Change in Heat Vulnerability and Land-use Influence

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Introduction

This 1-year research is funded by the Connecticut Institute for Resilience & Climate Adaptation (CIRCA), as part of the Resilient Connecticut Project.

Main Objective: Understand the role of landscape changes on spatial-temporal variations to surface temperature.

- Classify the different types of landscapes considering form and permeability;
- Analyze land surface temperature data (LST), acquired from satellite images, to identify areas where heat islands are occurring;
- Understand the linkages between LST changes and landscape changes, to understand the relationship between temperature variation and land cover.

Case Study: Fairfield and New Haven Counties, Connecticut, USA

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Project Phases

Phase 1:

- **Short-term analysis of LST →** focus on a 5-year timeframe to understand the current conditions for the studied region.
- **Assist CIRCA to deploy temperature heat sensors→** indicate different landscape typologies to collect air temperature and humidity data to evaluate apparent temperature.

Phase 2:

- **Long-term analysis of LST and LULC →** look at 20 years into the past to understand the relationship between LULC and LST changes to interpret the appearance and/or intensification of urban heat islands.

Phase 3:

- **Establish urban heat island intensity metrics→** interpret relationships between findings from satellite and in-situ measurements and identify performance capacity of both measurement methods

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Methodology

Local Climate Zones (LCZ) classification framework (Stewart and Oke, 2012)

- Classification beyond land use and land cover.
- Analyze landscapes in 3D to visualize the morphology and permeability of space.
- Bridge between urban climatology and landscape architecture.

World Urban Database and Access Portal Tools (WUDAPT): www.wudapt.org

- Machine learning approach that uses Google Earth Pro and SAGA GIS to develop LCZ classification based on aerial images (Google and LANDSAT 8). → 2015-2019 for current conditions.

Google Earth Engine → remote sensing and surface urban heat island analysis

- Land Surface Temperature → Code based analysis using methodology and code developed by Ermida et al 2020.

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Results: Local Climate Zone Classification

LCZ 2: Compact Mid-Rise

Pervious Surface Fraction:
0-20%

Form:
Tightly packed buildings of 3 to 9 stories tall. Separated by narrow streets. Sky view from street level significantly reduced. Heavy building materials (stone, brick, tile). Thick roof and walls. Landcover mostly paved. Few or no trees. Moderate to heavy traffic flow.

Function and Location:
Residential (multi-unit housing, multi-story tenement). Commercial (office buildings, hotels, retail shops). Industrial (warehouses and factories) Core (old city, old town: inner city, central business district)

LCZ 5: Open Mid Rise

Pervious Surface Fraction:
20-40%

Form:
Open arrangement of buildings, 3-9 stories tall. Sky view from street level slightly reduced. Heavy building materials (concrete, steel, stone, glass) and thick roofs and walls. Scattered trees and abundant plant cover. Low traffic flow.

Function:
Residential (multi-unit housing, multi-story tenements, apartment blocks). Commercial (office buildings, hotels). Institutional (research/business parks, campuses)

Location:
Periphery

LCZ 6: Open Low Rise

Pervious Surface Fraction:
30-60%

Form:
Attached Small buildings, 1-3 stories tall; detached or attached in rows, often in a grid pattern. Sky view from street level slightly reduced. Building materials vary (wood, brick, stone, tile). Scattered trees and abundant plant cover. Low traffic flow

Function:
Residential (single or multi-unit housing, low density terrace/row housing). Commercial (small retail shops).

Location:
City (medium density). Periphery (suburbs).

LCZ 8: Large Low Rise

Pervious Surface Fraction:
0-20%

Form:
Large low buildings, 1-3 stories tall, separated by extensive paved surfaces. Buildings extend outward, not upward. Roofs are flat. Few or no trees. Landcover is mostly paved. Moderate to heavy traffic flow.

Function:
Light industrial (modern warehousing); Commercial (shopping centers, storage facilities).

Location:
Periphery

LCZ 9: Sparsely Built

Pervious Surface Fraction:
60-95%

Form:
Small or medium sized buildings, widely spaced across natural landscape. Full sky view from ground level. Building materials vary. Scattered trees and abundant plant cover. Low traffic flow

Function:
Residential (single or multi-unit housing). Commercial (retail shops, office buildings). Institutional (research/business parks, campuses); agricultural (farms, estates).

Location:
Periphery (low density suburbs). Extended metropolitan regions. Rural towns and lightly settled countryside.

LCZ 10: Heavy Industry

Pervious Surface Fraction:
40-50%

Form:
Highly irregular mix of low and midrise industrial structures (tanks, towers, stacks). Structures openly spaced on hard-packed surfaces. Sky view from ground level slightly reduced. Building materials vary (steel, concrete, metal). Few or no trees. Large quantieies of waste heat and atmospheric pollutants (smelting, pulping, distilling). Low flow traffic.

Function:
Industrial (factories, refineries, mills, plants).

Location:

101: Dense Trees

Pervious Surface Fraction:
95-100%

Form:
Heavily wooded landscape of deciduous and/or evergreen trees. Land cover mostly pervious.

Function and Location:
Residential (multi-unit housing, multi-story tenement). Commercial (office buildings, hotels, retail shops). Industrial (warehouses and factories) Core (old city, old town: inner city, central business district)

102: Scattered Trees

Pervious Surface Fraction:
95-100%

Form:
Lightly wooded, scattered trees and fields.

104: Low Plants

Pervious Surface Fraction:
95-100%

Form:
Featureless landscape of grass or herbaceous plants/crops/wetlands. Few or no trees.

107: Water

Pervious Surface Fraction:
95-100%

Form:
Water

LCZ classification framework applied to the state of Connecticut in accordance with Stewart and Oke (2012)

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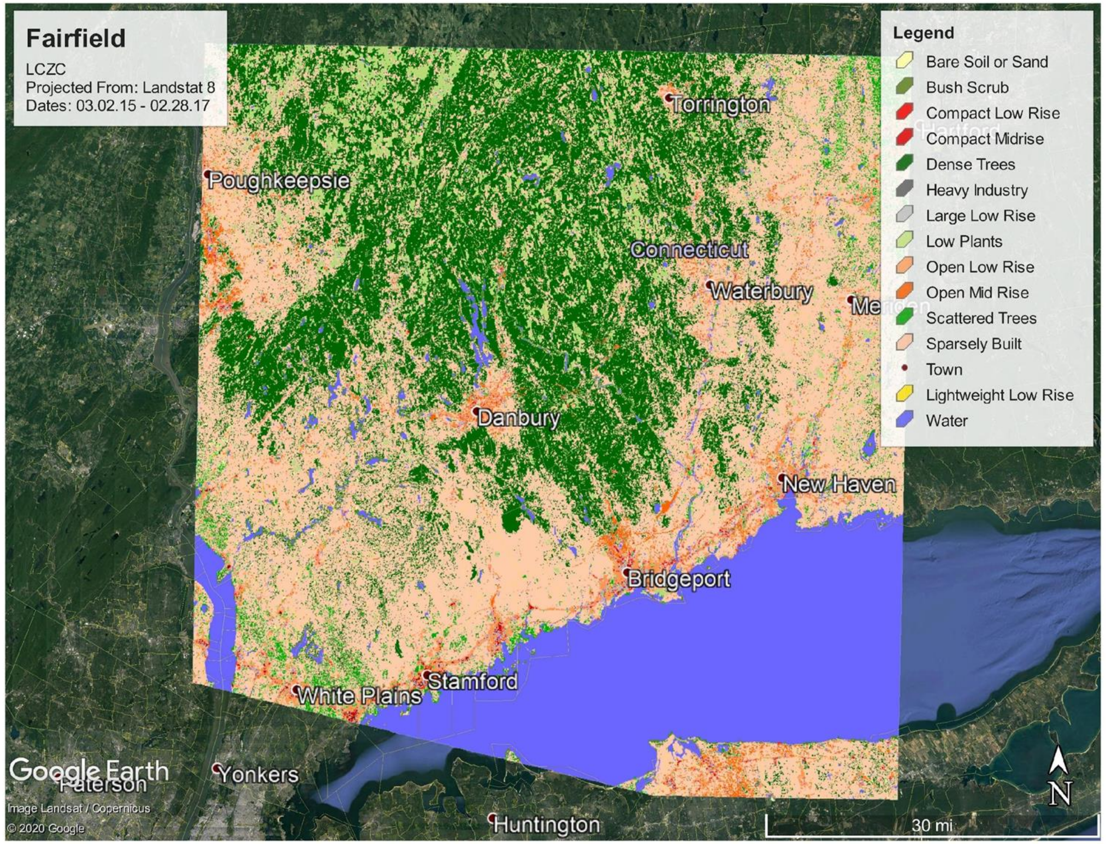
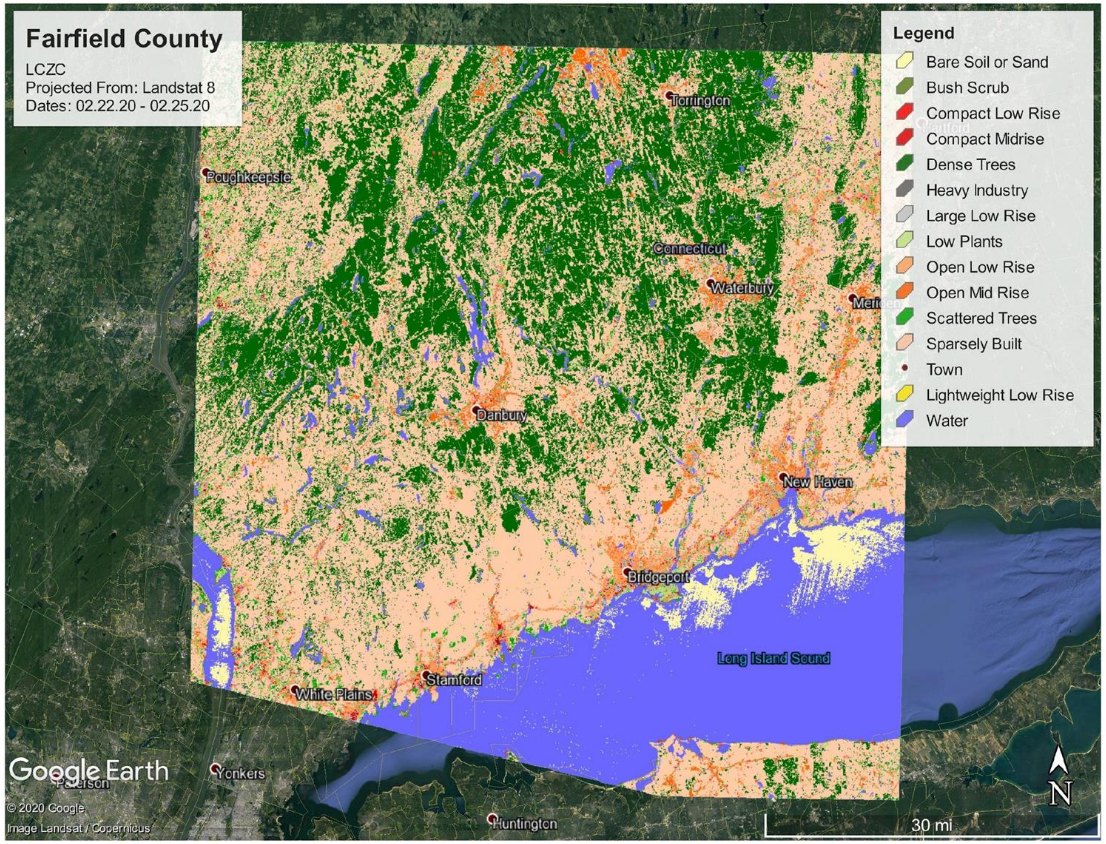
Results: Short-term Fairfield County



2015



2020

- Increase in human-based development in the Open Low Rise and Open Mid-Rise categories (orange colors above).
- Increase in the Sparsely Built category (peach color above).

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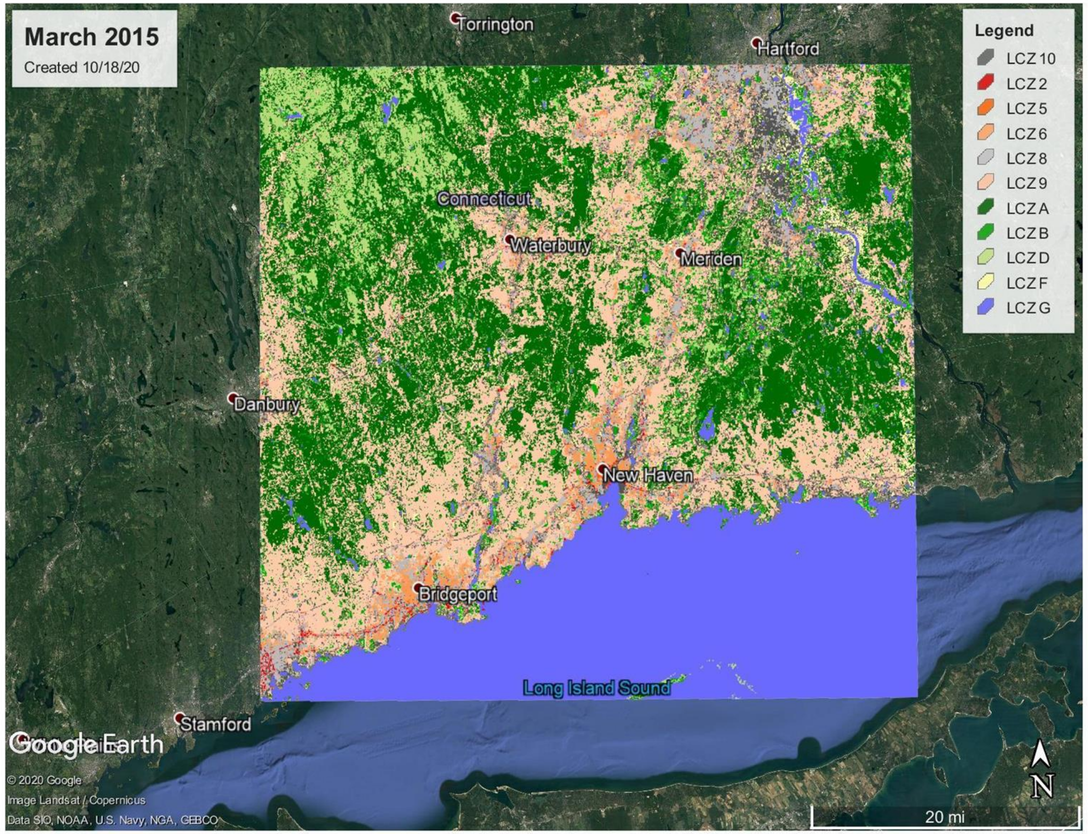
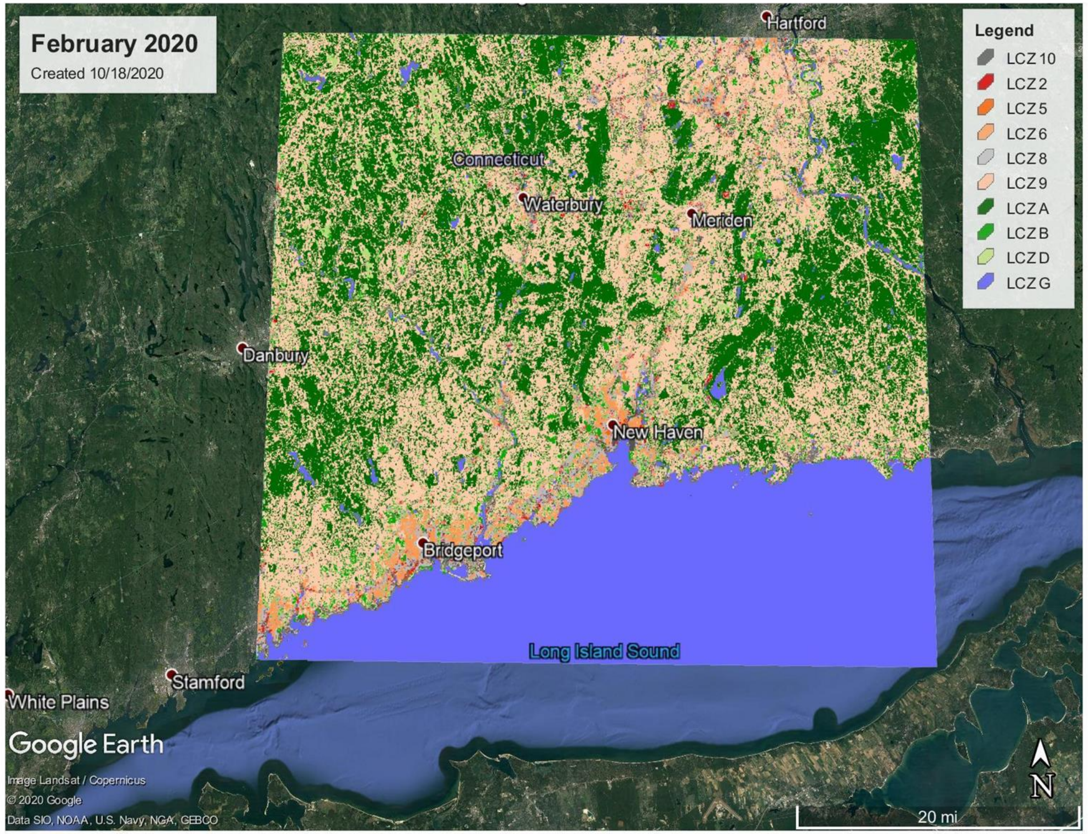
Results: Short-term New Haven County



2015



2020

- Increase in human-based development in the Open Low Rise and Open Mid-Rise categories (orange colors above).
- Increase in the Sparsely Built category (peach color above).

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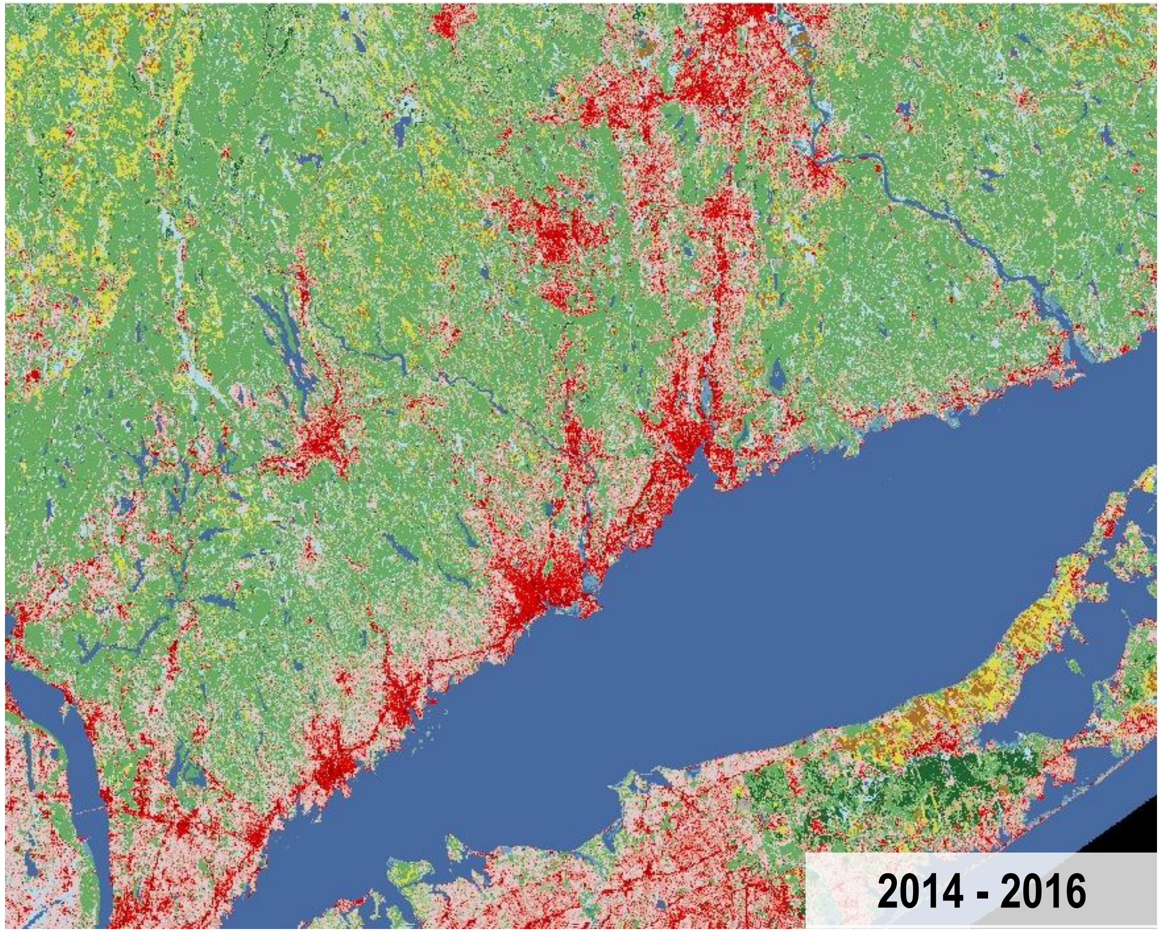
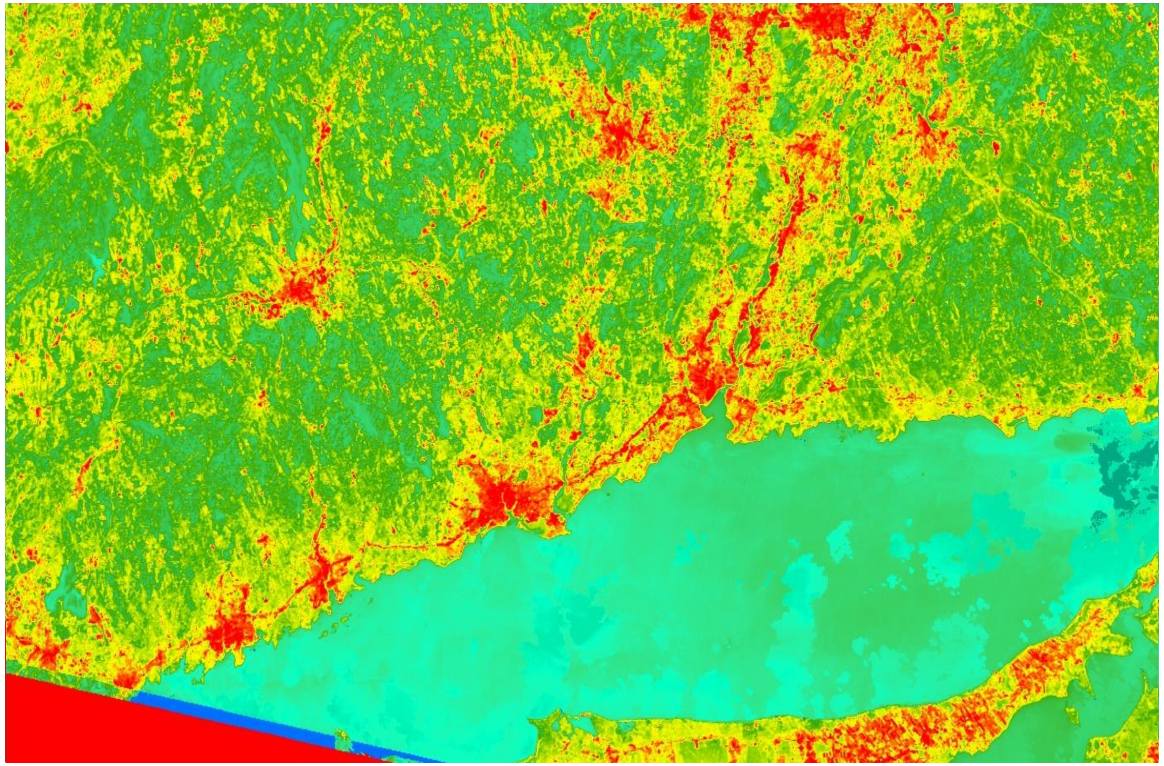
Results: Long-term Analysis

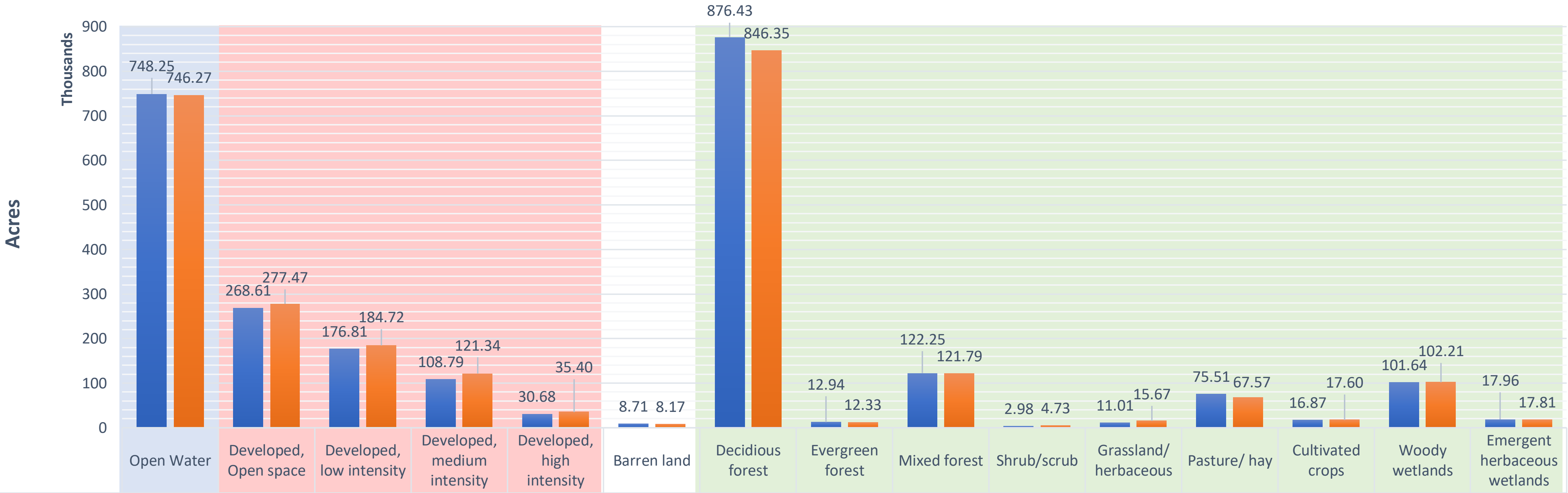




2014 - 2016

Results: Land Cover Changes

Land Cover Changes in Fairfield and New Haven Counties, CT (2001-2016)



	Open Water	Developed, Open space	Developed, low intensity	Developed, medium intensity	Developed, high intensity	Barren land	Decidious forest	Evergreen forest	Mixed forest	Shrub/scrub	Grassland/ herbaceous	Pasture/ hay	Cultivated crops	Woody wetlands	Emergent herbaceous wetlands
Total Area 2001	748247.35	268606.87	176811.20	108793.40	30677.84	8708.16	876425.75	12935.86	122251.88	2979.26	11008.96	75508.42	16866.12	101641.56	17964.29
Total Area 2016	746268.88	277465.97	184715.74	121342.23	35396.16	8166.41	846353.01	12328.09	121794.17	4728.32	15671.71	67574.75	17601.49	102205.76	17814.23
Loss (-)/ Gain (+)	**-0.27**	**+3.19**	**+4.28**	**+10.34**	**+13.33**	**-6.63**	**-3.55**	**-4.93**	**-0.38**	**+36.99**	**+29.75**	**-11.74**	**+4.18**	**+0.55**	**-0.84**

Land Cover Types

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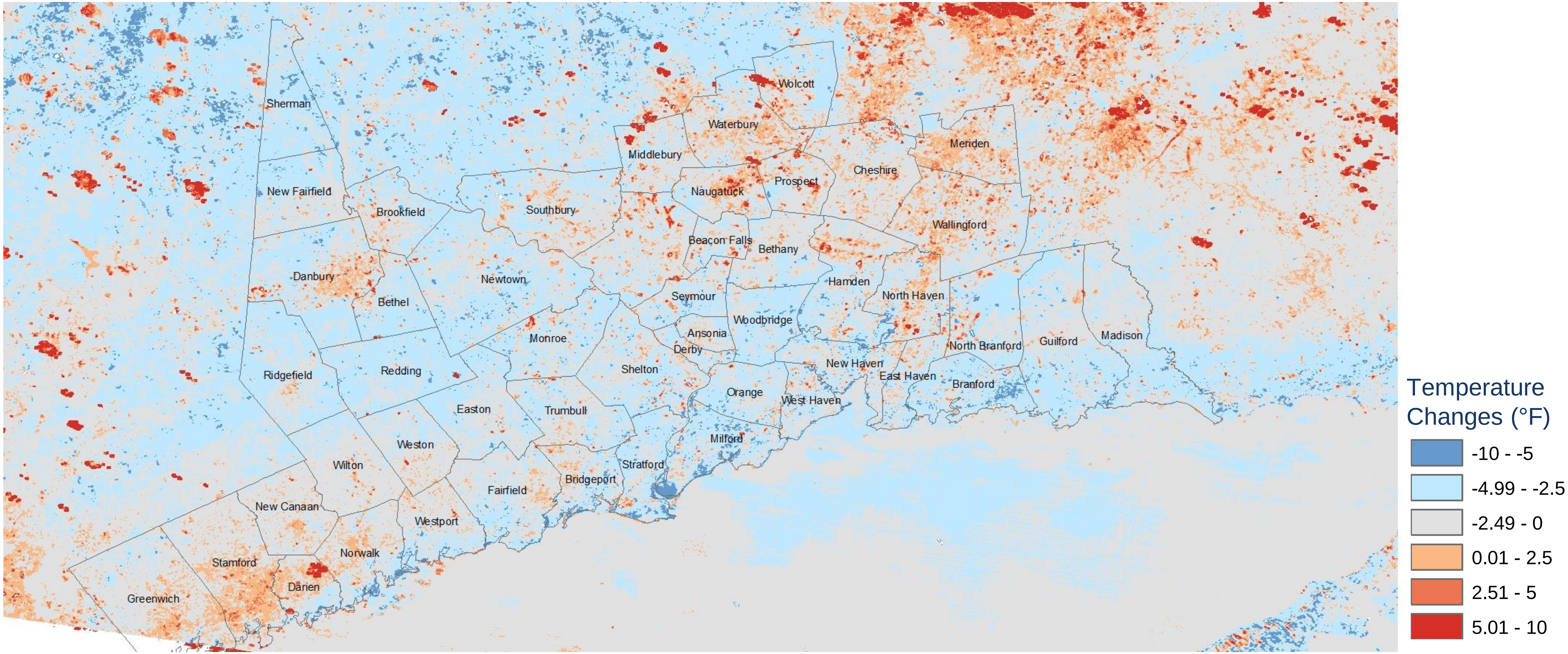
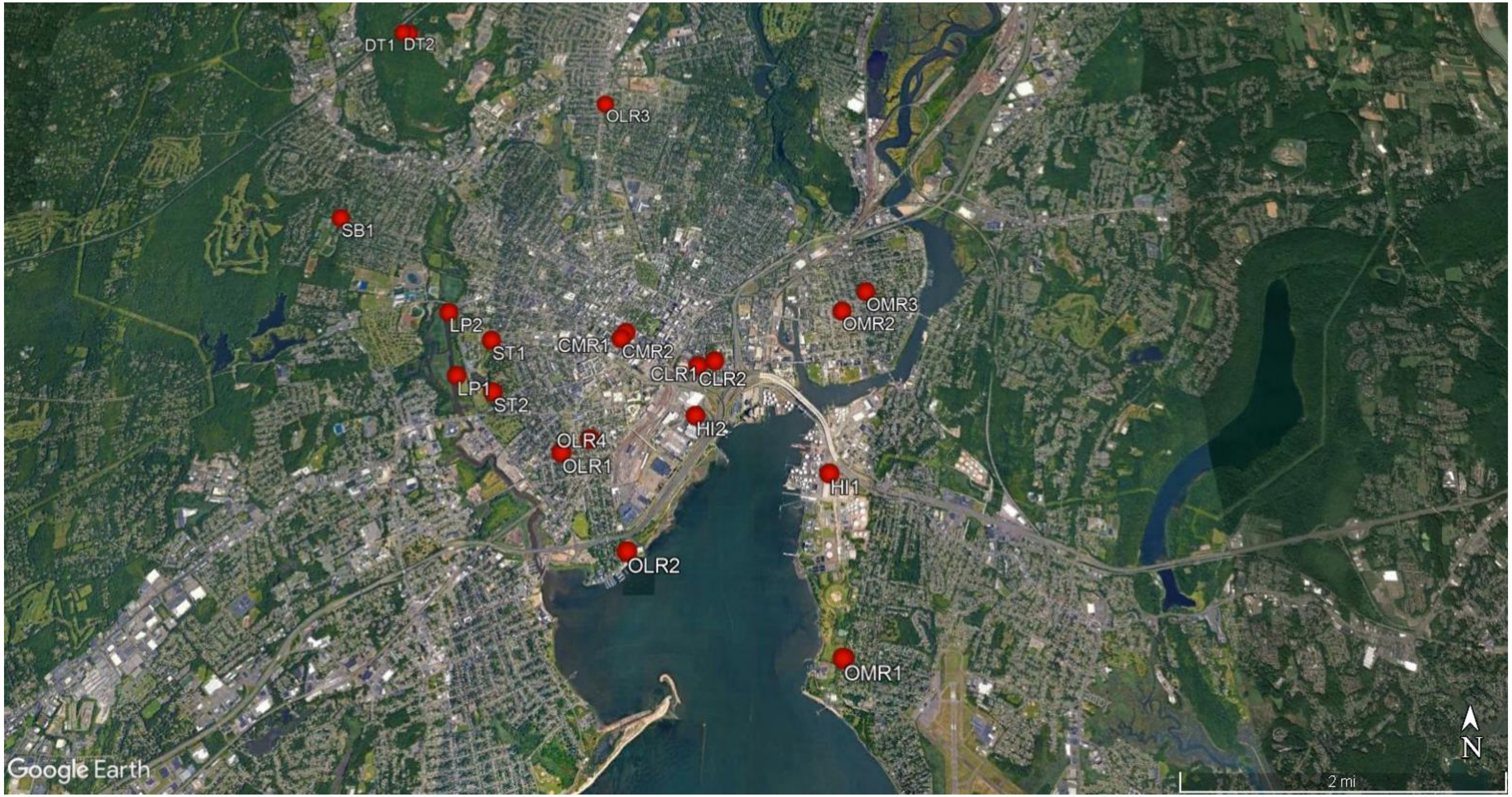
Results: LST Changes



Land surface temperature change between 1999 - 2020

Results: Heat Sensor Network



Sensor network composed of 20 sensors.

Deployed in August 2020, with consistent data retrieved between August and October 2020.

New round of analysis will be done for 2021.

Heat and humidity sensor network deployed in New Haven.

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Results: In-Situ Sensors

	Local Climate Zone	Sensor	Mean			Maximum		
			Air Temperature	Relative Humidity	Heat Index	Air Temperature	Relative Humidity	Heat Index
Developed	Heavy Industrial	HI1	74.59	71.78	75.82	92.54	100.00	102.00
		HI2	76.11	66.68	77.35	97.81	97.36	103.00
	Compact Mid-Rise	CMR1	74.91	68.52	76.02	91.94	97.16	97.00
		CMR2	74.96	68.29	76.04	92.11	96.38	97.00
	Open Mid-Rise	OMR1	73.88	73.86	75.09	92.38	100.00	101.00
		OMR2	75.18	69.36	76.43	96.65	100.00	104.00
		OMR3	75.02	69.27	76.20	94.25	99.35	100.00
	Compact Low Rise	CLR1	75.20	68.74	80.41	94.39	99.78	101.00
		CLR2	74.76	69.84	80.07	96.65	100.00	101.00
	Open Low Rise	OLR1	74.58	70.63	80.13	93.69	100.00	100.00
		OLR2	73.99	73.03	79.74	93.1	73.03	97.00
		OLR3	73.87	72.00	80.17	92.13	100.00	100.00
		OLR4	74.53	70.15	80.09	92.25	99.56	100.00
Vegetated	Sparsely Built	SB1	73.76	71.83	80.37	93.56	100.00	100.00
	Low Plants	LP1	73.49	74.34	80.23	92.98	100.00	101.00
		LP2	73.23	76.46	81.10	94.39	100.00	105.00
	Scattered Trees	ST1	74.42	71.29	80.60	96.38	100.00	106.00
		ST2	74.29	71.14	75.44	93.69	100.00	102.00
	Dense Trees	DT1	71.66	79.13	72.75	89.23	100.00	96.00
		DT2	72.17	75.59	76.02	88.71	100.00	96.00

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Discussion

This project shows the impacts of Land Cover Changes on Land Surface Temperature in the last 20 years in Connecticut.

- **Short-term analysis →** indicates variations in types of urban landscapes and aids in the understanding of the trends of urbanization in the last 5 years.
    - **Future expansion:** Is this trend true for the entire state?
- **Long-term analysis →** the gain of vegetation cover shows signs of cooling, yet intensification and expansion of urban heat islands have occurred in the west and inland in both counties.
    - **Future expansion:** How do these changes relate to policies and town planning? Is there a similar trend in the entire state?
- **New Haven Heat Sensor Network→** compliment the study by indicating the localized variability of air temperature and humidity in existing landscape typologies.
    - **Future expansion:** How are wind and shade contributing to cooling? Can these be signs of adaptation measures?

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