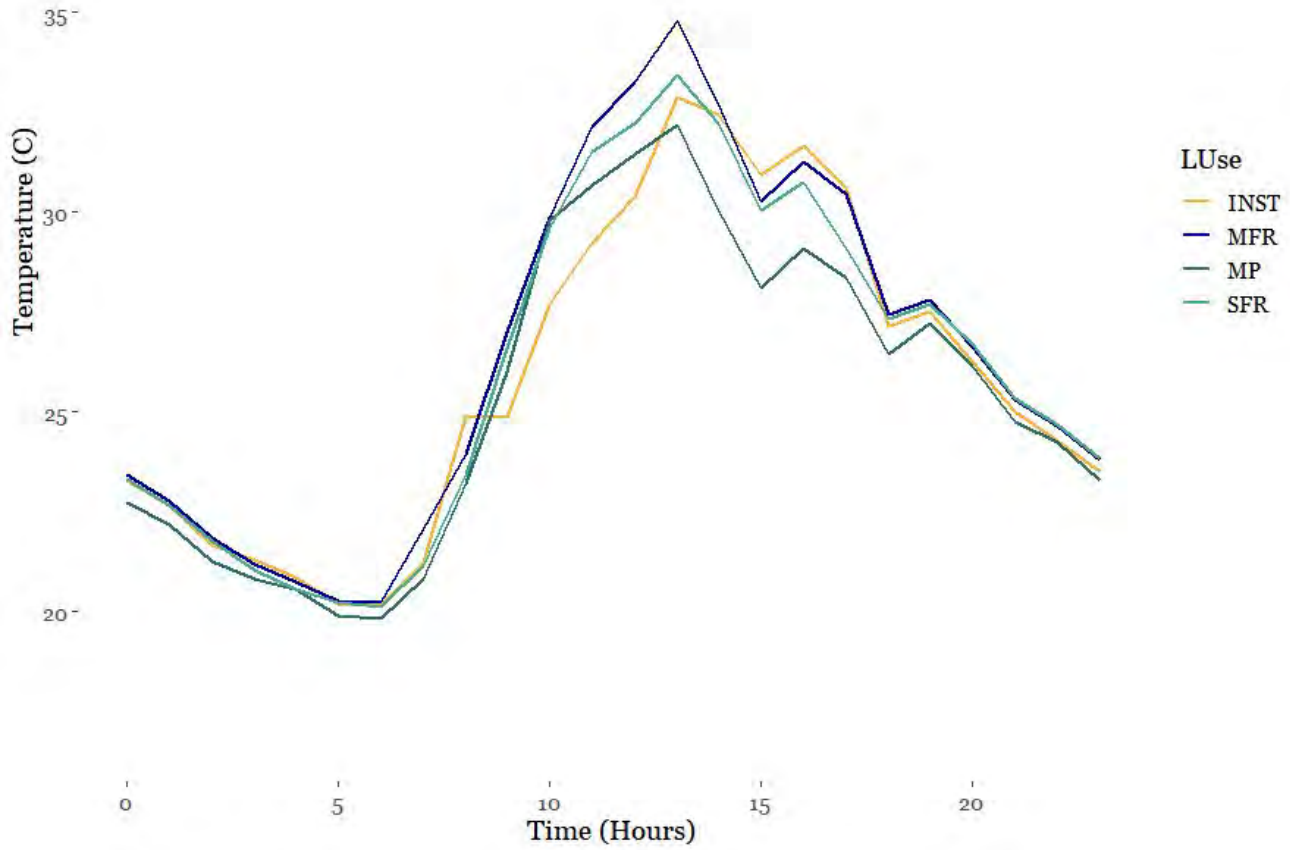
Chelsea

Maximum Temperature on August 22nd, 2017



Chelsea

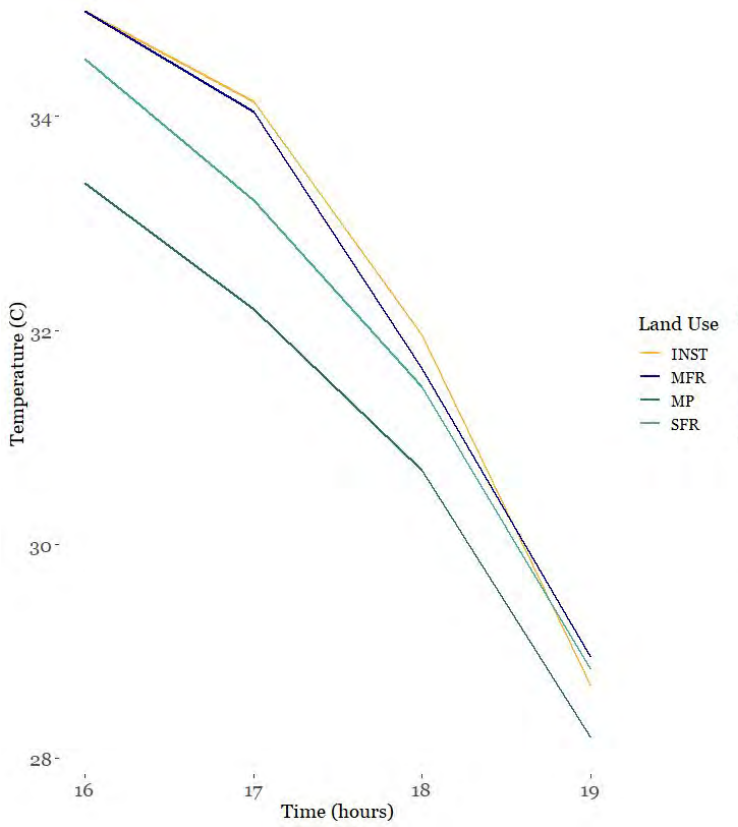
Diurnal Temperature on August 22nd, 2017



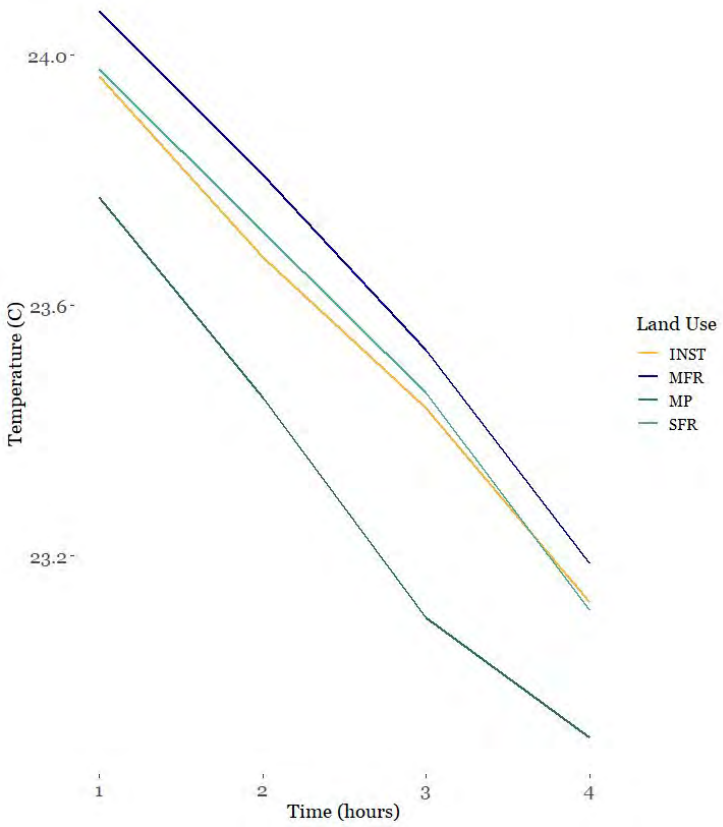
Chelsea

Temperature During Peak Load & Overnight Hours on August 22nd, 2017

Peak Load Hours



Overnight Hours



Chelsea

Objective 2:

Determine the effect of trees planted by DCR on temperature in residential areas

Chelsea

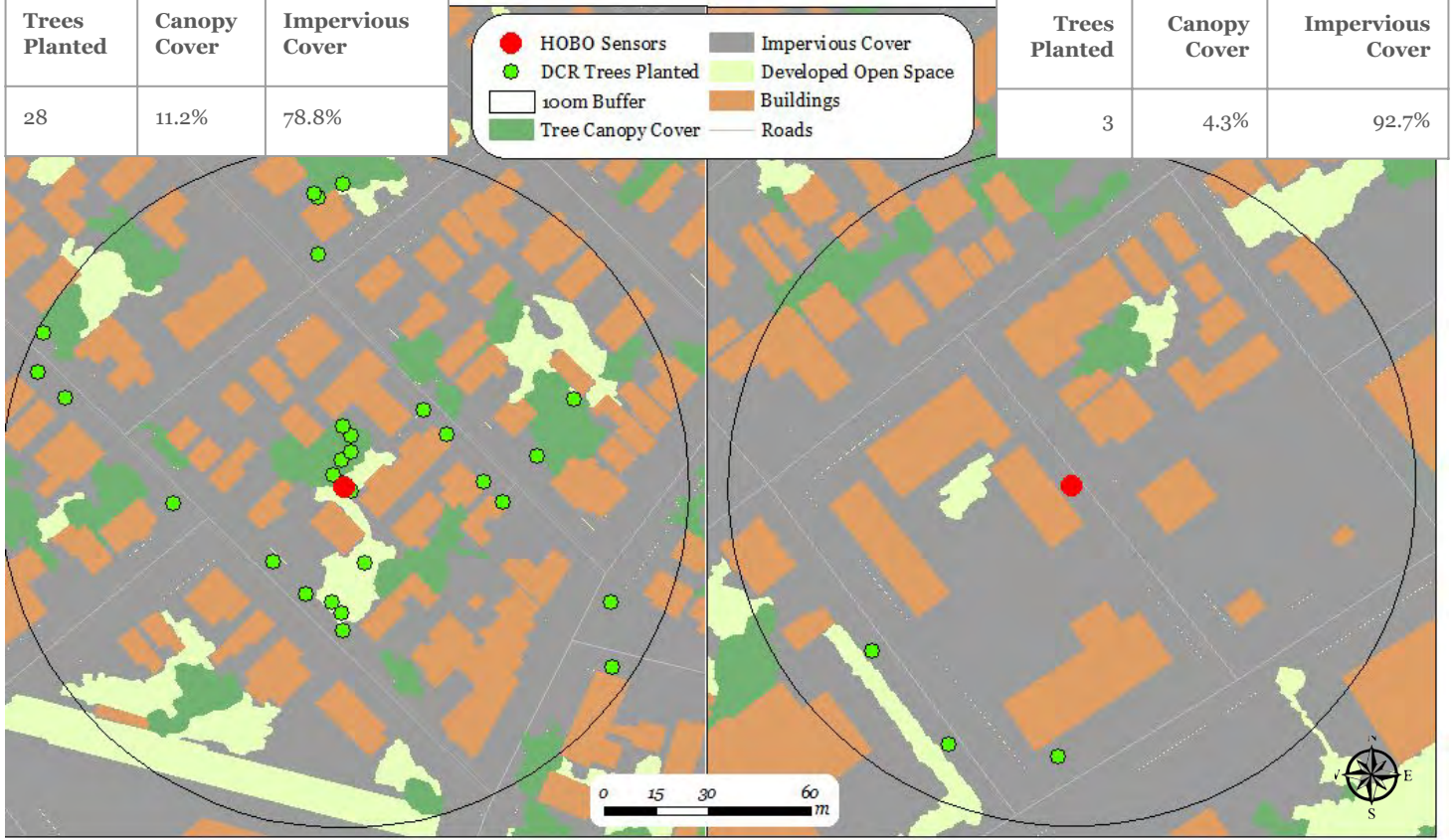
Multi-Family Residential Sensor Comparison

Site with More Planting

Trees Planted	Canopy Cover	Impervious Cover
28	11.2%	78.8%

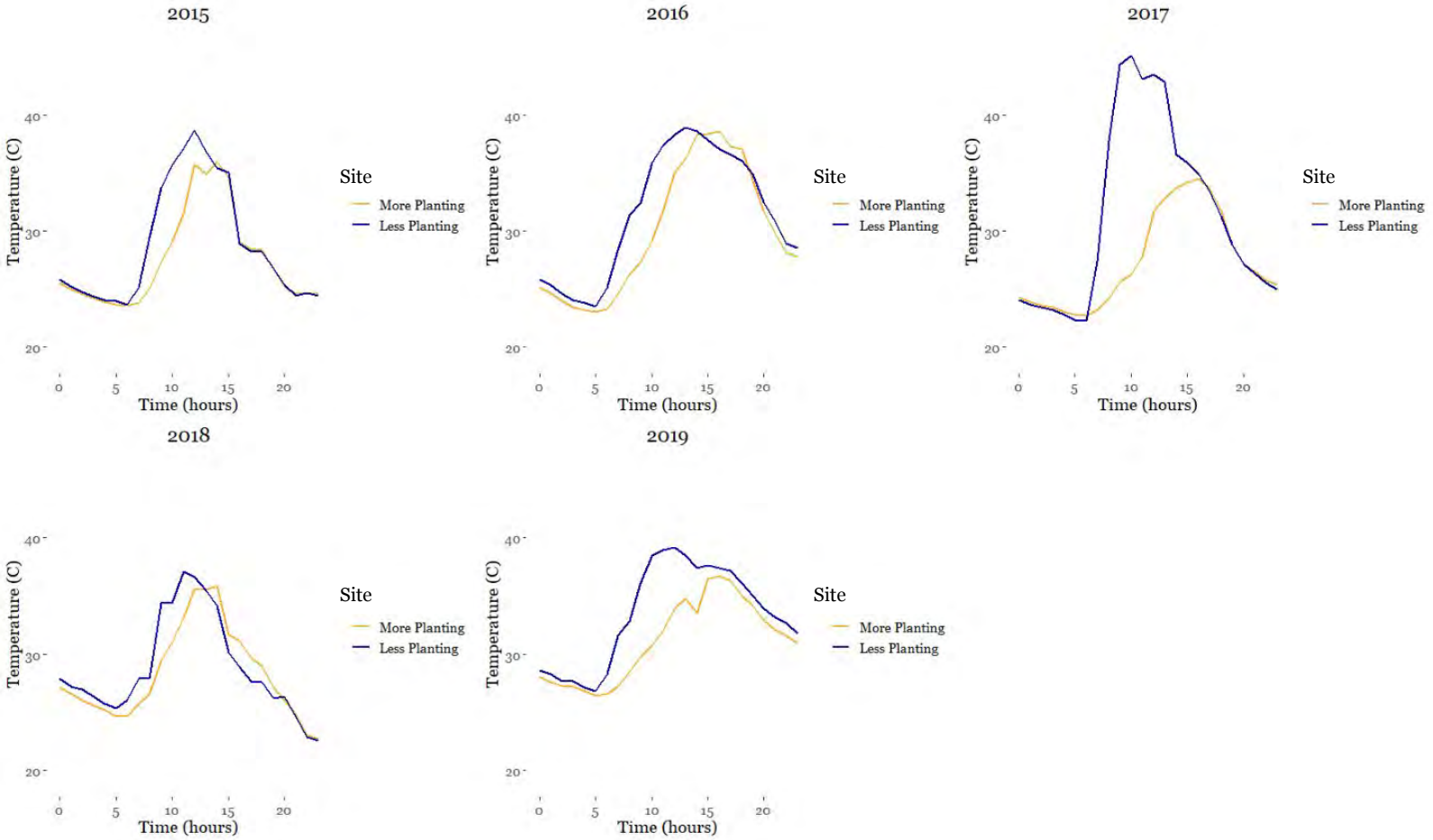
Site with Less Planting

Trees Planted	Canopy Cover	Impervious Cover
3	4.3%	92.7%



Chelsea

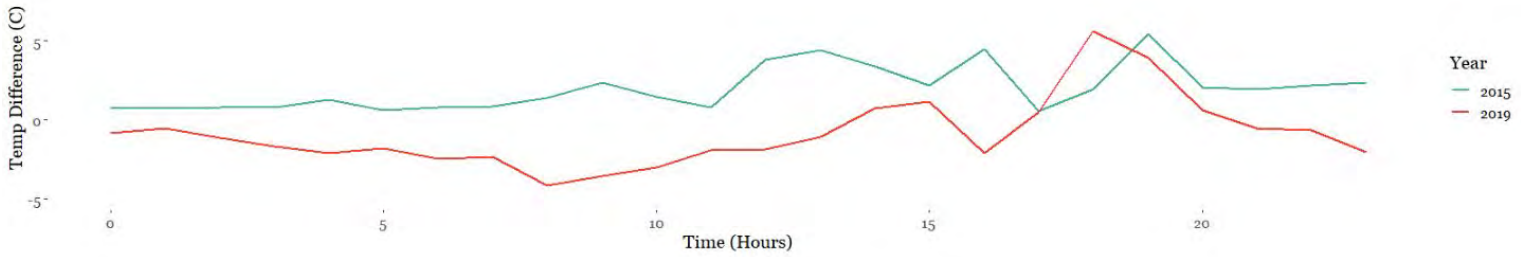
Comparison by Diurnal Temperature



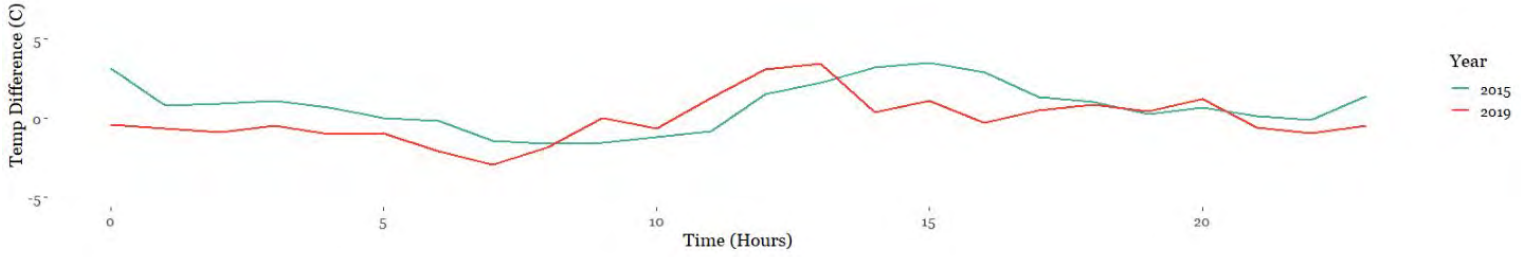
Chelsea

Comparison to Local Weather Station
Site with More Planting

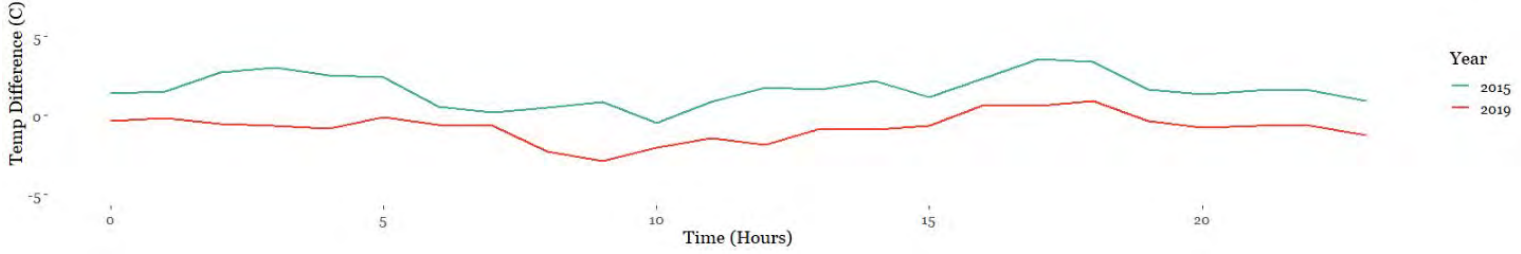
June 22nd



July 22nd



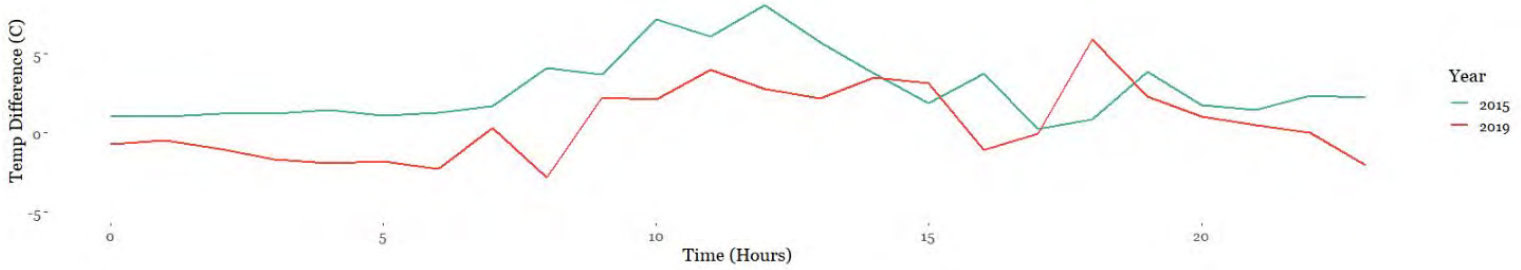
August 22nd



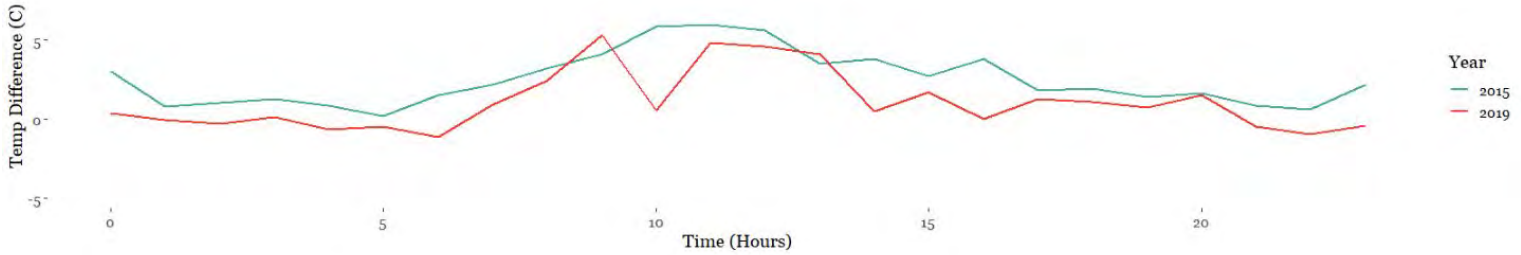
Chelsea

Comparison to Local Weather Station
Site with Less Planting

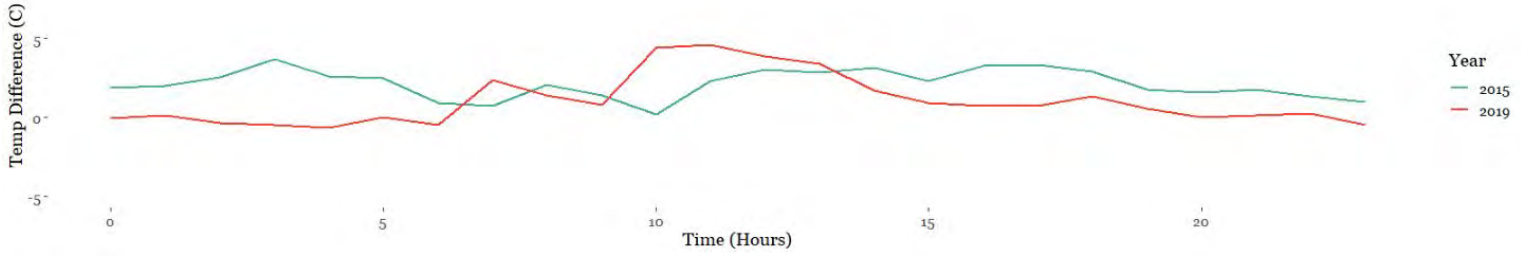
June 22nd



July 22nd

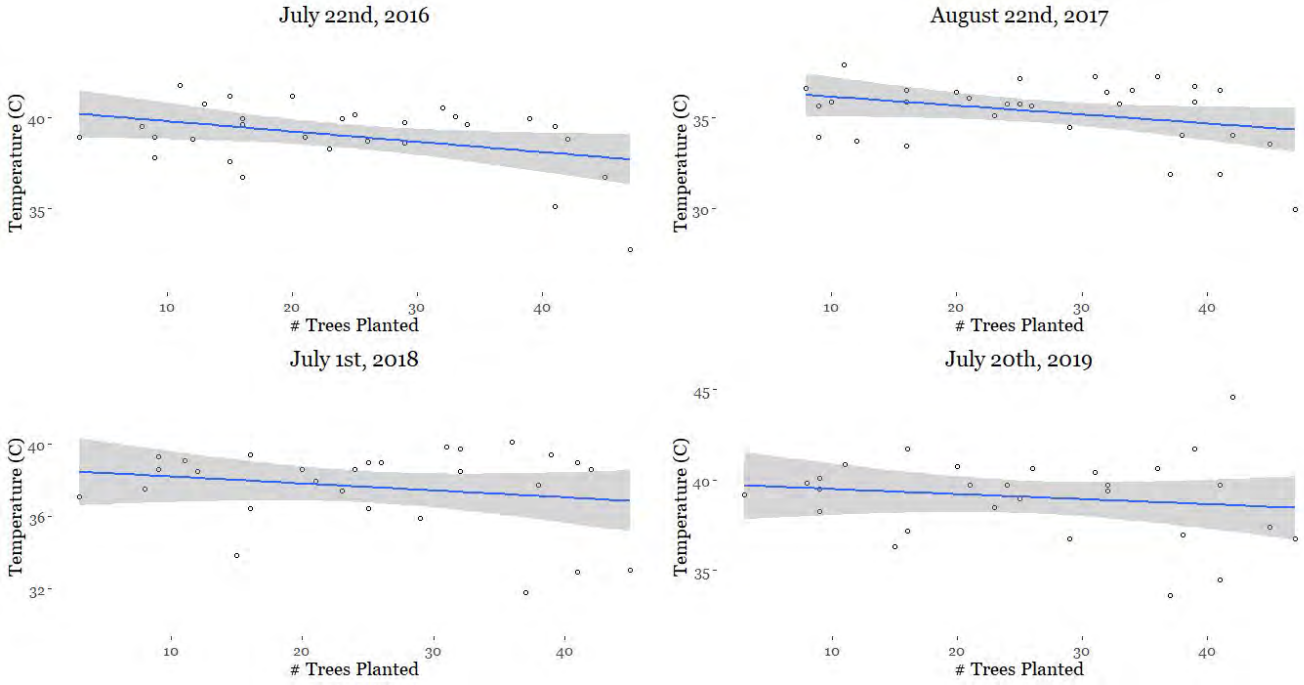


August 22nd



Chelsea

Modeling Effect of Tree Planting on Temperature



	2016	2017	2018	2019
Adjusted R^2	0.127	0.173	-0.019	-0.059
Model p-value	0.08377	0.03665	0.4901	0.6908

Chelsea Summary

Objective 1

- MFR was the warmest land use on the hottest day of the year, reaching 1° C warmer than other land uses in the afternoon

Objective 2

- The site with more trees was -0.75°C cooler in 2019 than it was in 2016 throughout the same day
- Due to high percentage of impervious surface, tree planting did not have a statistically significant association with temperature

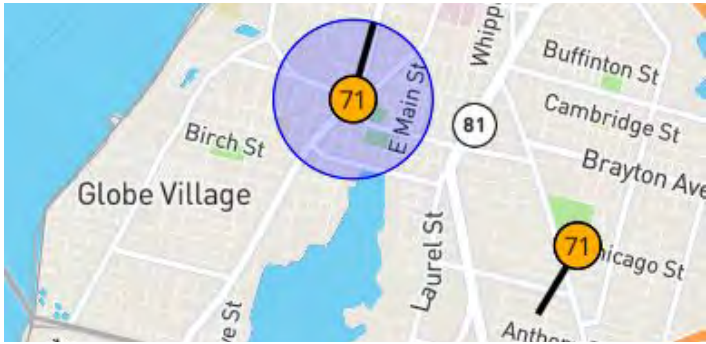
Final Takeaways & Recommendations

Conclusions

- The Hadwen Arboretum is a valuable green space to the Worcester community
  - Cooling effects from large patches of urban forest
  - Maintenance efforts have increased accessibility for locals
- Residential land use with 20 or more DCR trees planted shows evidence of cooling at peak energy hours
  - Statistically significant cooling found in Holyoke (0.07°C per tree)
- Geography matters
  - Moderate levels of canopy cover and developed open space in Holyoke
  - Ocean proximity and heterogeneous landscape adds complexity to Fall River
  - High levels of impervious surface in Chelsea

Future Research

- Fall River
  - Analyze 2018 and 2019 HOBO sensor data
  - Include weather station further from coast
- Holyoke
  - Track temperature variation in control and planting zone over time
- Chelsea
  - Continue a long-term collection of data
- Replicate approach for other GGCP cities



Weather Underground Weather Stations in Fall River

Acknowledgements

Mat Cahill, Department of Conservation & Recreation

Bob O'Connor, Massachusetts Executive Office of Energy & Environmental Affairs

Ruth Seward, Worcester Tree Initiative at Tower Hill Botanical Garden

Dr. Ben Weil, UMass Amherst

John T. O'Connor '78 Fund

Average Offset

	6/2016	6/2019	7/2016	7/2019	8/2016	8/2019
Holyoke 19226	-0.23	0.27	0.36	-2.22	0.51	-2.40
Holyoke 2484	0.13	0.75	0.40	-1.87	0.05	-1.41

	6/2017	6/2019	7/2017	7/2019	8/2017	8/2019
Fall River 1267	0.13	0.75	0.40	-1.87	0.05	-1.41
Fall River 26954	-0.80	-1.35	1.06	1.69	-1.45	-0.99

	6/2015	6/2019	7/2015	7/2019	8/2015	8/2019
Chelsea 899	1.96	-0.89	0.71	-0.11	1.64	-0.75
Chelsea 947	2.78	0.58	2.46	1.03	2.13	1.04