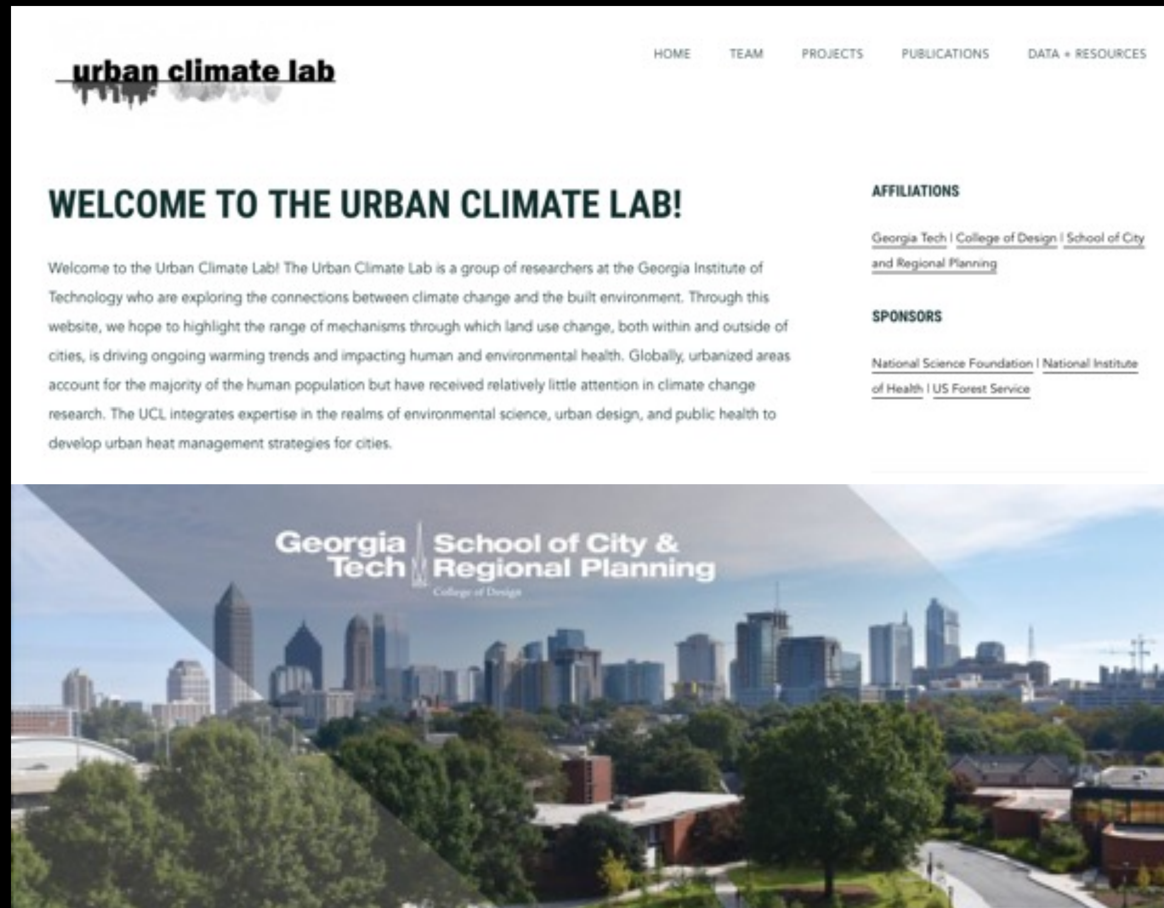
Worcester Heat Risk Assessment

January 23, 2023

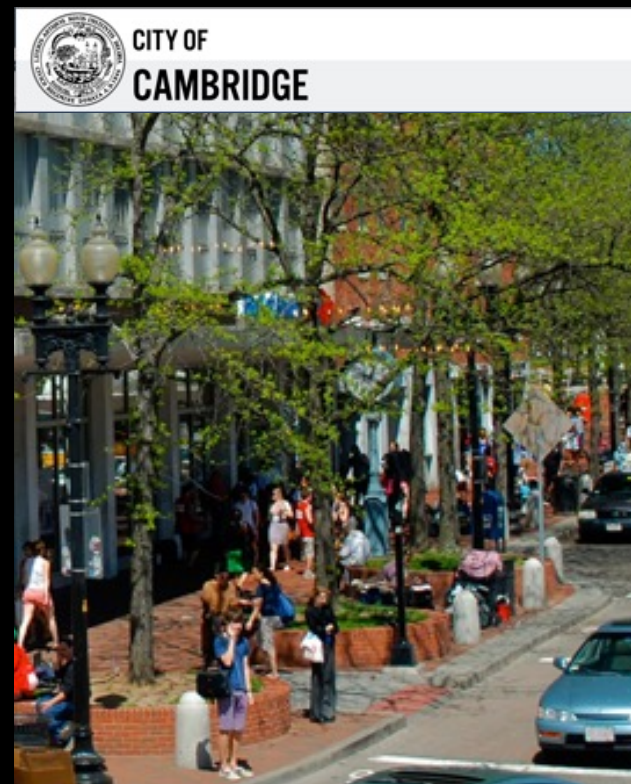
urban climate consulting

Who we are

We are researchers from the [Urban Climate Lab] at the Georgia Institute of Technology. We have been partnering with municipal governments to develop urban heat adaptation plans for more than a decade. In response to the need for a standardized, reliable, and low cost risk assessment process – as well as an approach that can measure and prioritize the needs of communities most at risk to extreme heat – we have developed and published an integrated approach to urban heat risk assessment and planning that leverages a new class of urban scale climate models to support the climate adaptation and resilience planning of cities.



Prior Urban Heat Management Work



Prior Work: Louisville, KY

The Urban Climate Lab's 2016 Louisville Urban Heat Management Study led directly to multiple city-wide urban forestry and heat mitigation policies:

Metro Government Tree Ordinance

- Regulate protection and maintenance of public trees across metro area.

Green Heart Project

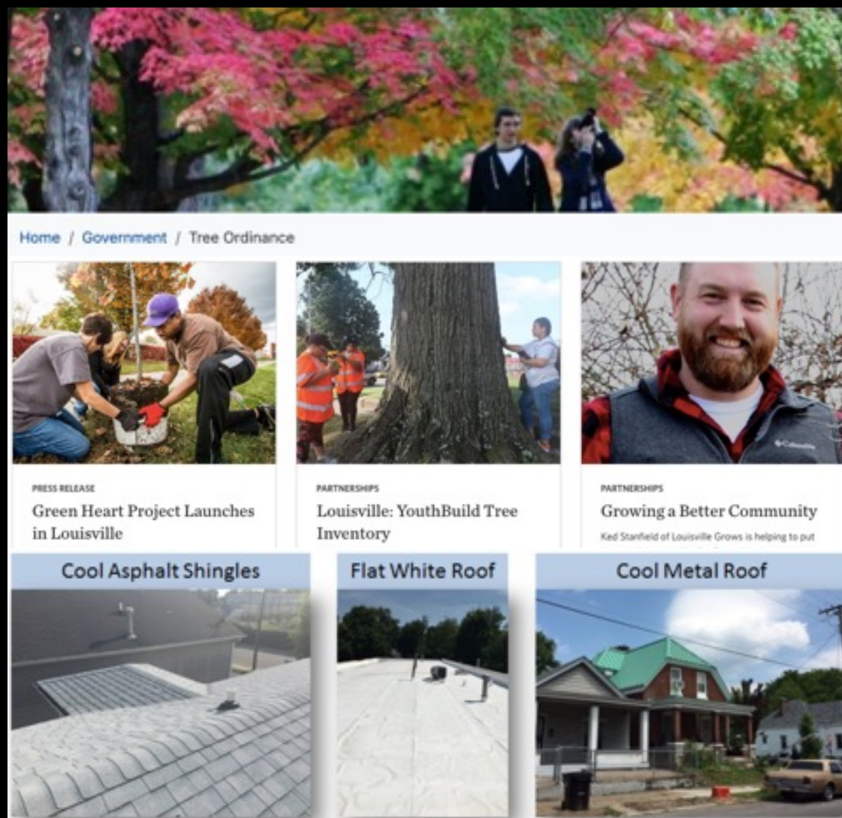
- City-wide greening to improve air quality and human health.

Depave Project

- Concrete and asphalt removal projects to make space for urban greening and reduce urban heat islands.

Cool Roof Incentive Program

- Subsidized cool roofing enhancement for residential and commercial structures.



Prior Work: Dallas, TX

In 2017, the Urban Climate Lab partnered with Texas Trees Foundation to conduct an urban heat island management study for Dallas, Texas. This work has been incorporated into the Dallas Comprehensive Environmental Action Plan, directly informing their tree planting and ecosystem management goals.

The plan is currently being implemented and has already reported significant progress in achieving its goals.

02

ALIGNMENT WITH OTHER PLANS

PLANS	Solid Waste B	Solid Waste C	Water A	Water B	Water C	Ecosystems A	Ecosystems B	Ecosystems C
	PLAN OBJECTIVES							
Forward Dallas! Comprehensive Plan (2006)	●		●			●	●	●
A Balanced Vision Plan for the Trinity River Corridor (2003)						●	●	●
Resilient Dallas (2018)				●		●	●	●
Building a Cool, Clean & Resilient Dallas (2018)			●	●		●	●	●
Sustainable Development & Construction: Green Building Ordinance (2015)								
Oncor Energy Efficiency Plan and Report (2018)								
Dallas Green Energy Policy (2019)								
2030 Transit System Plan (2006)								
City of Dallas Complete Streets Design Manual (2016)							●	
Dallas Bike Plan (2011)								
Dallas Trail Network Plan (2008)							●	
The 360 Plan (2017)								
Neighborhood Plus Plan (2015)								
Vulnerability and Risk Assessment for Transportation Infrastructure (2015)								
Clean Fleet Vehicle Policy (2015)	●							
City of Dallas Waste Characterization Study (2013)		●						
Litter and Illegal Dumping Assessment Study (2018)	●							
Local Solid Waste Management Plan 2011 - 2060 (2013)	●	●						
Wastewater Treatment Facilities Strategic Plan (2010)				●				
Interim Bacteria Reduction Plan (2012)			●					
Interior Drainage Study for the East and West Levee (2014)				●				
Water Conservation Five-Year Work Plan (2019)			●					
2014 Dallas Long Range Water Supply Plan to 2070 and Beyond (2015)			●		●			
Stormwater Management Plan (2019)			●	●	●			
Dallas Park and Recreation Department - Comprehensive Plan (2016)							●	
Great Trinity Forest Management Plan (2008)							●	
Urban Heat Island Management Study (2017)						●	●	
Healthy Food Dallas -Presentation by Economic Development Committee (2017)								

CANOPY COVER CITYWIDE
33% by 2030
37% by 2040
40+% by 2050

URBAN HEAT ISLAND INDEX
20% reduction by 2030
50% reduction by 2040
75% reduction by 2050

PARK OR TRAIL ACCESS
80% of the population by 2030
90% of the population by 2040
95% of the population by 2050
(1/2 mile walk from home)

Approach

Our study approach is informed by the three dimensions of population vulnerability to heat and other environmental hazards:

- ***Exposure***: Intensity of heat stress experienced by an individual
- ***Sensitivity***: Degree to which an individual is affected by the resulting heat exposure
- ***Adaptive Capacity***: Ability of an individual or community to cope with or manage heat exposure.

To assess overall heat risk we will rank neighborhoods by the incidence of heat-related mortality, which is a product of both heat exposure and population sensitivity. We will also rank each neighborhood by the percentage of homes equipped with central air conditioning. Total heat risk will then be ranked by the combination of these two quintile scores.

Study Objectives

Exposure	1. Simulate hourly near-surface air temperature over the full period (June, July, August) of a recent summer ranking among the hottest summers on record (2020).
Sensitivity	2. Estimate heat-related mortality resulting from the simulated temperatures at the neighborhood scale to assess neighborhood-level heat risk. Estimate heat-related mortality resulting from five heat management scenarios co-produced with City staff.
Adaptive Capacity	3. Estimate neighborhood level adaptive capacity for heat based on air conditioning prevalence.
Total Heat Risk	4. Combine the resulting estimates of heat-related mortality and AC prevalence to rank zones by heat risk to inform urban heat management and heat wave response planning efforts.
Recommendations	5. Provide specific neighborhood-level recommendations on the extent of tree planting and cool materials needed to meet the assumptions of the health impact assessment.

Heat Management Scenarios

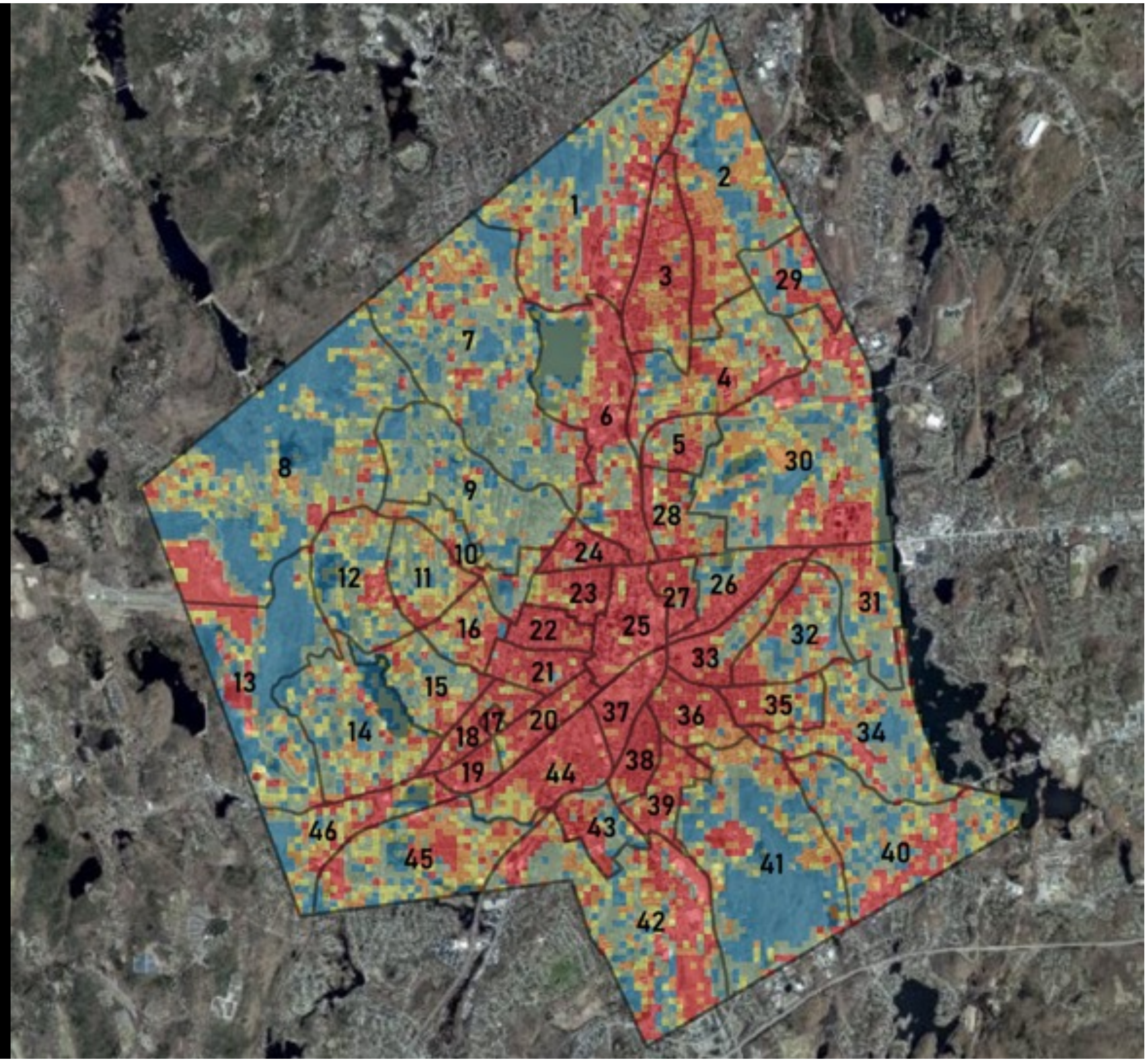
1. Base Case: Current conditions
2. Tree Loss: Reduction in base case tree canopy of 10% for all census tracts
3. Cool Materials (Albedo), rooftops and surface paving
4. Moderate Street Trees: All streets >= 15% canopy coverage
5. High Street Trees: All streets >= 25% canopy coverage
6. Moderate Greening: Tree canopy >= 25% for all census tracts
7. High Greening: Tree canopy >= 50% for all census tracts
8. Combined: Combination of Cool Materials and High Greening scenarios

The average modeled temperature for June, July, August of 2020 across the City was 72.12 °F, which closely matches the summer average temperature of 72.11 °F recorded at the Worcester Regional Airport.

The clustering of high air temperatures in the central, highest-density census tracts of the city align well with underlying land cover patterns.

BASE SCENARIO

Tavg Summer
by Grid Cell (100m)



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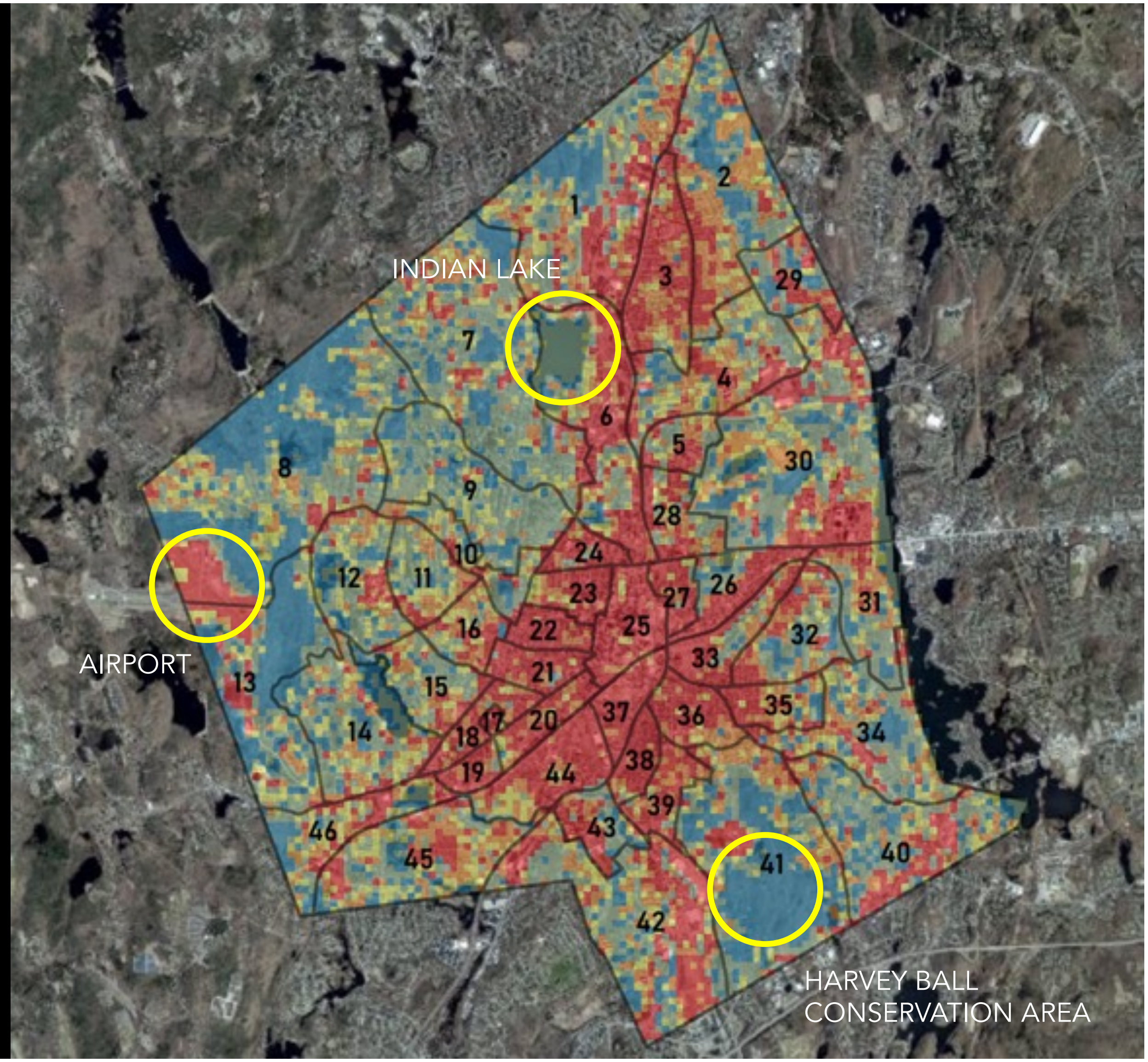
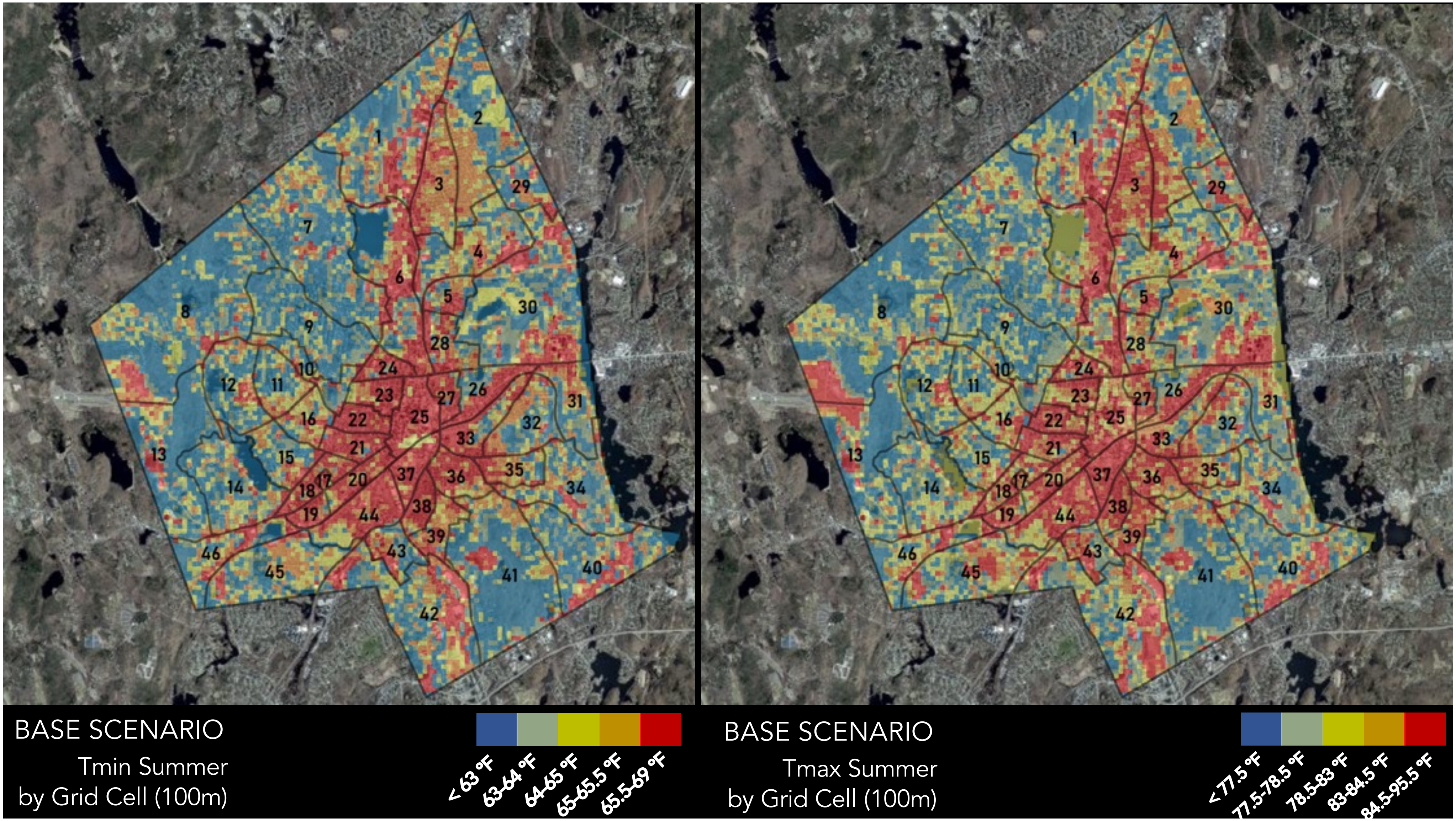
The clustering of high air temperatures in the central, highest-density census tracts of the city align well with underlying land cover patterns.

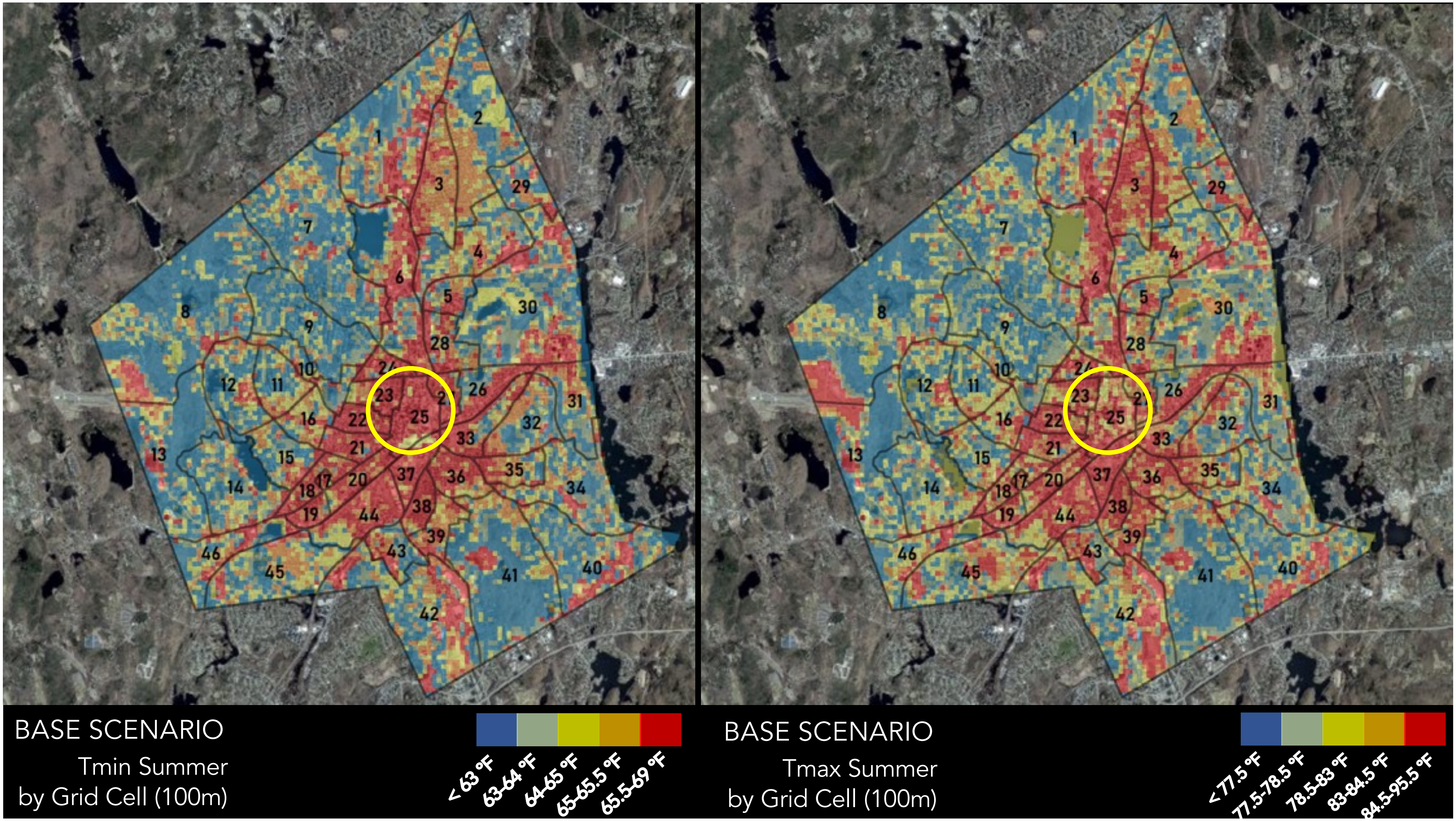
BASE SCENARIO

Tavg Summer
by Grid Cell (100m)

<70 °F | 70-71 °F | 71-73 °F | 73-74 °F | 74-80 °F




BASE SCENARIO
Tmin Summer
by Grid Cell (100m)
< 63 °F
63-64 °F
64-65 °F
65-65.5 °F
65.5-69 °F
BASE SCENARIO
Tmax Summer
by Grid Cell (100m)
<77.5 °F
77.5-78.5 °F
78.5-83 °F
83-84.5 °F
84.5-95.5 °F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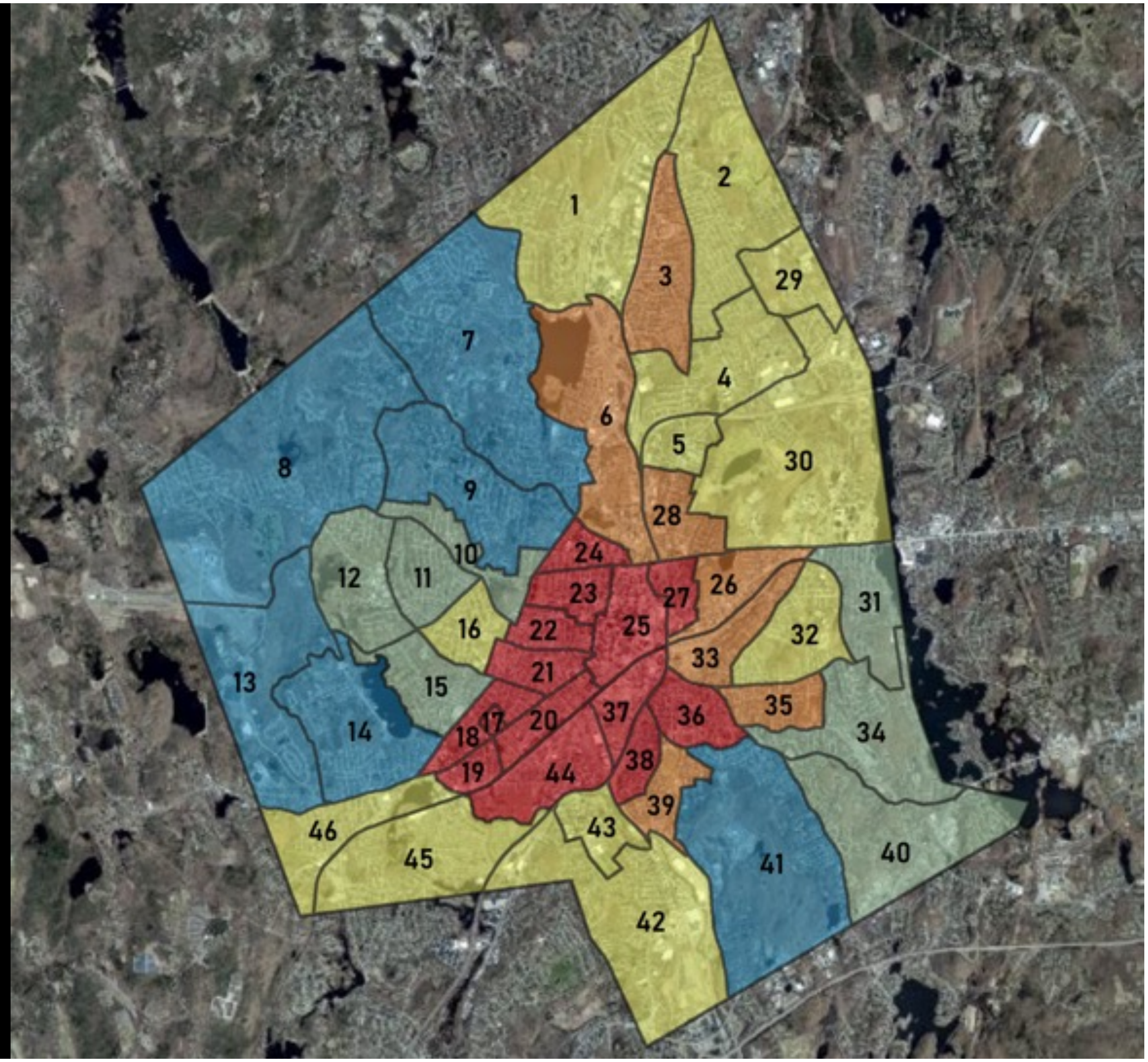
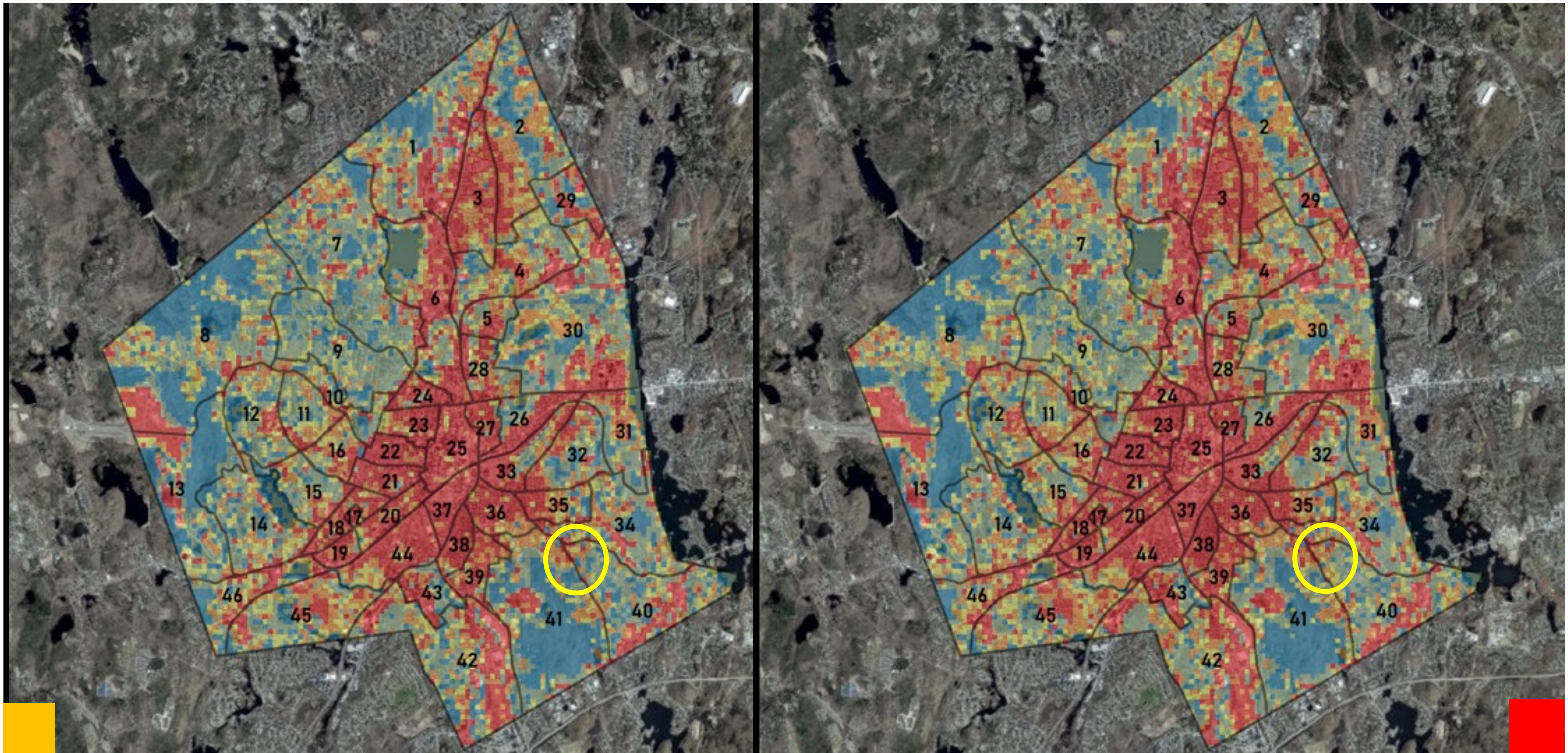
Tmax Summer
by Grid Cell (100m)
<77.5 °F
77.5-78.5 °F
78.5-83 °F
83-84.5 °F
84.5-95.5 °F

BASE SCENARIO

Tavg Summer
by Census Tract

<71.5 °F
71.5-72 °F
72-73 °F
73-74 °F
74-75 °F



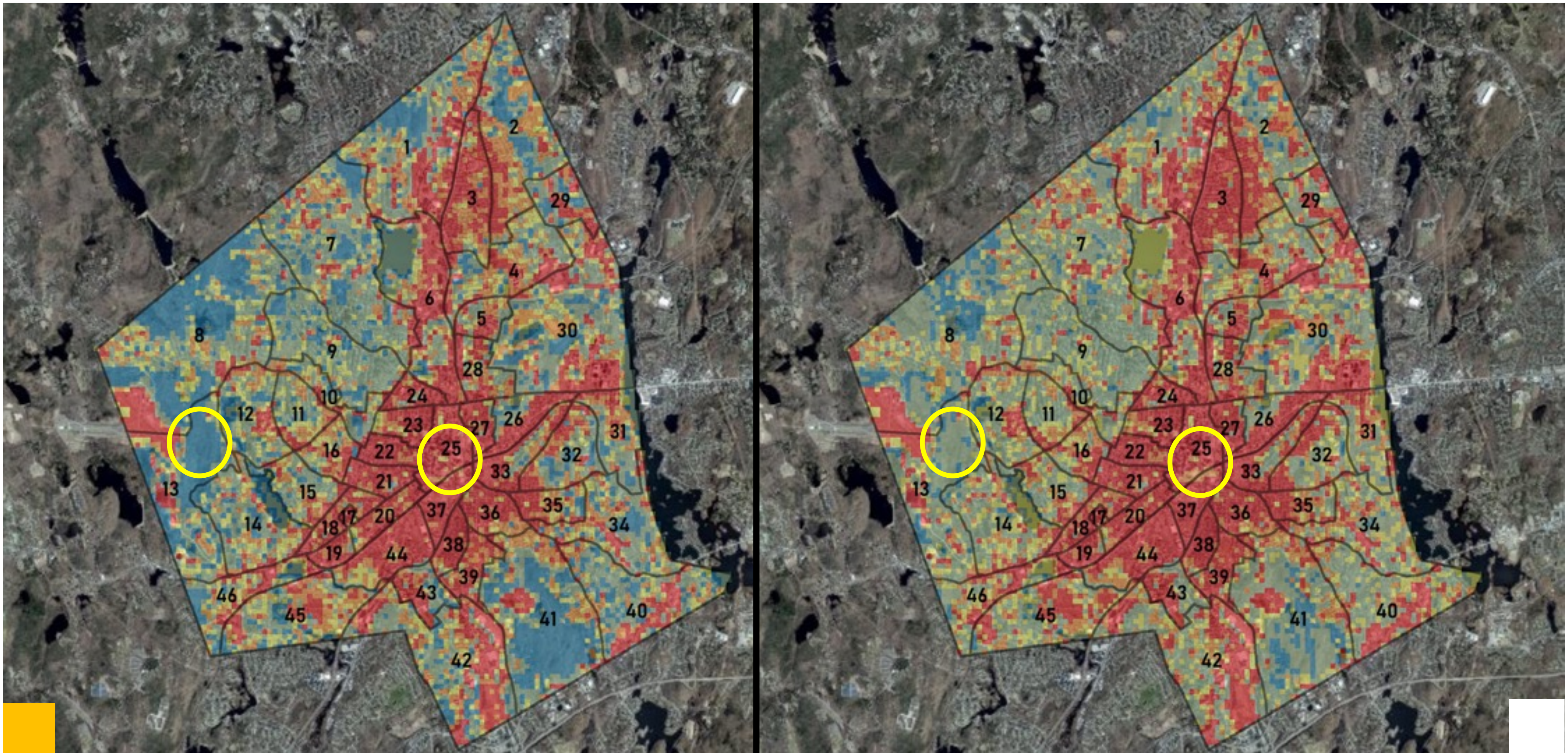


BASE SCENARIO

< 70 °F | 70-71 °F | 71-73 °F | 73-74 °F | 74-80 °F

A uniform loss of 10% of canopy cover per grid cell results in a consistent but modest warming effect across the City.

TREE LOSS SCENARIO

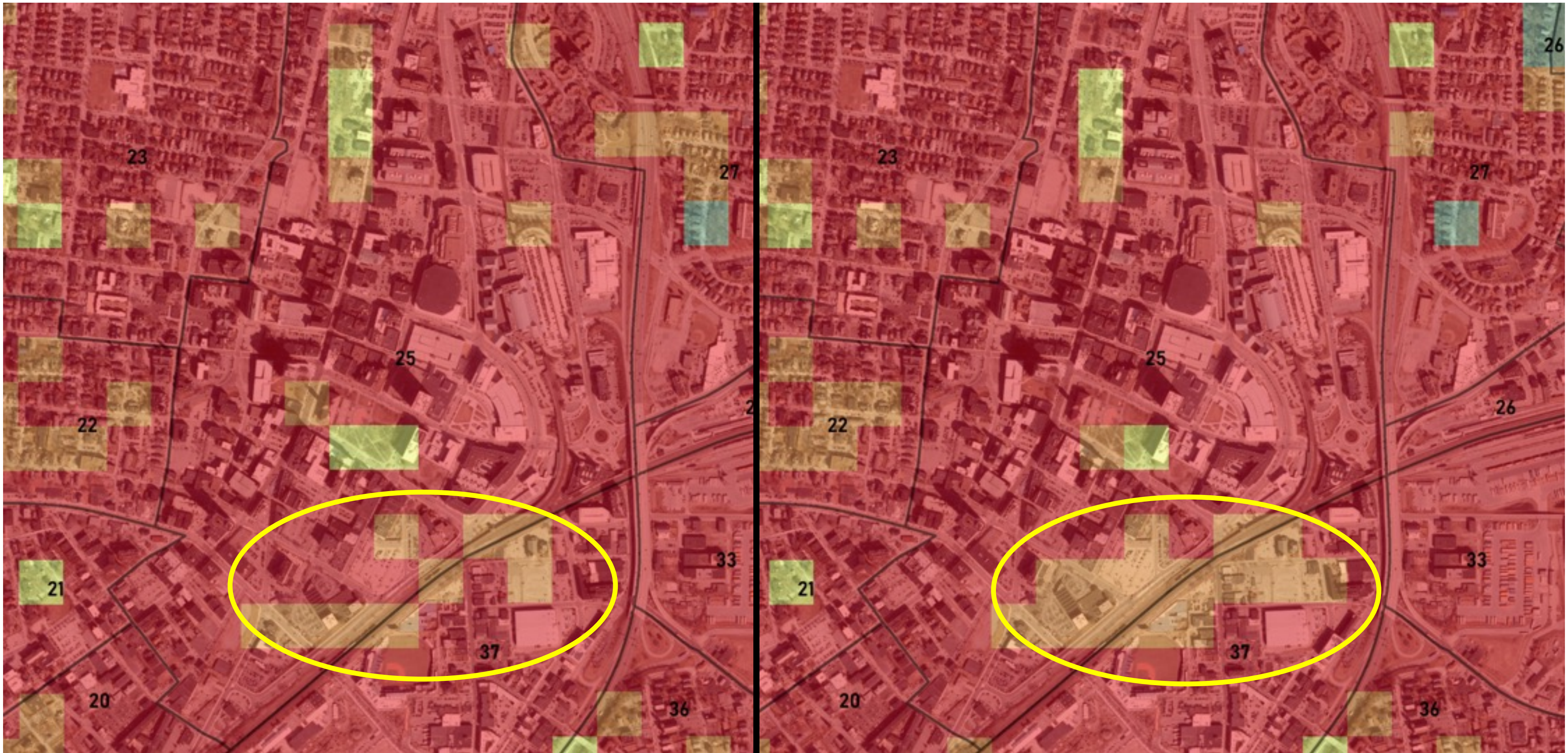


BASE SCENARIO

< 70 °F | 70-71 °F | 71-73 °F | 73-74 °F | 74-80 °F

An increase in the reflectivity of paved surfaces and rooftops has the general effect of increasing air temperatures where tree canopy is extensive and reducing temperatures where canopy is sparse. The overall trend was toward more warming than cooling.

ALBEDO SCENARIO

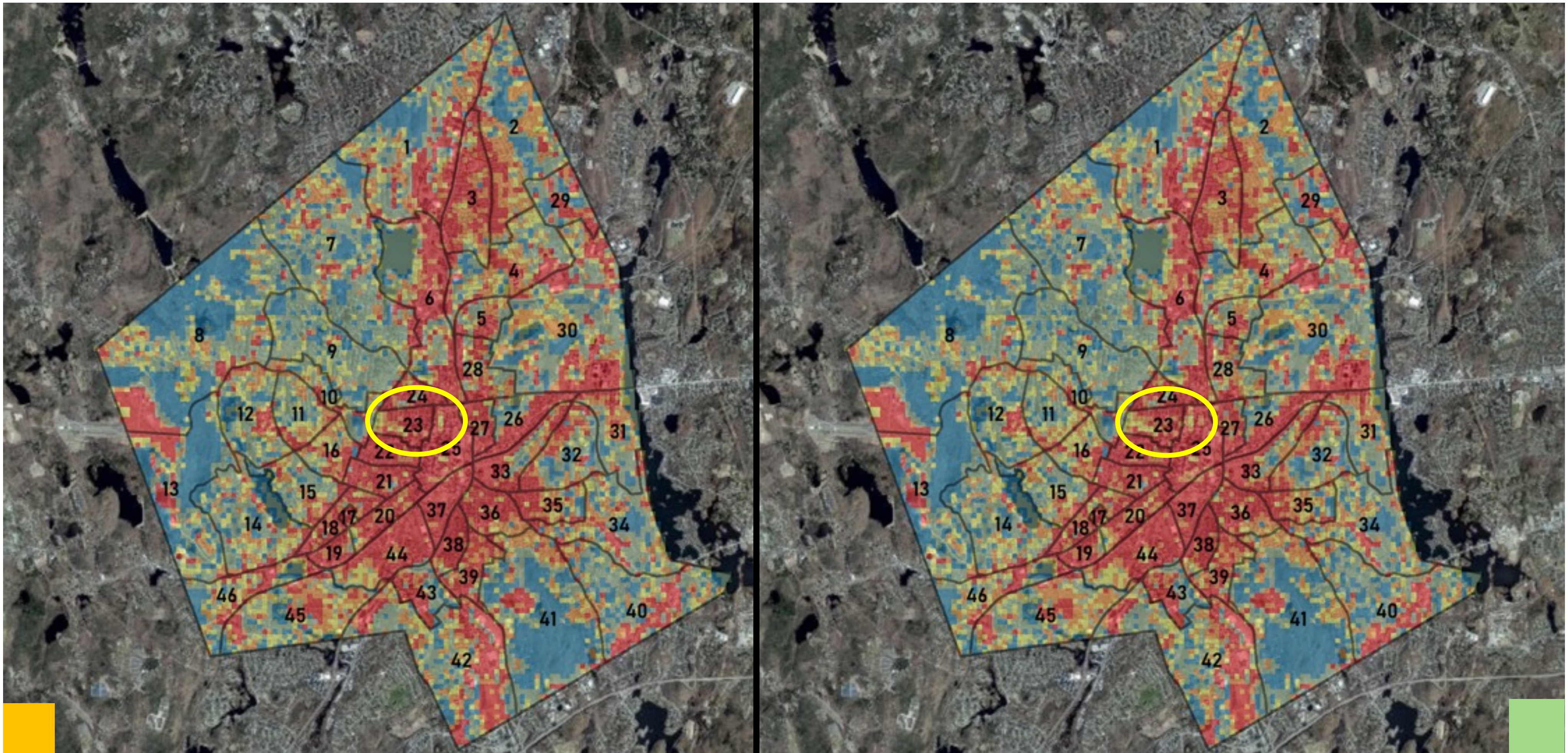


BASE SCENARIO

< 70 °F | 70-71 °F | 71-73 °F | 73-74 °F | 74-80 °F

Increased reflectivity of paved surfaces and rooftops yields modest cooling in areas with extensive surface parking.

ALBEDO SCENARIO

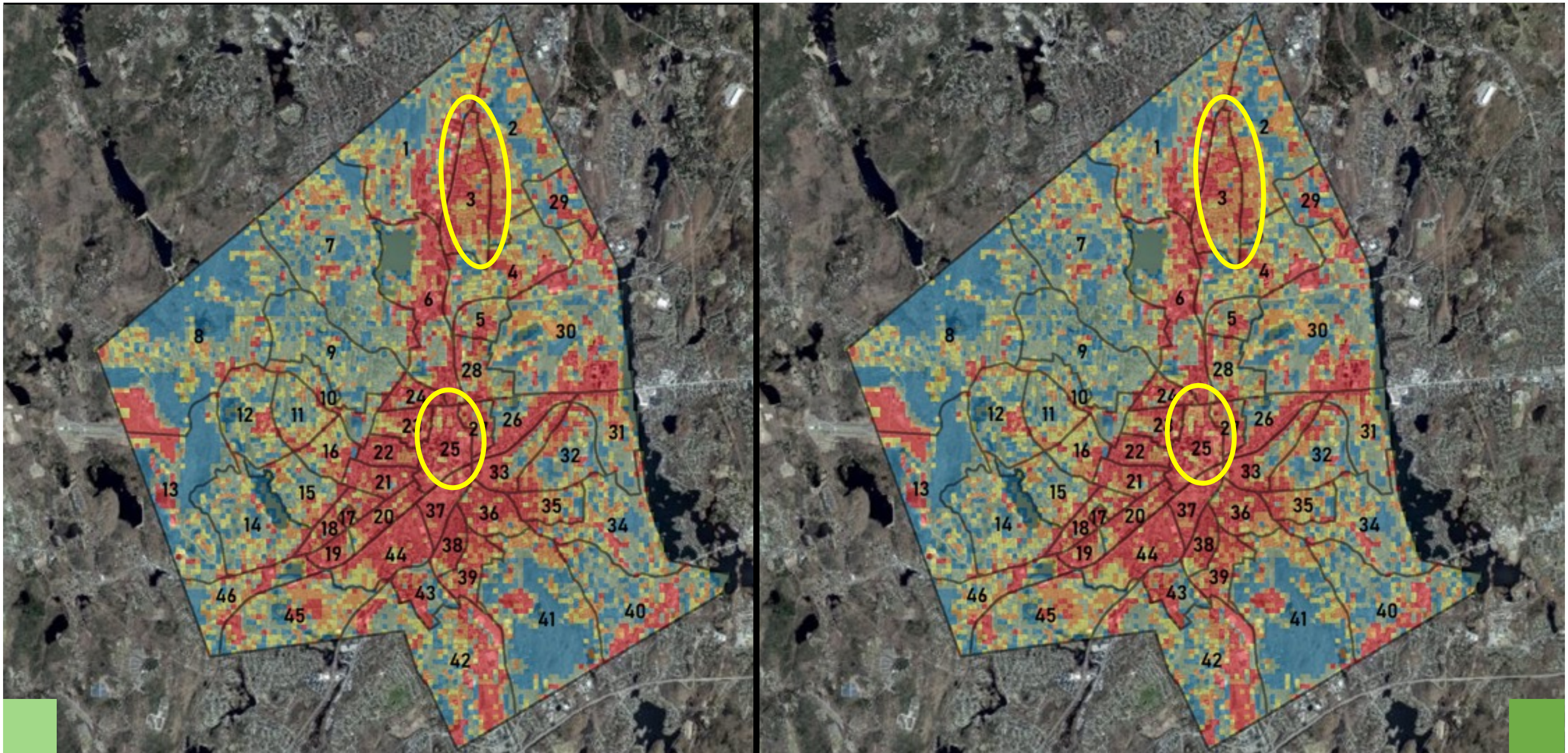


BASE SCENARIO

<70 °F | 70-71 °F | 71-73 °F | 73-74 °F | 74-80 °F

The STREET TREE (15%) scenario is most effective in reducing temperatures along large roadways and in high density zones.

STREET TREE (15%) SCENARIO

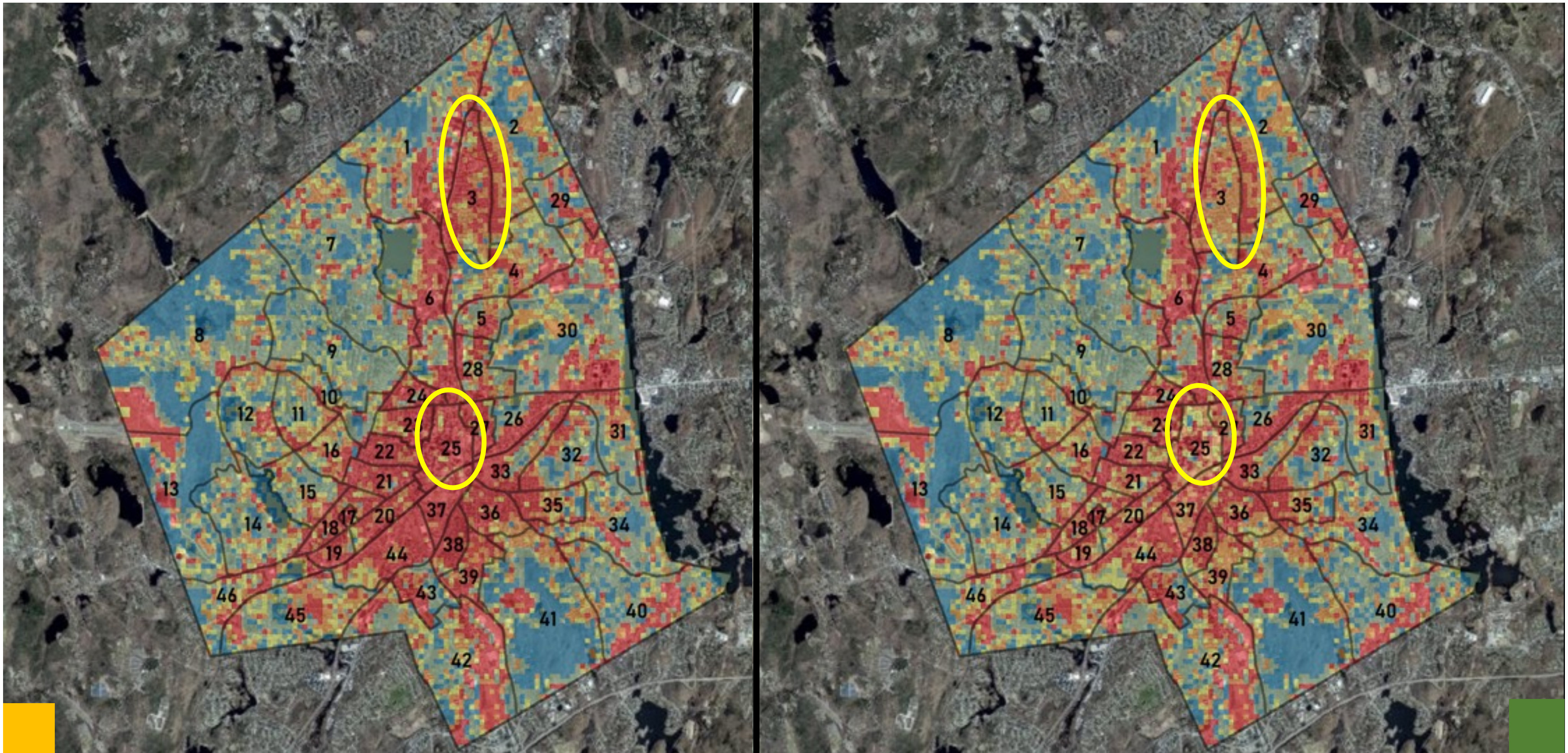


STREE TREE (15%) SCENARIO

< 70 °F | 70-71 °F | 71-73 °F | 73-74 °F | 74-80 °F

The STREET TREE (25%) scenario yields more significant cooling in high density zones across the city.

STREET TREE (25%) SCENARIO

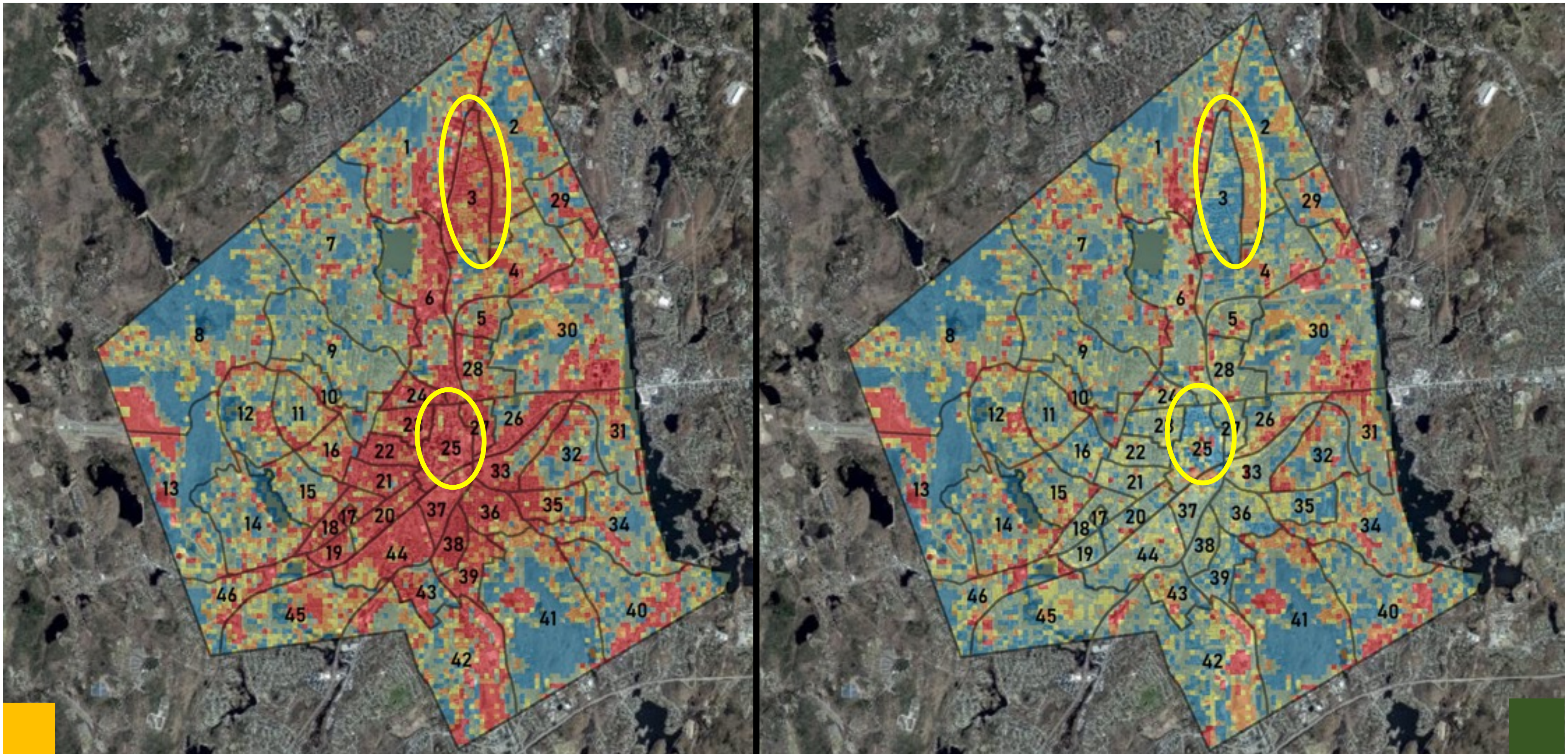


BASE SCENARIO

< 70 °F | 70-71 °F | 71-73 °F | 73-74 °F | 74-80 °F

An increase in tract-level tree canopy up to 25% for any tract exhibiting less than 25% canopy cover under current conditions substantially reduces air temperatures in the hottest zones of the City.

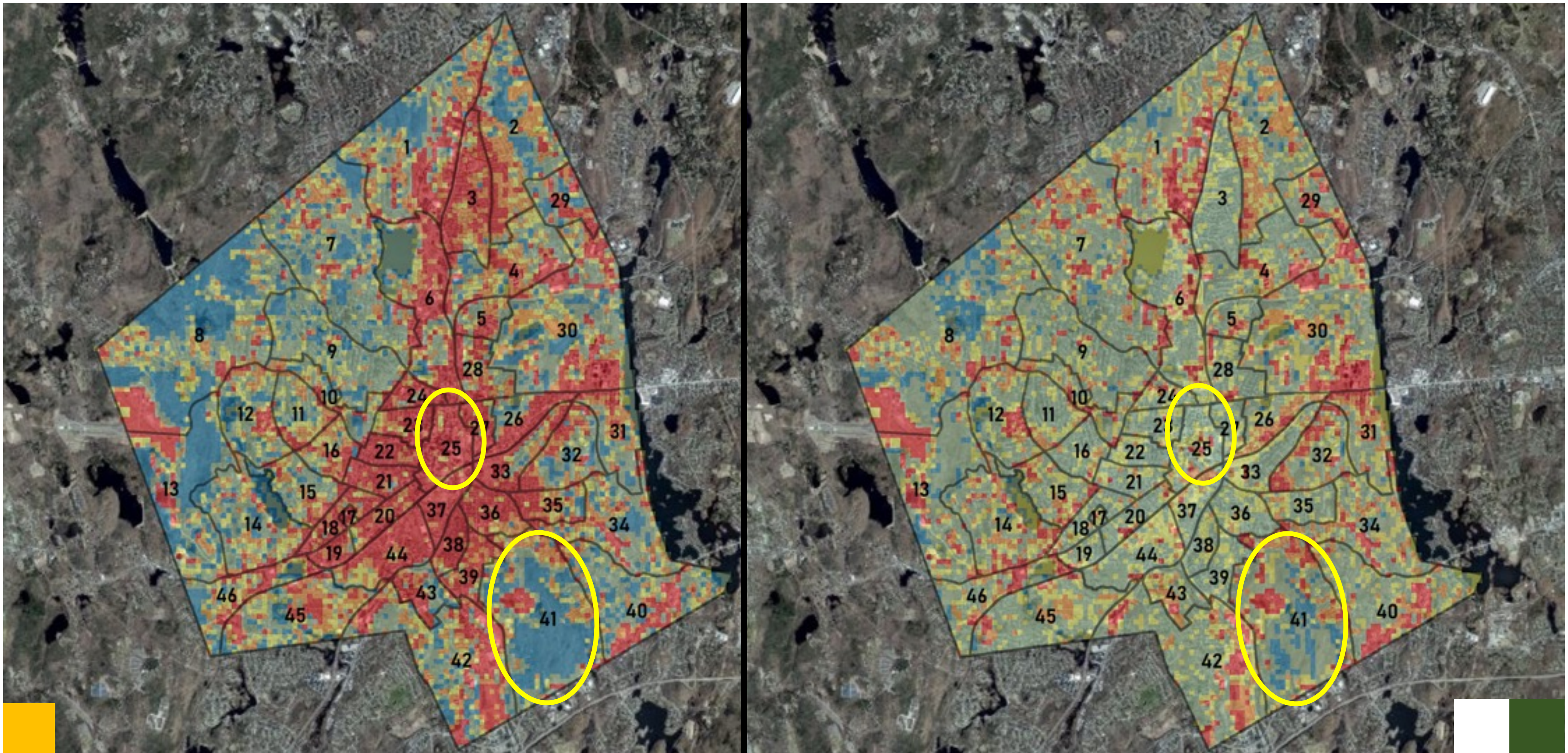
GREENING (25%) SCENARIO



BASE SCENARIO

An increase in tract-level tree canopy up to 50% for any tract exhibiting less than 50% canopy cover under current conditions largely mitigates the city's urban heat island and yields cooling up to 10 °F.

GREENING (50%) SCENARIO



BASE SCENARIO

< 70 °F | 70-71 °F | 71-73 °F | 73-74 °F | 74-80 °F

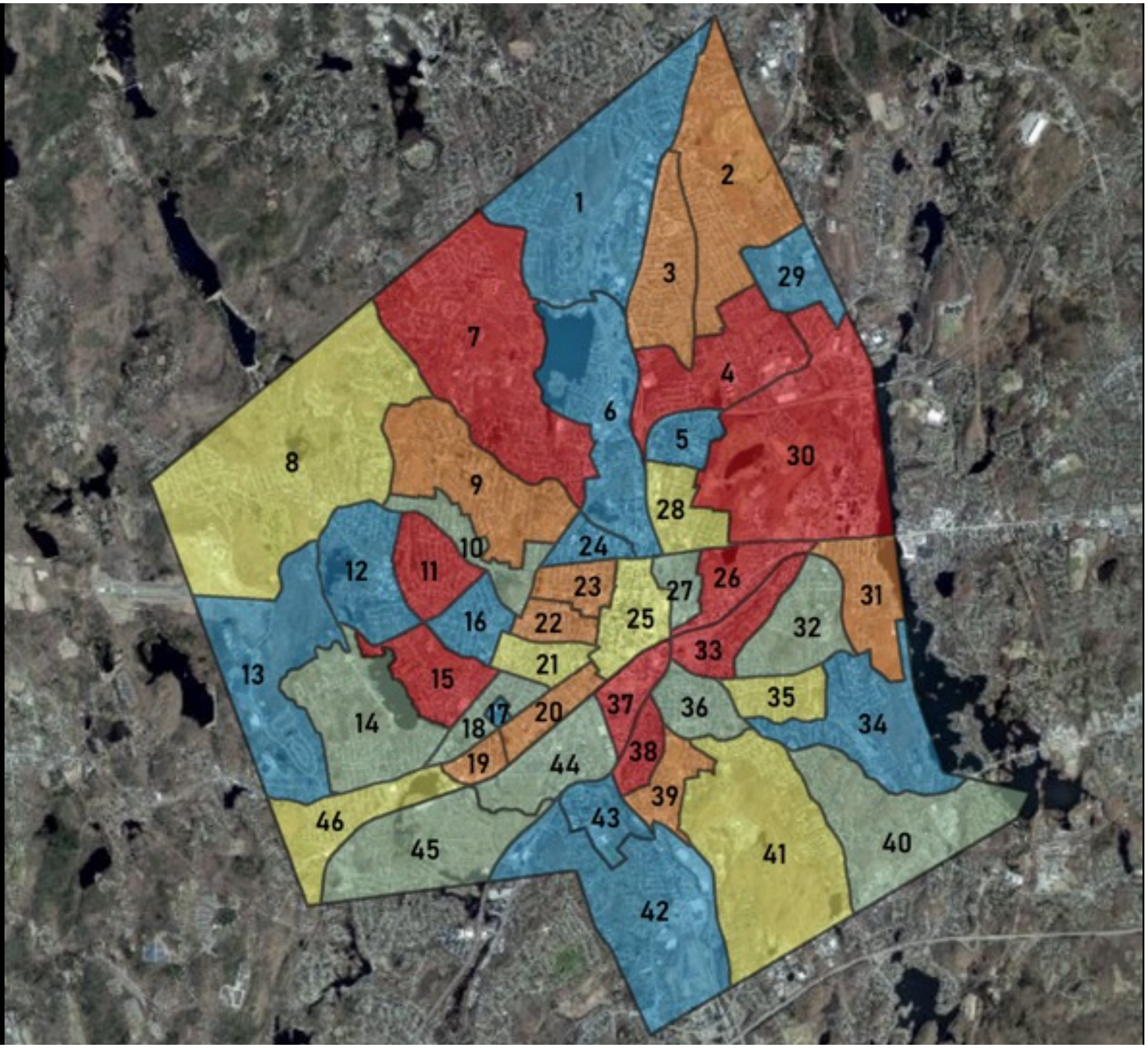
The combination of tree planting and enhanced surface reflectivity has the effect of generally lowering temperatures in the urban center and elevating temperatures in heavily canopied tracts.

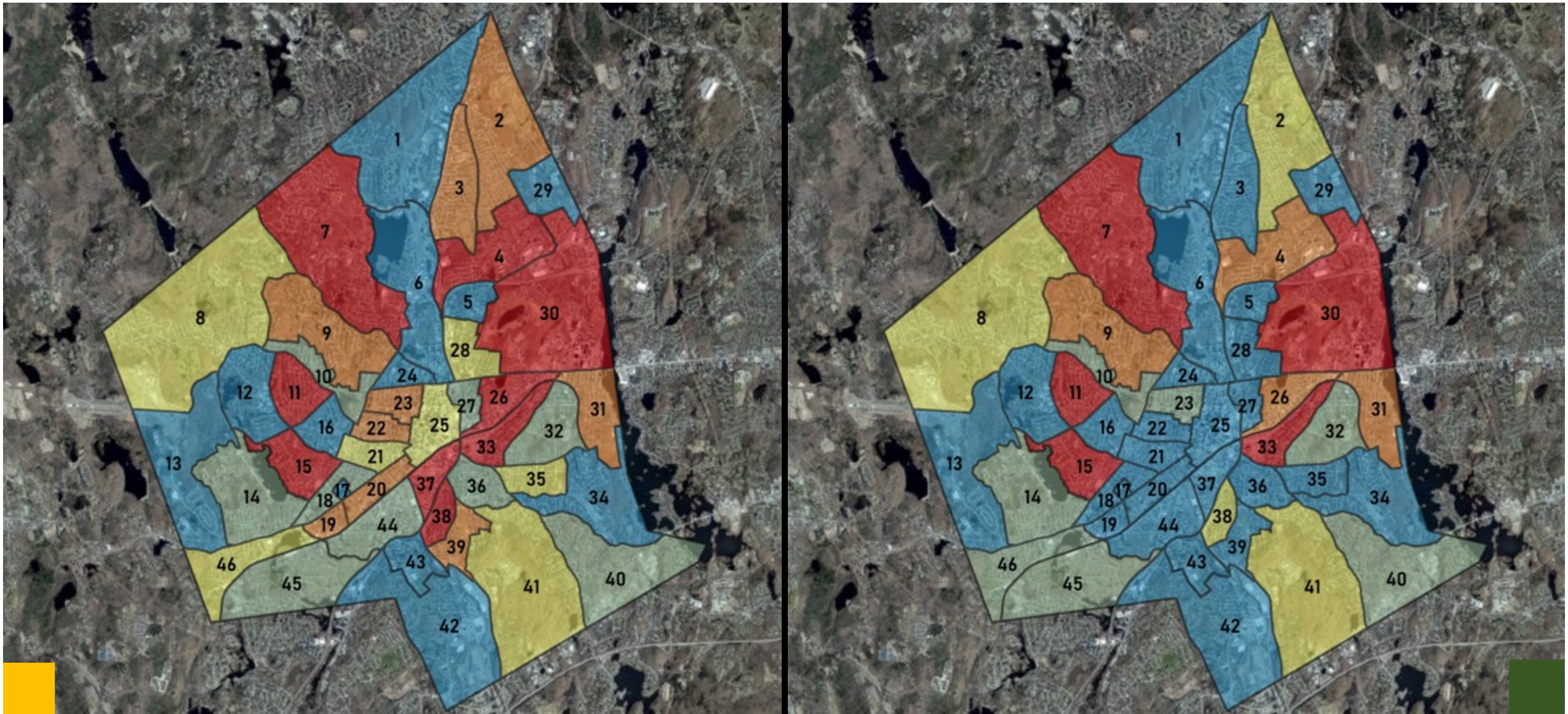
ALL COMBINED SCENARIO

The zones with the highest rate of heat mortality are found in both the City center and outer-lying census tracts. Tracts with relatively low heat exposure, such as 7, 11, and 15 exhibit high heat mortality due to a greater share of elderly population than other neighborhoods. Total heat-related mortality for the summer of 2020 is estimated at 8 deaths. The number of hospital visits for heat-related illness has been found in prior work to range from about 15-40 times the number of deaths, or approximately 120-320 emergency department visits in Worcester for the summer of 2020.

BASE SCENARIO

Heat-Related Mortality
by Census Tract (per 100,000)





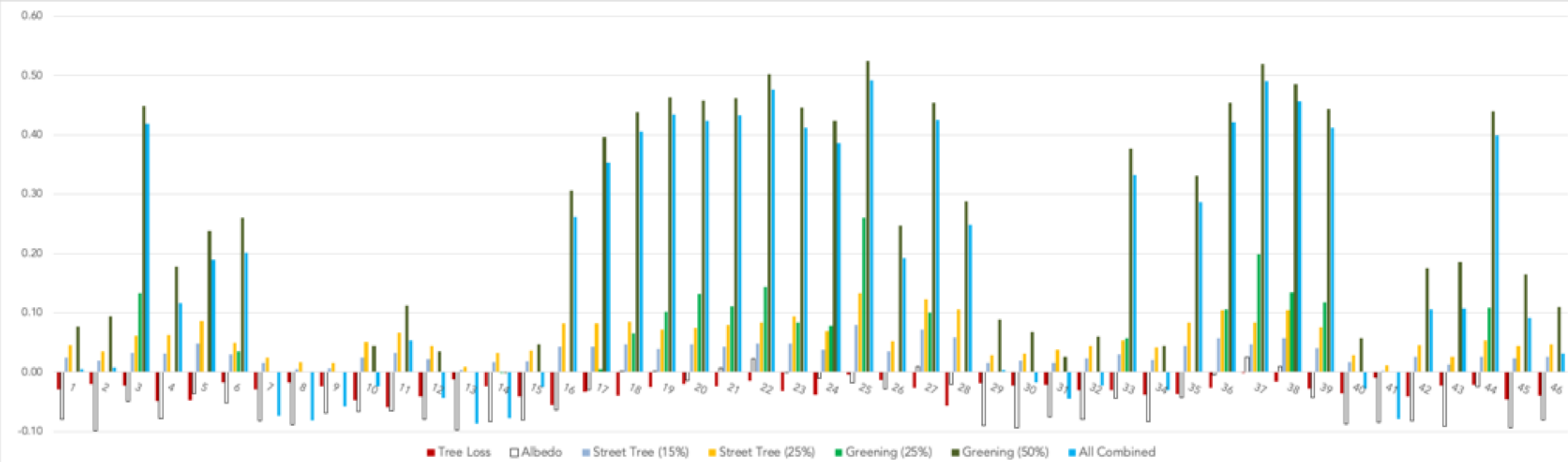
BASE SCENARIO

>3 3-4 4-5 5-6 6-10

The GREENING (50%) scenario reduces citywide heat mortality by 23%, with tract level reductions as high as 52%.

GREENING (50%) SCENARIO

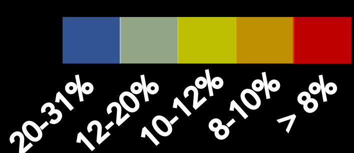
Reduction in heat-related mortality relative to base case by scenario (%)

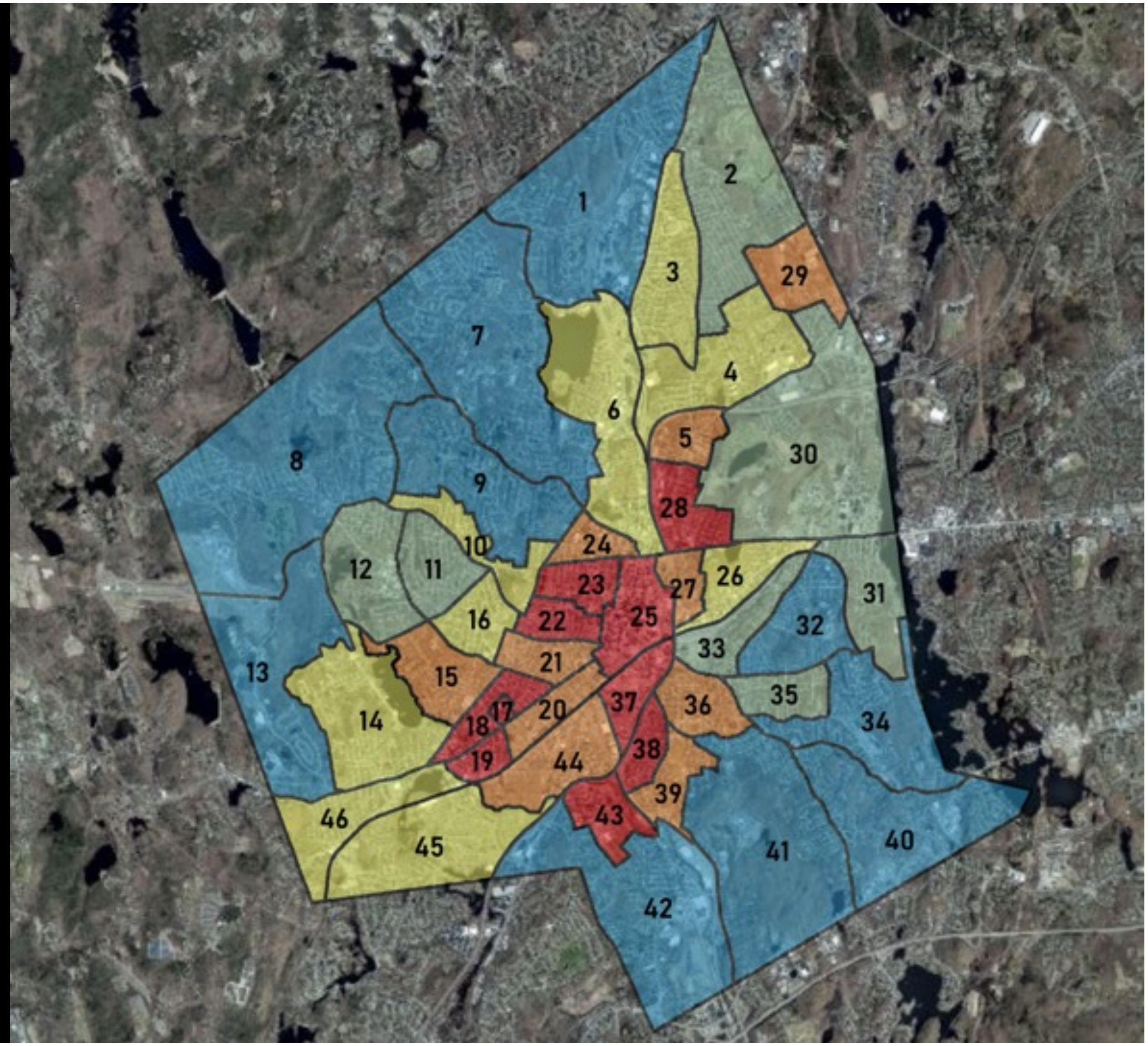


* Negative values indicate increase in mortality relative to base case

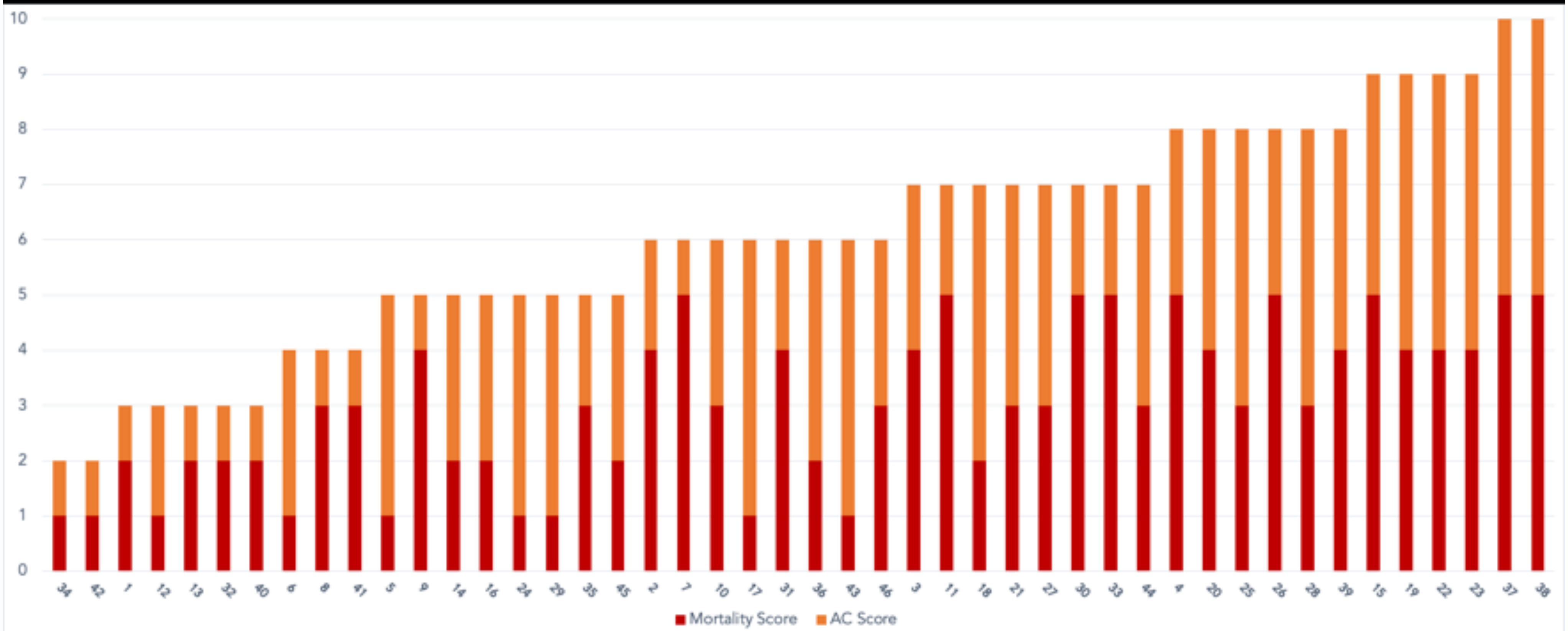
According to tax accessor records, the average prevalence of central air conditioning across all census tracts is 10%. The wide disparity between zones is suggestive of disparities in adaptive capacity for heat within the home. Driven by outdoor temperatures only, the mortality estimates are not reflective of household adaptive capacity.

AC Prevalence
by Census Tract



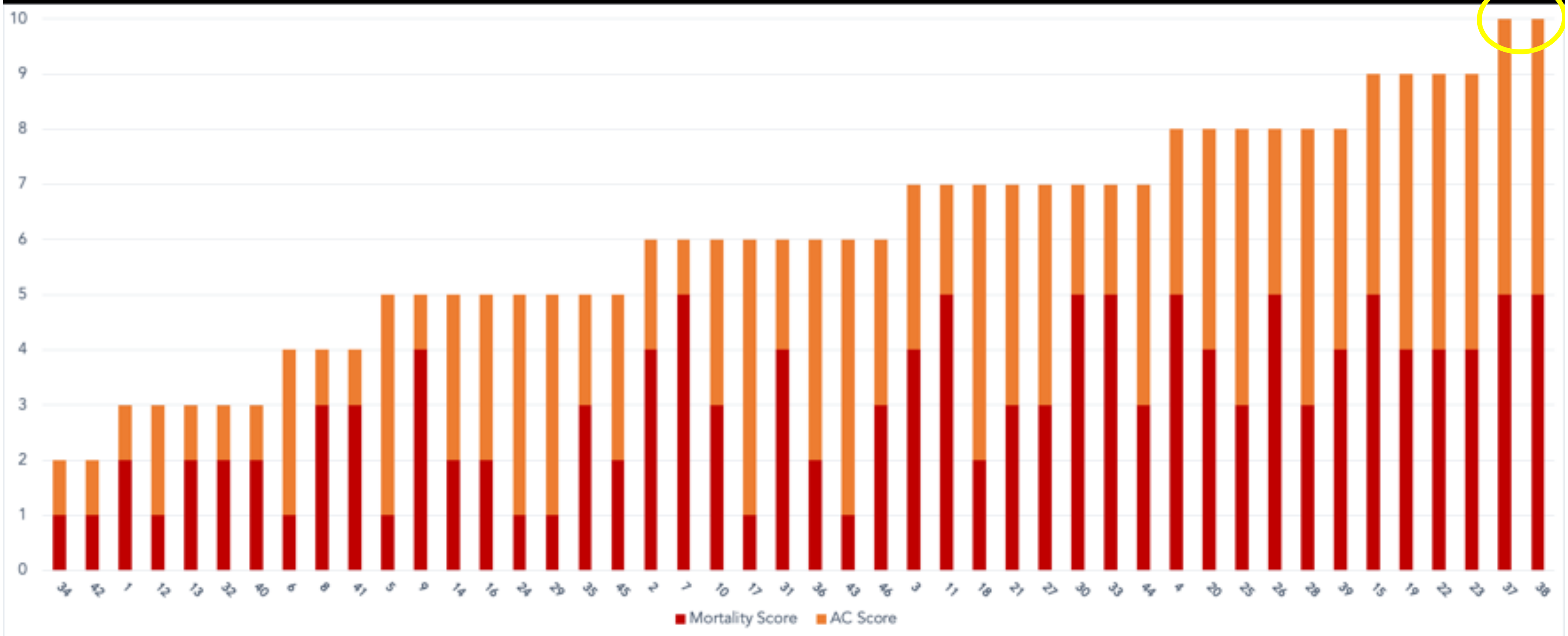


Total Heat Vulnerability Score by Census Tract



The mortality and AC scores are based on quintile rankings of tract-level heat mortality rate (per 100,000 population) and central AC prevalence (% of all parcels). Total heat vulnerability by tract is computed by summing the mortality and AC prevalence rankings (1 through 5, with 5 indicating the highest level of estimated heat mortality or the lowest level of AC prevalence). Higher total scores indicate higher levels of exposure and sensitivity combined with lower levels of adaptive capacity for heat stress.

Total Heat Vulnerability Score by Census Tract

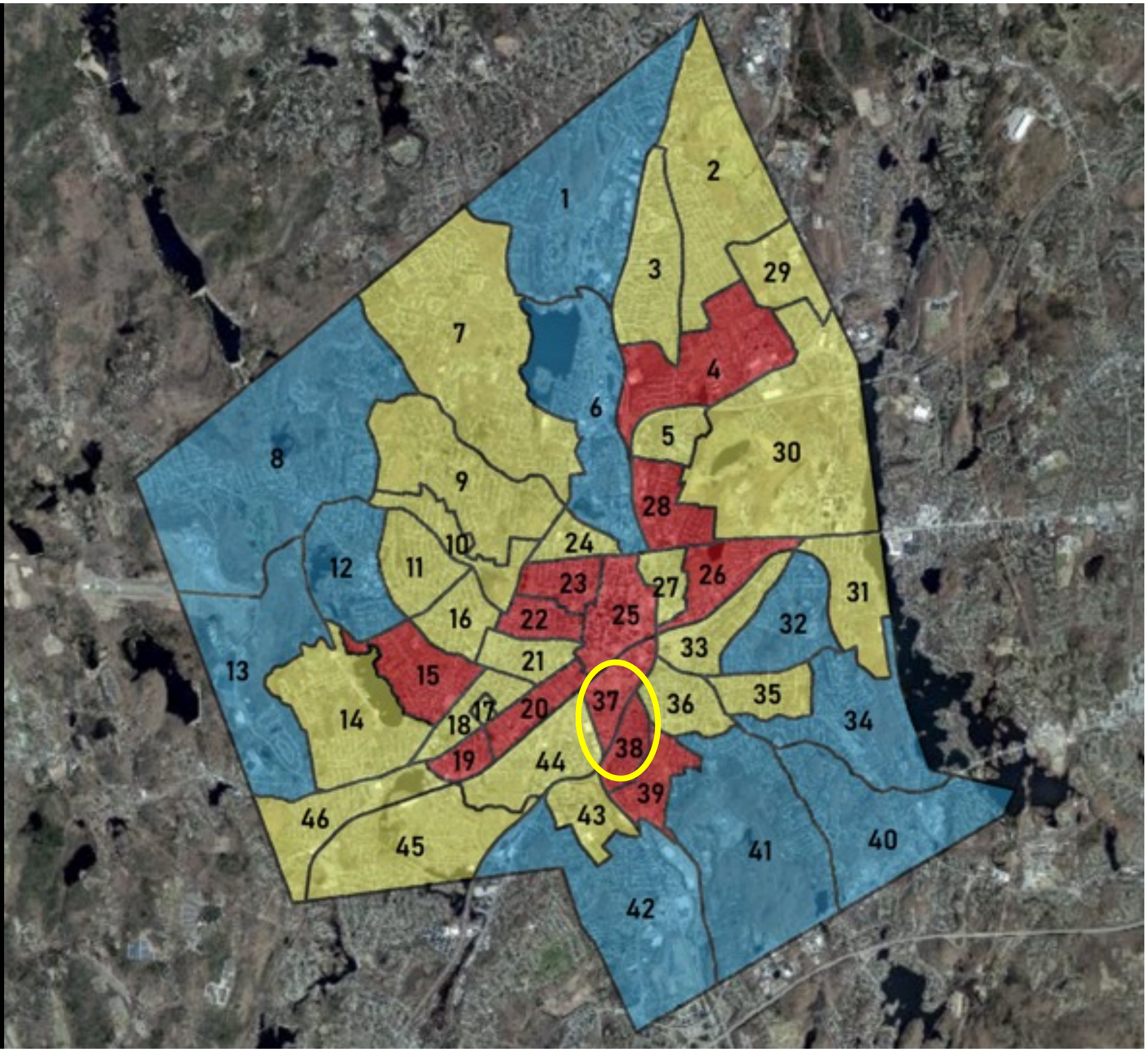


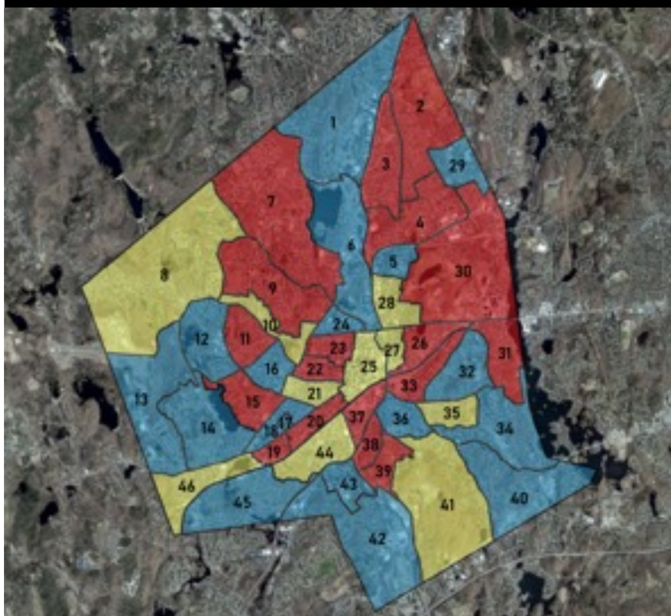
Tracts 37 and 38 exhibit the highest total heat vulnerability across the City. Both tracts are characterized by the highest level of heat mortality and the lowest level of AC prevalence.

Total heat vulnerability, when classified into low, medium, and high zones, shows centralized and higher density tracts to exhibit the highest total levels of heat vulnerability, on average.

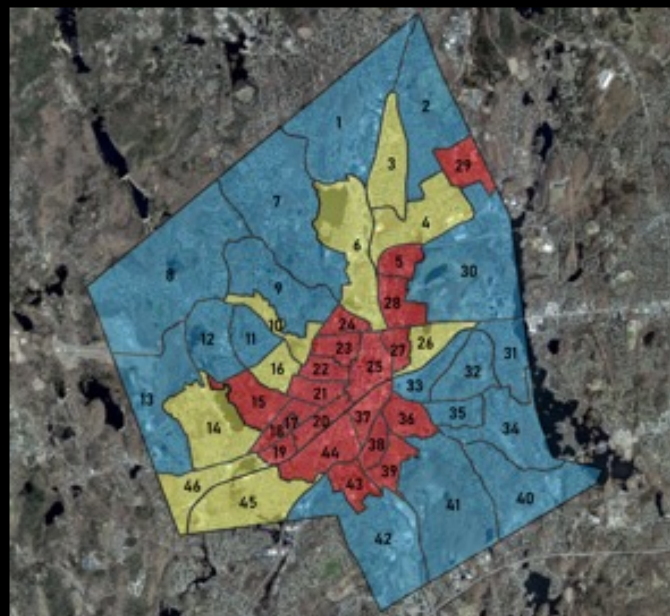
Total Heat Vulnerability

- Low
- Medium
- High

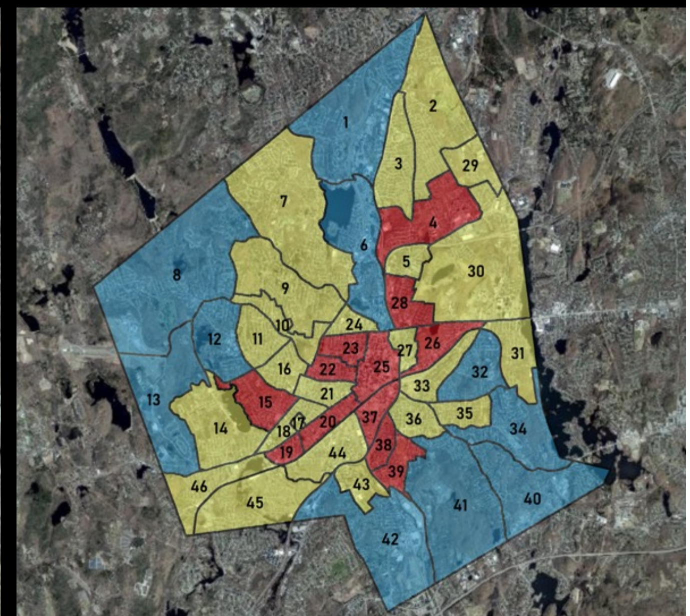




Heat Exposure + Sensitivity Score



Adaptive Capacity Score



Total Vulnerability Score

Overall heat risk does not fully align with estimated mortality rates for heat. Despite relatively high levels of estimated heat mortality, Tract 7, for example, is scored has having moderate total risk, while Tract 43, with a low mortality score, also is found to exhibit a moderate level of heat risk when accounting for adaptive capacity.

Land Cover Change by Scenario

Tract #	Tree Loss	St Tree (15%)	St Tree (25%)	Greening (25%)	Greening (50%)	Paving Albedo (m^2)	Roof Albedo (m^2)
20	(37)	66	114	211	779	3,728,830	1,582,681
21	(34)	80	138	210	747	3,887,576	1,576,352
22	(25)	82	140	226	693	3,709,111	1,499,196
23	(42)	76	131	129	658	3,757,247	1,507,075
24	(31)	54	94	113	527	3,043,385	1,354,658
25	(20)	200	335	661	1,520	8,073,958	3,746,655
26	(110)	104	182	-	714	5,449,660	1,758,076
27	(29)	81	137	128	541	3,070,037	919,323
28	(107)	115	202	-	708	5,277,110	2,072,912
29	(168)	64	107	-	382	3,001,672	979,898
30	(952)	271	488	-	1,409	15,226,678	4,831,259
31	(249)	71	147	-	123	4,168,632	1,462,814
32	(295)	102	186	-	291	4,807,072	1,938,320
33	(79)	73	129	159	1,083	5,777,631	1,480,165
34	(488)	164	303	-	367	7,710,266	2,934,281
35	(81)	79	138	-	637	3,142,844	1,541,175
36	(55)	115	195	225	978	4,630,285	2,033,731
37	(11)	120	202	505	1,117	4,908,338	1,692,300
38	(27)	94	159	212	687	3,241,312	1,296,964
39	(44)	81	139	246	925	3,338,703	1,367,317
40	(564)	153	274	-	746	9,624,652	3,259,707
TOTAL*	(14,988)	5,674	10,274	4,706	33,890	290,122,271	107,913,188

*Totals reported for all 46 Census Tracts

Recommendations

1. Increase total tree canopy across Worcester by 30,000 – 35,000 trees. Tree investments should be prioritized in tracts with a total vulnerability score of 8 or higher. All trees added by the City should be positioned to shade impervious surfaces.

2. Given the mixed benefits of cool roofing at high latitudes for overall building energy consumption, combined with the poor performance of cool materials for lessening ambient heat exposures, we do not recommend pursuing cool materials strategies without further analysis.

3. Assess the number and siting of cooling centers for extreme heat events. The greatest number of cooling centers per unit of population should be located in central census tracts with relatively lower levels of adaptive capacity. All cooling centers should be equipped with backup power generation and the capacity to operate during an extended blackout period.

4. Establish a citywide heat surveillance system with a density of at least 5 weather stations per census tract and real-time public reporting of weather conditions. Establish a program to evaluate the performance of heat management investments over time.