

Satellite Remote Sensing for Measuring Urban Heat Islands and Constructing Heat Vulnerability Indices

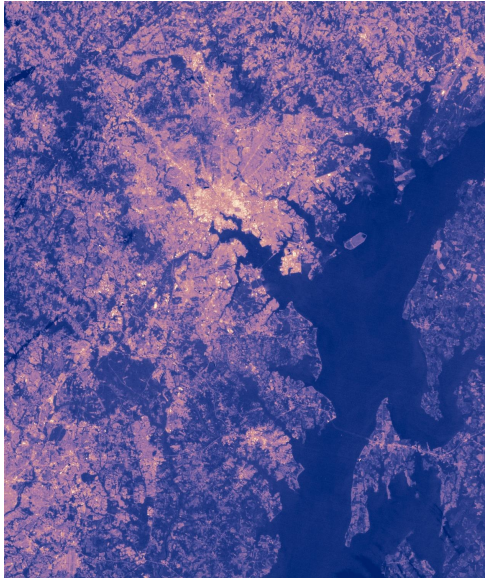
Part 2: Integrating Socioeconomic Data with Satellite Imagery for Constructing Heat Vulnerability Indices (Session 2)

Kathryn Conlon, PhD, MPH & Evan Mallen, PhD, MUP – August 9, 2022



Training Outline

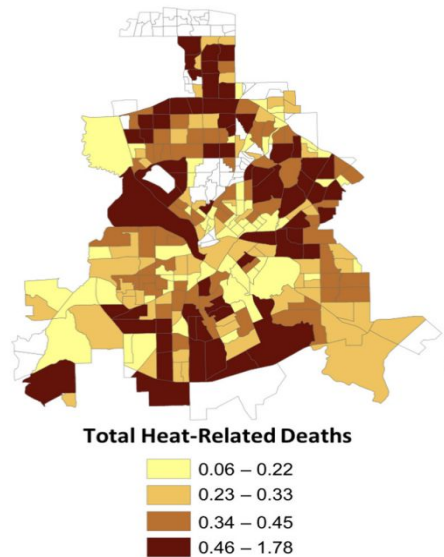
2 August 2022



Credit: [NASA](#)

Land Surface
Temperature-based Urban
Heat Island Mapping

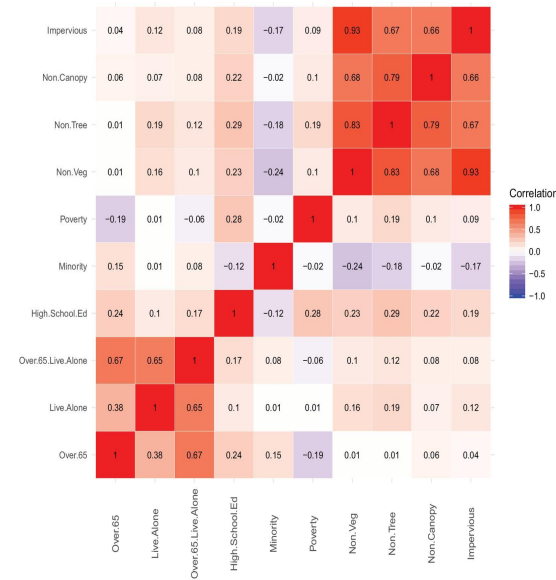
4 August 2022



Credit: [Mallen et al., 2019](#)

Integrating
Socioeconomic Data
with Satellite Imagery
for Constructing Heat
Vulnerability Indices -
Session 1

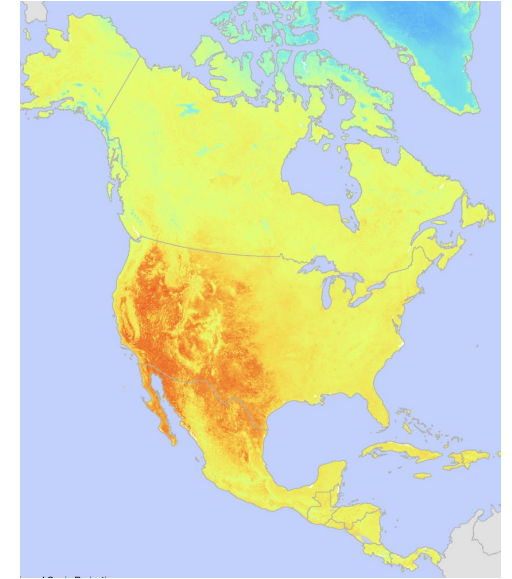
9 August 2022



Credit: [Conlon et al., 2020](#)

Integrating
Socioeconomic Data
with Satellite Imagery
for Constructing Heat
Vulnerability Indices -
Session 2

11 August 2022



Credit: [CIESIN](#)

Using High-Resolution,
Satellite Derived
Hot-Humid Heat Estimates
and Gridded Population
Data to Map Extreme
Heat Exposure Worldwide



Course Structure and Materials

- Webinar recordings, presentations, and the homework assignment can be accessed from the training page:
 - <https://appliedsciences.nasa.gov/join-mission/training/english/arset-satellite-remote-sensing-measuring-urban-heat-islands-and>



Homework and Certificate

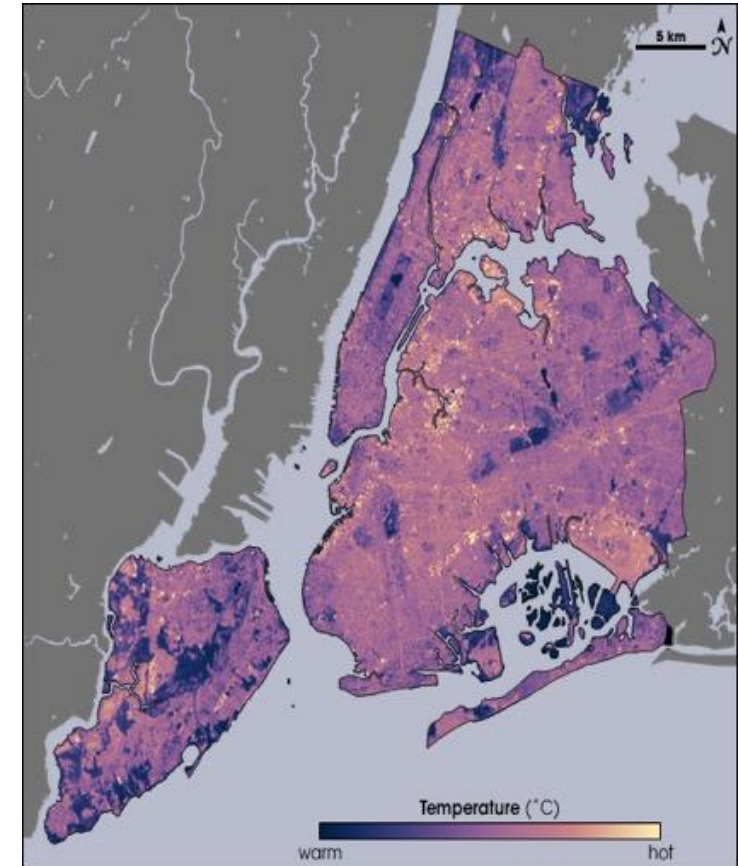
- Homework Assignment:
 - There will be one homework assignment for this webinar series.
 - Answers must be submitted via instructions found on the [training page](#).
 - Due date: August 25, 2022
- A certificate of completion will be awarded to those who:
 - Attend all live webinars
 - Complete the homework assignment by the deadline
 - You will receive a certificate approximately two months after the completion of the course from marines.martins@ssaihq.com



Learning Objectives

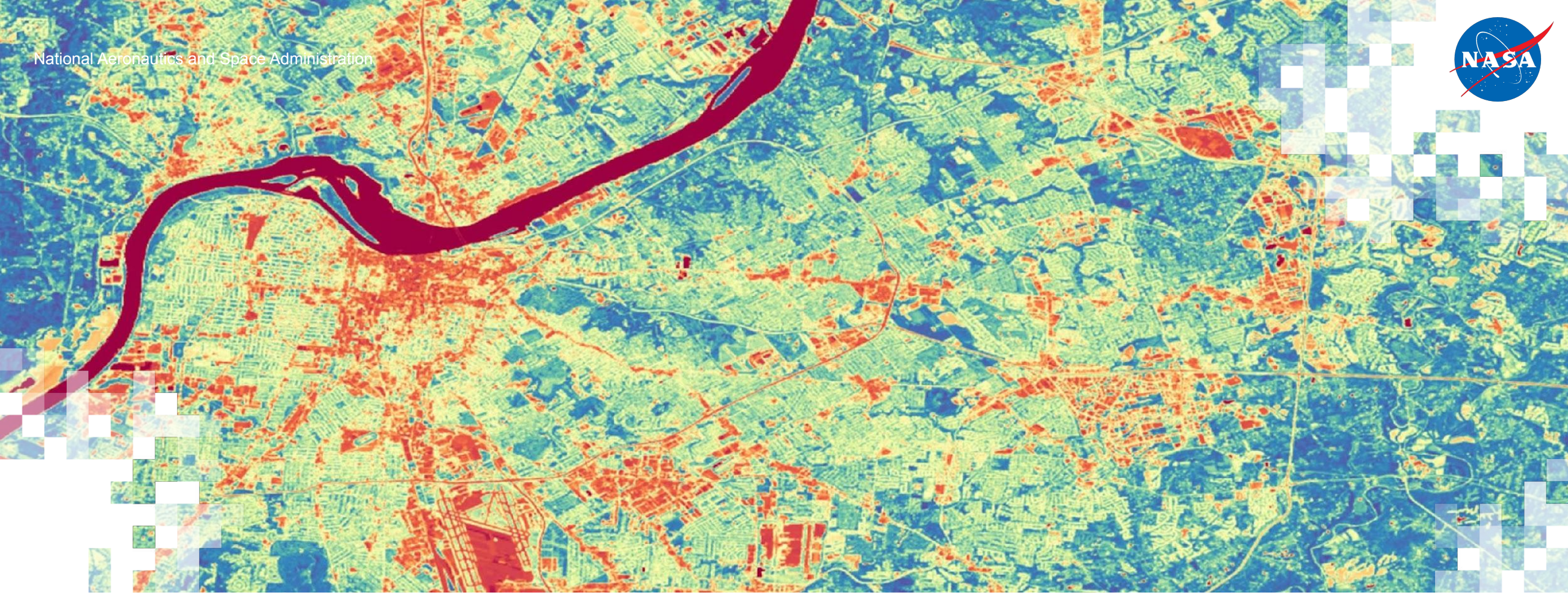
After participating in today's training, attendees will be able to:

- Identify data sources for creating heat vulnerability indices (HVI)
- Give examples of common methods used to create HVI
- Construct HVI for your own area of interest



Credit: [NASA Earth Observatory](#)



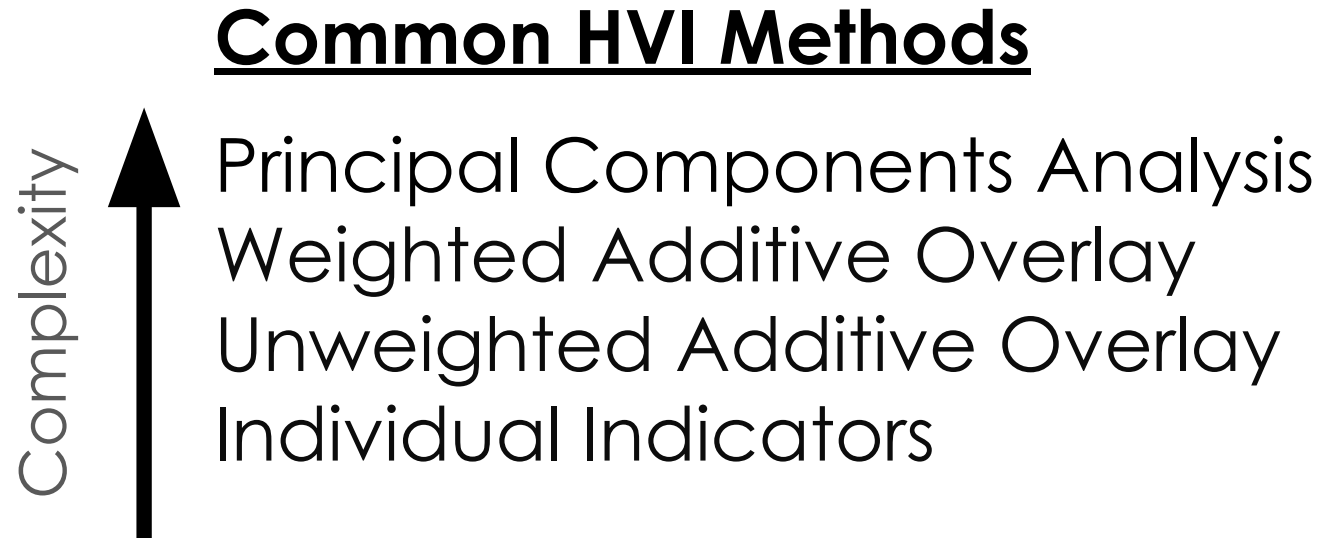


Constructing Heat Vulnerability Indices

HVI Construction

Important! Input variables:

- Unidirectional
- Confer vulnerability



Remember: An increase in your indicators should lead to an increase in vulnerability



Common Vulnerability Indicators

Exposure

Hot/heatwave days
Consecutive hot days
Min/Mean/Max temp.
Land surface temp.
Impervious surfaces
Vegetation
Urban density
Land cover
Land use
Homes w/o AC
Population density

Sensitivity

Older adults
Infants, young age
Sex
Diabetes
Cardiopulmonary
Renal
Respiratory
Obesity

Adaptive Capacity

Air conditioning access
Living alone
Income / wealth
Rental / homeowner
Unhoused
Education
Ethnicity
Language
Foreign-born
Cognitive impairment
Mobility / Transportation

Vulnerability



Common Vulnerability Indicators

Exposure

Hot/heatwave days
Consecutive hot days
Min/Mean/Max temp.
Land surface temp.
Impervious surfaces
Vegetation
Urban density
Land cover
Land use
Homes w/o AC
Population density

Sensitivity

Older adults
Infants, young age
Sex
Diabetes
Cardiopulmonary
Renal
Respiratory
Obesity

Adaptive Capacity

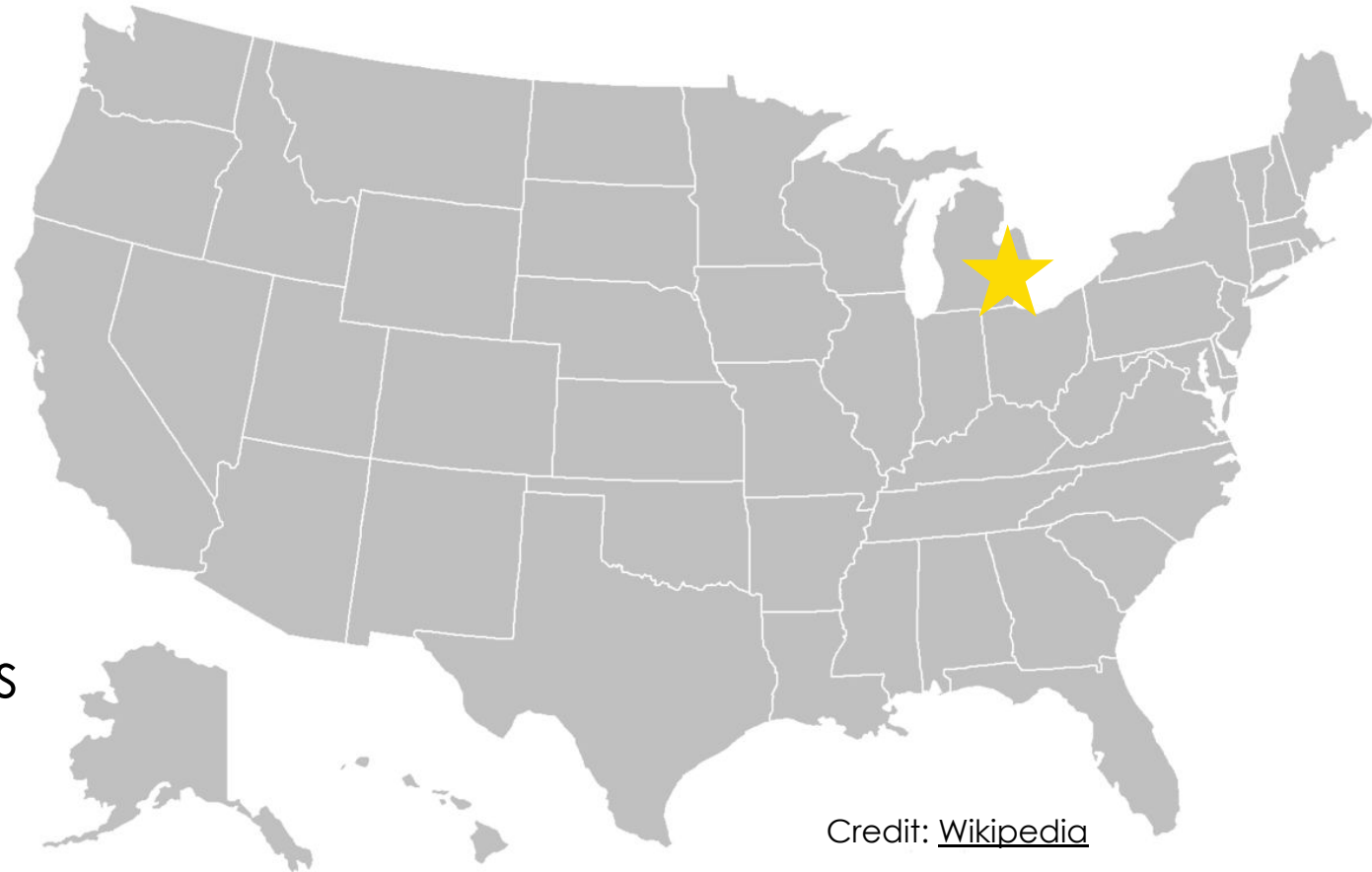
Air conditioning access
Living alone
Income / wealth
Rental / homeowner
Unhoused
Education
Ethnicity
Language
Foreign-born
Cognitive impairment
Mobility / Transportation

Vulnerability



Case Study: Detroit, Michigan, USA

- Cold winters
- Warm, humid summers
- Variation in green space
- Low air conditioning prevalence
- High sensitivity among residents to extreme heat

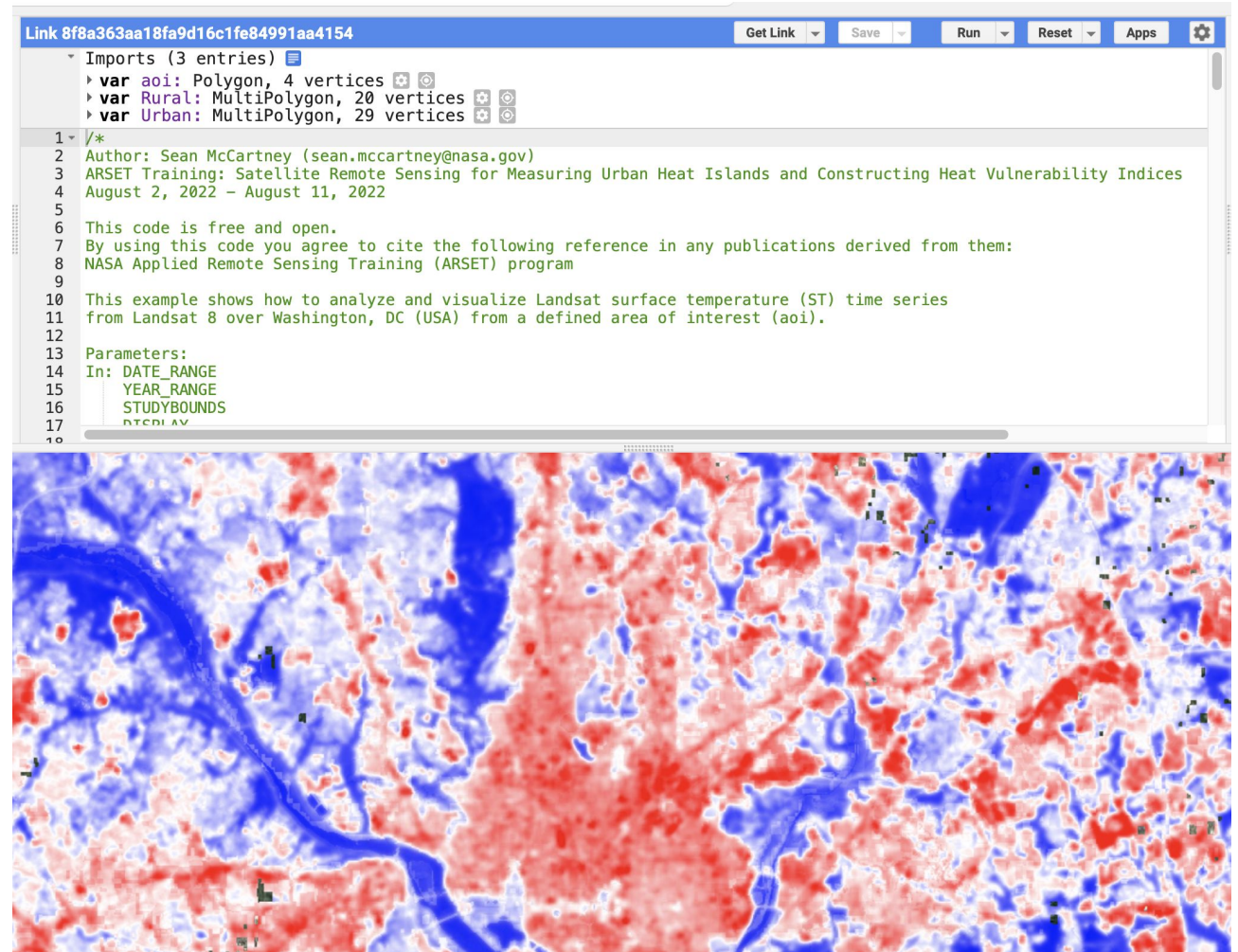


Credit: [Wikipedia](#)



For deriving areas of exposure to land surface temperature in Google Earth Engine using Landsat data, refer to **Part 1** of the webinar series: ***Land Surface Temperature-Based Surface Urban Heat Island Mapping***:

<https://appliedsciences.nasa.gov/join-mission/training/english/arset-satellite-remote-sensing-measuring-urban-heat-islands-and>



EarthExplorer [Manage Criteria](#)[System Notification \(1\)](#) [Item Basket \(0\)](#) [Help](#) [Feedback](#) [Logout \[esmallen\]](#)[Search Criteria](#)[Data Sets](#)[Additional Criteria](#)**[Results](#)**

4. Search Results

If you selected more than one data set to search, use the dropdown to see the search results for each specific data set.

[Show Result Controls](#)

Data Set

[Click here to export your results »](#)

Landsat 4-9 C2 U.S. ARD



Vertical: 7



Tile ID: LC08_CU_024006_20160619_20210502_02

Acquisition Date: 2016-06-19

Horizontal: 24

Vertical: 6



Tile ID: LC08_CU_024007_20160619_20210502_02

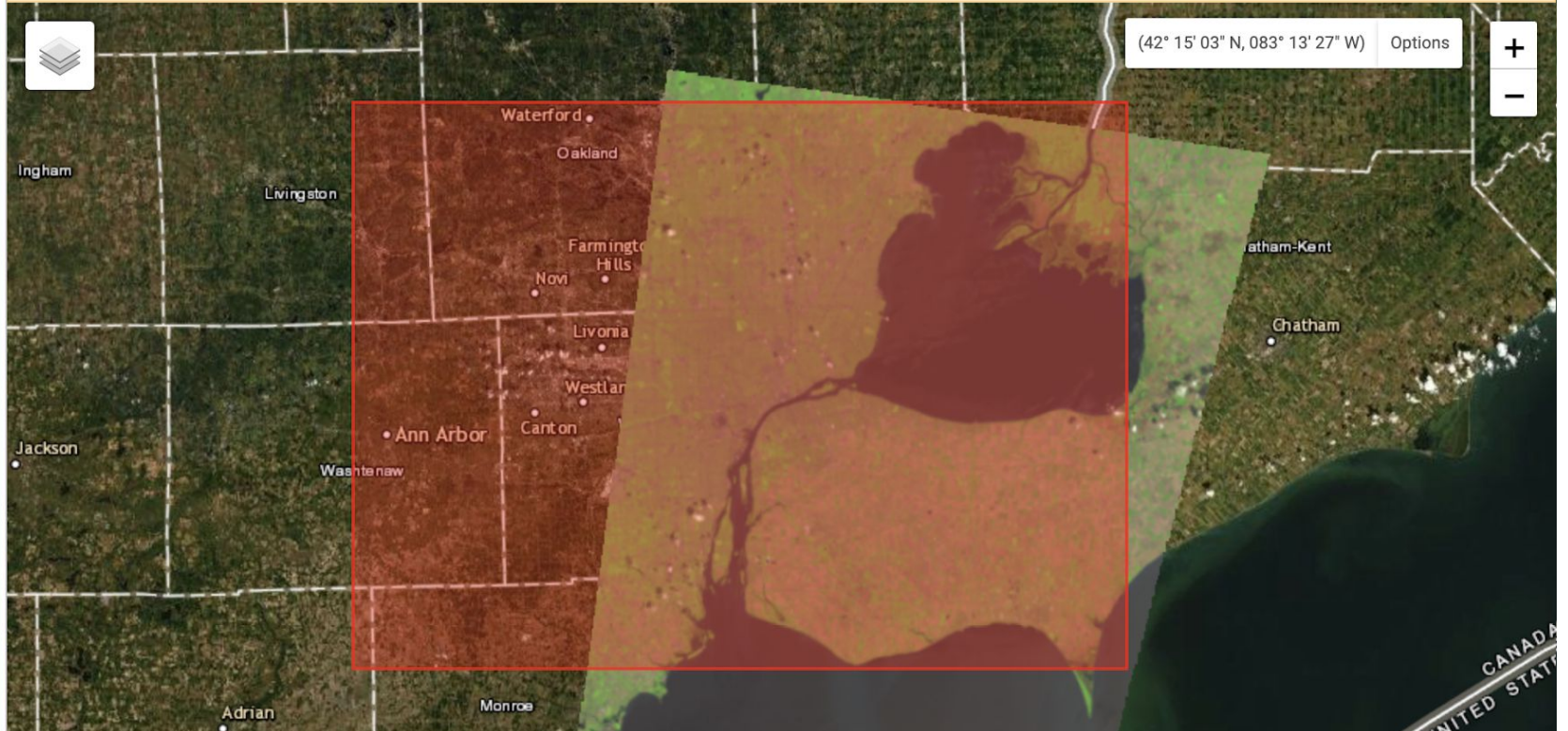
Acquisition Date: 2016-06-19

Horizontal: 24

Vertical: 7



Search Criteria Summary (Show)

[Clear Search Criteria](#)Credit: [USGS Earth Explorer](#)

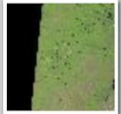
EarthExplorer [Manage Criteria](#)[System Notification \(1\)](#) [Item Basket \(0\)](#) [Help](#) [Feedback](#) [Logout \[esmallen\]](#)[Search Criteria](#) [Data Sets](#) [Additional Criteria](#) **Results**

4. Search Results

If you selected more than one data set to search, use the dropdown to see the search results for each specific data set.

[Show Result Controls](#)**Data Set**[Click here to export your results »](#)

Landsat 4-9 C2 U.S. ARD



Tile ID: LC08_C2_03007_20160619_20210502_02
Acquisition Date: 2016-06-19
Horizontal: 23
Vertical: 7



Tile ID: LC08_CU_024006_20160619_20210502_02
Acquisition Date: 2016-06-19
Horizontal: 24
Vertical: 6



Tile ID: LC08_CU_024007_20160619_20210502_02
Acquisition Date: 2016-06-19
Horizontal: 24

Search Criteria Summary (Show)[Clear Search Criteria](#)

(42° 34' 45" N, 084° 23' 19" W)

[Options](#)

Chatham-Kent

Chatham

CANADA
UNITED STATESCredit: [USGS Earth Explorer](#)

The screenshot displays the USGS Earth Explorer web application. The top navigation bar includes the USGS logo, 'EarthExplorer', 'Manage Criteria', and links for 'System Notification (1)', 'Item Basket (0)', 'Help', 'Feedback', and 'Logout [esmallen]'. The main content area is divided into 'Search Criteria', 'Data Sets', 'Additional Criteria', and 'Results' tabs. The 'Results' tab is active, showing '4. Search Results'. A red arrow points from the search results to a 'Download Options' pop-up window. The pop-up window lists several download options for the selected data set (LC08_CU_023007_20160619_20210502_02):

- Product Options ▾ C2 ARD Tile Quality Assessment Bundle Download
- Download C2 ARD Tile Full-Resolution Browse (Natural Color) JPEG (6.00 MiB)
- Product Options ▾ C2 ARD Tile Metadata Bundle Download
- Product Options ▾ C2 ARD Tile Surface Reflectance Bundle Download
- Product Options ▾ C2 ARD Tile Surface Temperature Bundle Download
- Product Options ▾ C2 ARD Tile Top of Atmosphere Reflectance Bundle Download
- Product Options ▾ C2 ARD Tile Brightness Temperature Bundle Download

The background map shows a satellite image of a coastal area with labels for 'Chatham-Kent' and 'Chatham'. The map coordinates are (42° 00' 08" N, 083° 04' 42" W).

Credit: USGS Earth Explorer



The screenshot displays the USGS Earth Explorer web application. On the left, the 'Search Results' section shows a list of data sets. A red arrow points from the 'Data Set' section to the 'Product Download Options' modal. The modal is titled 'Product Download Options for LC08_CU_023007_20160619_20210502_02' and shows a bundle download of 153.94 MiB. Below this, a table lists individual tile bands available for download.

The following items are available for individual download		
(Item Name Filter)		
	9.50 MiB	LC08_CU_023007_20160619_20210502_02_ST_ATRAN.TIF <i>C2 ARD Tile Band Download</i>
	39.02 MiB	LC08_CU_023007_20160619_20210502_02_ST_B10.TIF <i>C2 ARD Tile Band Download</i>
	10.07 MiB	LC08_CU_023007_20160619_20210502_02_ST_CDIST.TIF <i>C2 ARD Tile Band Download</i>
	5.99 MiB	LC08_CU_023007_20160619_20210502_02_ST_DRAD.TIF <i>C2 ARD Tile Band Download</i>
	21.01 MiB	LC08_CU_023007_20160619_20210502_02_ST_EMIS.TIF <i>C2 ARD Tile Band Download</i>
	10.44 MiB	LC08_CU_023007_20160619_20210502_02_ST_EMSD.TIF <i>C2 ARD Tile Band Download</i>

Buttons at the bottom of the modal: Add All to Bulk, Close.

Credit: [USGS Earth Explorer](#)





Celebrating 20+ years of Partnership
Multi-Resolution Land Characteristics
Consortium

The screenshot displays the MRLC National Land Cover Database web application interface. The main map area shows a detailed view of the 2016 CONUS Impervious Surface dataset, with impervious surfaces highlighted in red and blue. The map is titled "All NLCD Impervious Surface 2016 CONUS Impervious Surface".

Contents Legend:

- Dataset
 - Hydrography
 - NLCD Impervious Surface
 - ☒ 2019 CONUS Impervious Surface
 - ☒ 2016 CONUS Impervious Surface
 - ☐ 2013 CONUS Impervious Surface
 - ☐ 2011 CONUS Impervious Surface
 - ☐ 2008 CONUS Impervious Surface
 - ☐ 2006 CONUS Impervious Surface
 - ☐ 2004 CONUS Impervious Surface
 - ☐ 2001 CONUS Impervious Surface
 - ☐ 2016 AK Impervious Surface
 - ☐ 2011 AK Impervious Surface
 - ☐ 2001 AK Impervious Surface
 - ☐ 2011 - 2016 AK Change Pixels
 - ☐ 2001 - 2016 AK Change Pixels
 - ☐ 2001 - 2011 AK Change Pixels
 - ☐ 2001 HI Impervious Surface
 - ☐ 2001 PR Impervious Surface
 - NLCD Impervious Descriptor
 - NLCD Tree Canopy
 - ☐ 2016 CONUS Tree Canopy

Tools:

- Data Download
- Feature Info
- Spatial Locking Tool
- Arrange Windows Tool

Credit: [MRLC](#)





Celebrating 20+ years of Partnership
Multi-Resolution Land Characteristics
Consortium

Contents Legend

All

New Map Window

- 2001 PR Impervious Surface
- 2001 PR Impervious Surface
- NLCD Impervious Descriptor
- NLCD Tree Canopy
 - ☒ 2016 CONUS Tree Canopy
 - CONUS Tree Canopy Change
 - 2011 CONUS Tree Canopy
 - 2016 AK Tree Canopy
 - AK Tree Canopy Change
 - 2011 AK Tree Canopy
 - 2016 HI Tree Canopy
 - HI Tree Canopy Change
 - 2011 HI Tree Canopy
 - 2016 PR Tree Canopy
 - PR Tree Canopy Change
 - 2011 PR Tree Canopy
- NLCD Land Cover
 - CONUS Land Cover Change Index
 - 2019 CONUS Land Cover
 - 2016 CONUS Land Cover
 - 2013 CONUS Land Cover
 - 2011 CONUS Land Cover

All NLCD Tree Canopy 2016 CONUS Tree Canopy


Tools

- Data Download
- Feature Info
- Spatial Locking Tool
- Arrange Windows Tool

☒ All NLCD Tree Canopy 2016 CONUS Tree Canopy

Credit: MRLC





Centers for Disease Control and Prevention
CDC 24/7: Saving Lives. Protecting People.™

Search

Chronic Disease and Health Promotion Data & IndicatorsHealth Areas ▾DevelopersVideo Guides

FacebookTwitterYouTubeInstagramSign In

Search

Categories ▾

500 Cities & Places ✕

Alcohol-Related Disease Impact

Assisted Reproductive Technology (ART)

Behavioral Risk Factors

Chronic Disease Indicators

Healthy Aging


Heart Disease & Stroke Prevention

Welcome to the 500 Cities & PLACES Data Portal

Featured Content

PLACES: Local Data for Better Health


External Content



PLACES provides model-based estimates for chronic disease measures by county, place, census tract and ZIP Code Tabulation Area (ZC...

PLACES: Local Data for Better Health, County Data...


December 1, 202124.9K Views



This dataset contains model-based county-level estimates for the PLACES 2021 release. PLACES is the expansion of the original 500 Cities Proje...

PLACES: County Data (GIS Friendly Format), 2021 rele...


December 1, 20218,461 Views





This dataset contains model-based county-level estimates for the PLACES 2021 release in GIS-friendly format. PLACES is the expansion o...

Credit: [CDC](#)

NASA's Applied Remote Sensing Training Program

18





Tables Maps Pages Microdata

find
tables

Economic Census

EC1700BASIC | All Sectors: Summary Statistics for the U.S., States, and Selected Geographies: 2017

2017: ECN Core Statistics Summary Statistics for the U.S., States, and Selected Geographies: 2017

Notes

Geos

Years

Topics

Surveys

Codes

123

Hide

Filter

Restore

Excel

CSV

ZIP

Print

More Data

Map

Geographic Area Name	Meaning of NAICS code	Meaning of Tax status co...	Number of firms	Sales, value of shipmen...	First-quarter payroll (\$...
United States	Mining, quarrying, and oil a...	All establishments	18,618	400,465,610	12,599,
United States	Mining, quarrying, and oil a...	All establishments	18,618	400,465,610	12,599,
United States	Utilities	All establishments	5,886	57,100,462	20,865,
United States	Construction	All establishments	701,329	1,994,166,047	69,419,
United States	Manufacturing	All establishments	249,014	5,548,796,809	169,056,
United States	Wholesale trade	All establishments	297,379	8,734,807,041	107,679,
United States	Wholesale trade	All establishments	260,879	5,700,966,914	83,174,
United States	Wholesale trade	All establishments	2,384	2,331,241,413	21,010,
United States	Retail trade	All establishments	647,480	4,949,601,481	108,214,
United States	Transportation and wareho...	All establishments	184,735	895,225,411	60,377,
United States	Information	All establishments	79,418	1,582,097,611	95,655,
United States	Finance and insurance	All establishments	236,950	4,340,010,907	204,635,
United States	Real estate and rental and l...	All establishments	309,393	674,147,020	28,525,
United States	Professional, scientific, and ...	All establishments	810,213	1,844,780,952	179,169,
United States	Professional, scientific, and ...	Establishments subject to fe...	807,117	1,795,588,791	173,855,
United States	Professional, scientific, and ...	Establishments exempt from ...	3,185	49,192,161	5,314,
United States	Management of companies ...	All establishments	29,319	121,526,125	105,189,
United States	Administrative and support ...	All establishments	347,192	950,894,923	114,041,
United States	Educational services	All establishments	70,954	65,718,406	5,184,
United States	Educational services	Establishments subject to fe...	58,711	48,139,827	3,762,

☐ Search...

☐ Geographic identifier code

☒ Geographic Area Name

☐ 2017 NAICS code

☒ Meaning of NAICS code

☐ Type of operation code

☐ Meaning of Type of operation code

☐ Tax status code

☐ Meaning of Tax status code

☐ Year

☒ Number of firms

☐ Number of establishments

☒ Sales, value of shipments, or revenue (\$

☐ Annual payroll (\$1,000)

☒ Row Groups

Drag here to set row groups

☒ Values

Drag here to aggregate

Explore the thousands of tables we have. We are adding new tables every week.

[Explore Tables](#)



Don't forget to include all geographic identifiers

Credit: [U.S. Census](#)



Social Explorer

Tables

Professional plan provided by Georgia Institute of Technology

Create Account

Login

Explore Maps

Tables

Teach and Learn

Lecture Launchers

Training Modules

Data Snacks

Demographic Profiles

Geodata Beta

Data Dictionary and documentation

Website · LibGuides

Blog · Help · Privacy and Legal

508 Compliance · Feedback

New! Try out our redesigned reporting application.

Create report

U.S. Decennial CensusNEW

American Community Surveys (5-Year Estimates)NEW

American Community Surveys (3-Year Estimates)

American Community Surveys (1-Year Estimates)

American Community Surveys (Supplemental Estimates)

U.S. Citizen Voting Age Population Special TabulationNEW



Don't forget to include all geographic identifiers

Credit: Social Explorer



HVI Mapping: Finding Shapefiles

 An official website of the United States government [Here's how you know](#) ▾



 Search

BROWSE BY TOPICEXPLORE DATALIBRARYSURVEYS/ PROGRAMSINFORMATION FOR...FIND A CODEABOUT US

// [Census.gov](#) / [Census Mapping Files](#) / [TIGER/Line Shapefiles](#)

WITHIN CENSUS GEOGRAPHIES

[Mapping Files](#)

[Mapping Tools](#)

[Reference Files](#)

[Reference Maps](#)



TIGER/Line Shapefiles

Format:

- Shapefile - 2007 to Present
- TIGER/Line ASCII format - 2006 and earlier
- Census 2000 available in both formats

The core TIGER/Line Files and Shapefiles do not include demographic data, but they do contain geographic entity codes (GEOIDs) that can be linked to the Census Bureau's demographic data, available on [data.census.gov](#).

2021 2020 2019 2018 2017 2016 2015 2014 [MORE](#) ▾

2021

All legal boundaries and names are as of January 1, 2021. Released October 7, 2021.

User note on [Congressional and State Legislative Districts in Geographic Products](#).

Related Information

[TIGER/Line Shapefiles and TIGER/Line Files Technical Documentation](#)

[TIGER/Line Files and Shapefiles Errata and User Notes](#)

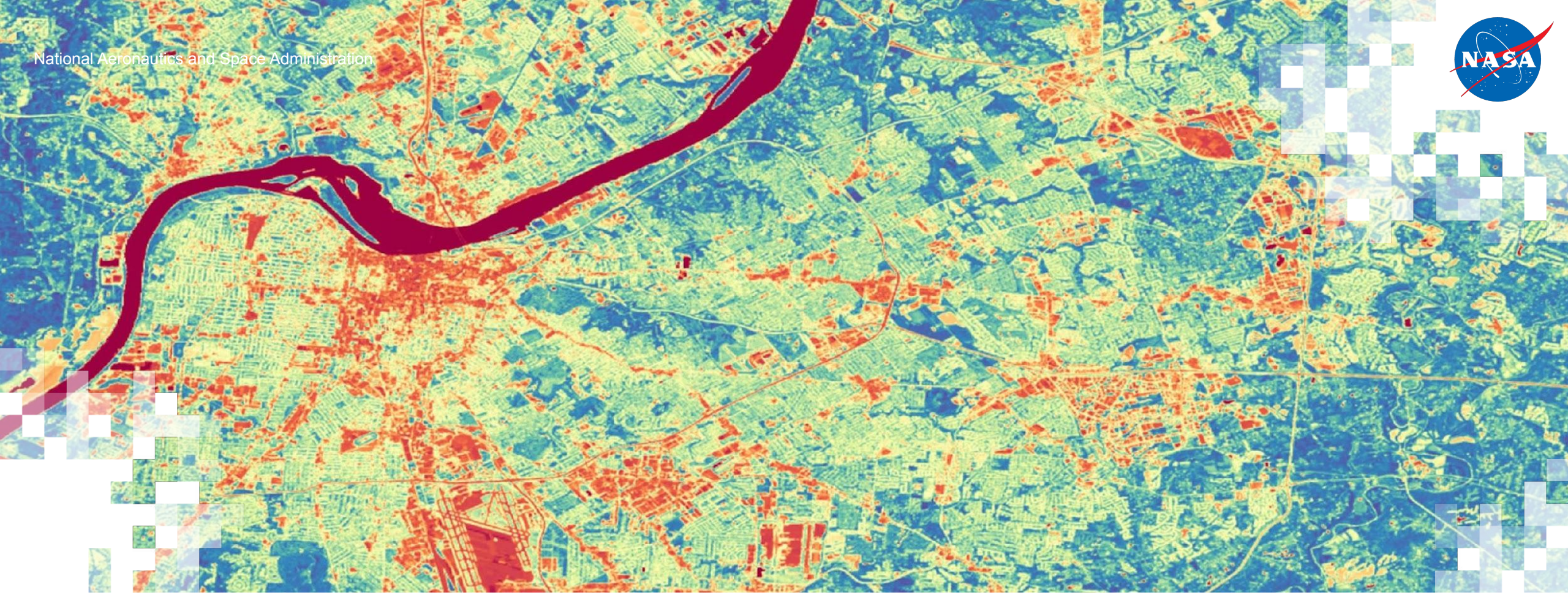
[Geography Mapping Files](#)

<https://www.census.gov/geographies/mapping-files/time-series/geo/tiger-line-file.html>



US Census geographies were updated with the 2020 decennial census. Make sure your data and census shapefile dates match! Example: Disease prevalence data from 2016 should use 2010 census geographies.





Build Your HVI Dataset

Spatial Components in GIS

There are a variety of tools for processing and mapping HVIs, with more free and open-source options emerging.



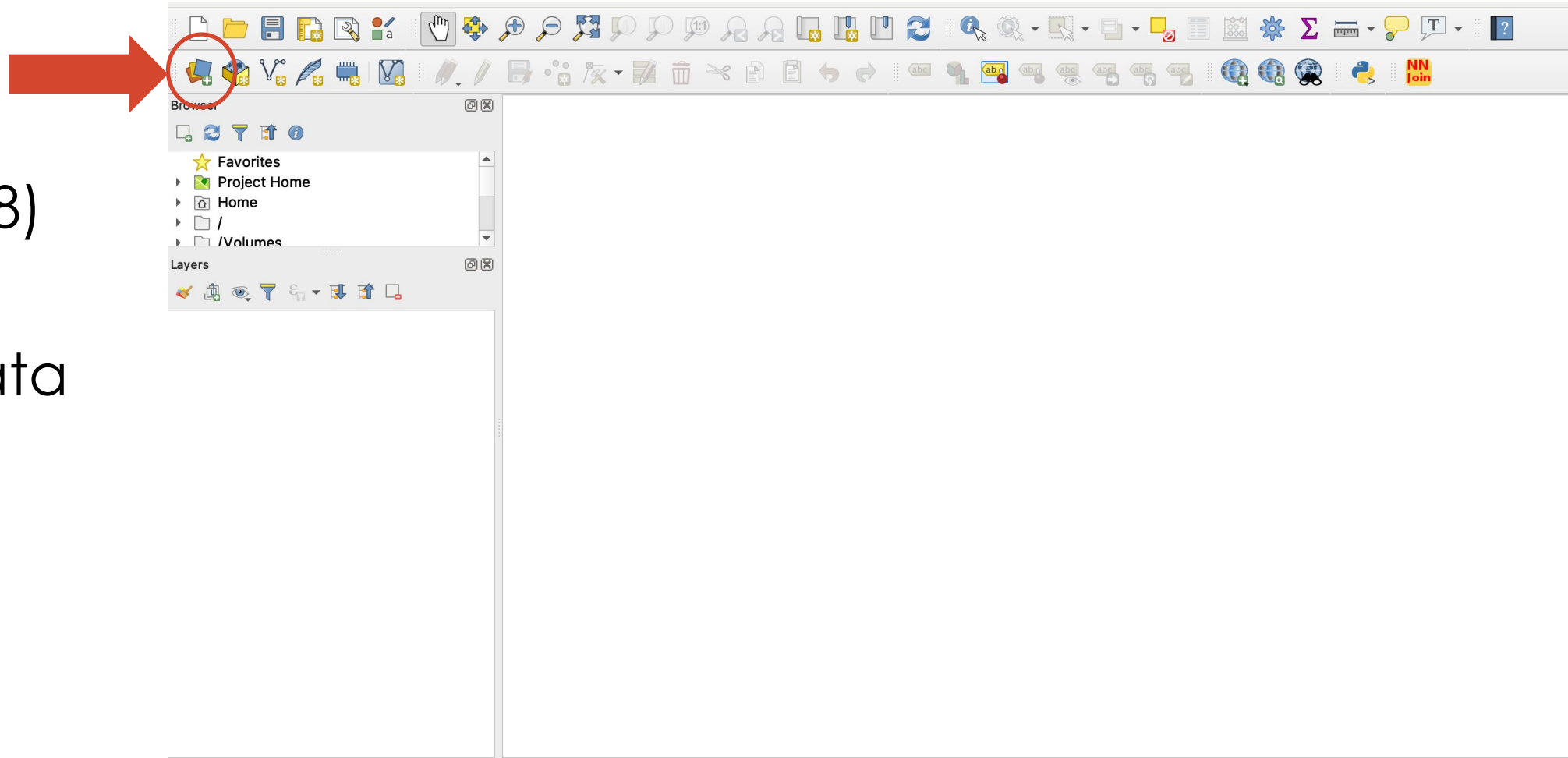
Processing Spatial Components – Shapefiles



Example:

- QGIS (v3.8)

Add your data

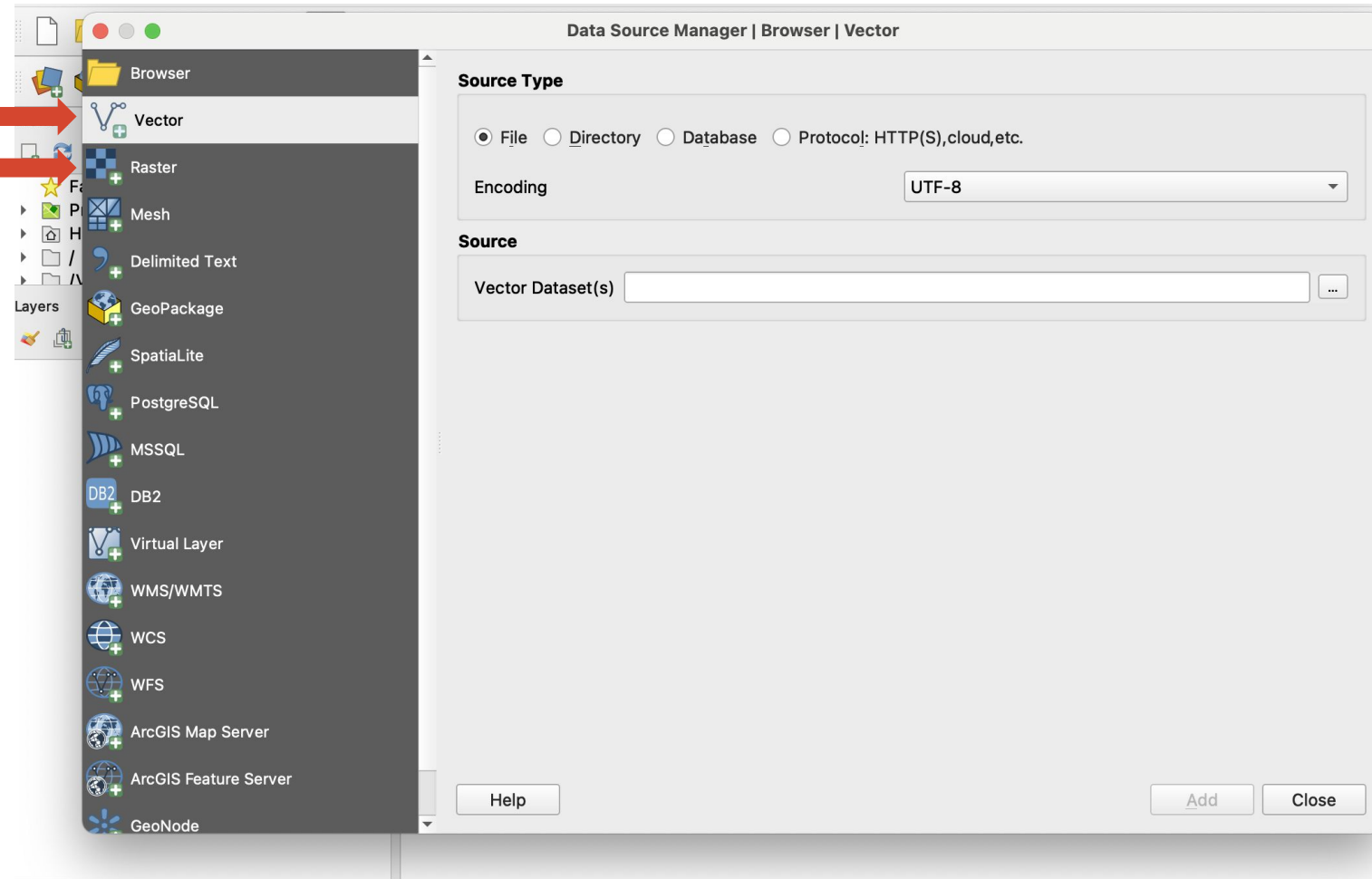


Processing Spatial Components – Shapefiles



Boundary shapefiles

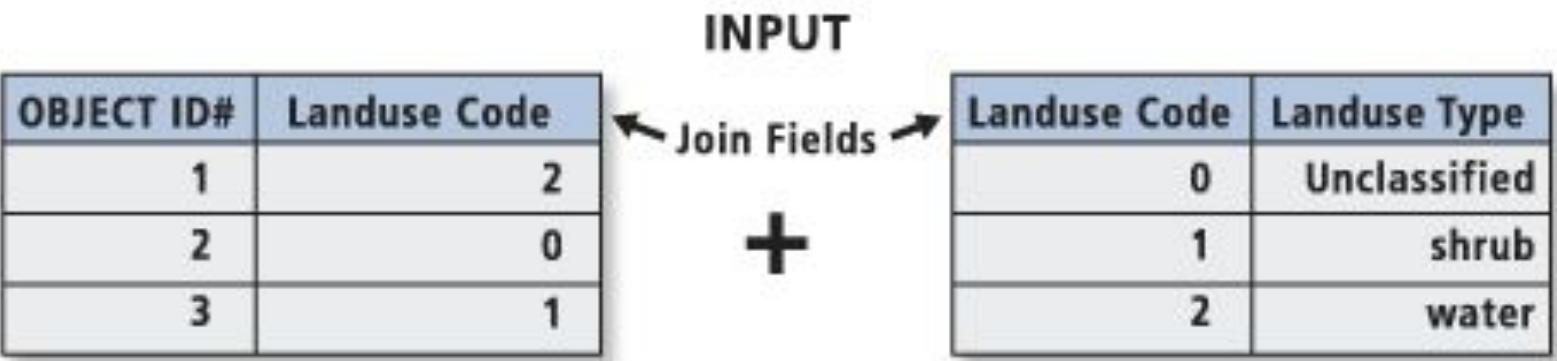
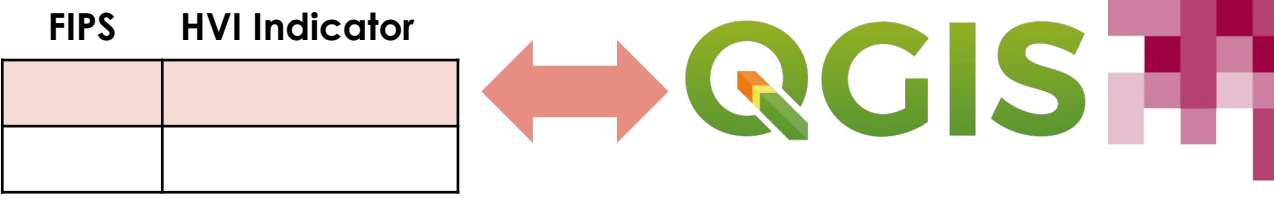
Exposure data (LST)



Joining Your Data

You can begin to consolidate your data in QGIS now to prepare for your HVI processing.

First, you will need a unique identifier (key) to join your data.



OUTPUT

OBJECT ID#	Landuse Code	Join Table Landuse Code	Join Table Landuse Type
1	2	2	water
2	0	0	Unclassified
3	1	1	shrub

<https://desktop.arcgis.com/en/arcmap/latest/tools/data-management-toolbox/add-join.htm>



Creating a Key to Join Data



GEOID = FIPS

Convert to string
for easier joining
later

The screenshot shows the QGIS interface with a table of Detroit tracts. Two red arrows point to the 'STATEFP10' and 'GEOID10' columns. The 'GEOID10' column is circled in red. The table has columns for STATEFP10, COUNTYFP10, TRACTCE10, GEOID10, NAME10, NAME10SAD10, MTFCC10, FUNCSTAT10, ALAND10, and AWATER10. The first row is highlighted with a green border around the 'STATEFP10' cell.

	STATEFP10	COUNTYFP10	TRACTCE10	GEOID10	NAME10	NAME10SAD10	MTFCC10	FUNCSTAT10	ALAND10	AWATER10
1	26	163	531100	26163531100	5311	Census Tract...	G5020	S	623803	0 +
2	26	163	531200	26163531200	5312	Census Tract...	G5020	S	1079279	0 +
3	26	163	531300	26163531300	5313	Census Tract...	G5020	S	579536	0 +
4	26	163	531400	26163531400	5314	Census Tract...	G5020	S	502012	0 +
5	26	163	531500	26163531500	5315	Census Tract...	G5020	S	865980	0 +
6	26	163	531600	26163531600	5316	Census Tract...	G5020	S	559379	0 +
7	26	163	531700	26163531700	5317	Census Tract...	G5020	S	749294	0 +
8	26	163	531800	26163531800	5318	Census Tract...	G5020	S	868850	0 +
9	26	163	526300	26163526300	5263	Census Tract...	G5020	S	1013504	0 +
10	26	163	526400	26163526400	5264	Census Tract...	G5020	S	567045	0 +
11	26	163	530100	26163530100	5301	Census Tract...	G5020	S	1292334	0 +
12	26	163	530200	26163530200	5302	Census Tract...	G5020	S	1426268	0 +
13	26	163	530300	26163530300	5303	Census Tract...	G5020	S	1611629	0 +
14	26	163	530400	26163530400	5304	Census Tract...	G5020	S	445674	0 +
15	26	163	530500	26163530500	5305	Census Tract...	G5020	S	750419	0 +
16	26	163	530800	26163530800	5308	Census Tract...	G5020	S	1167896	0 +



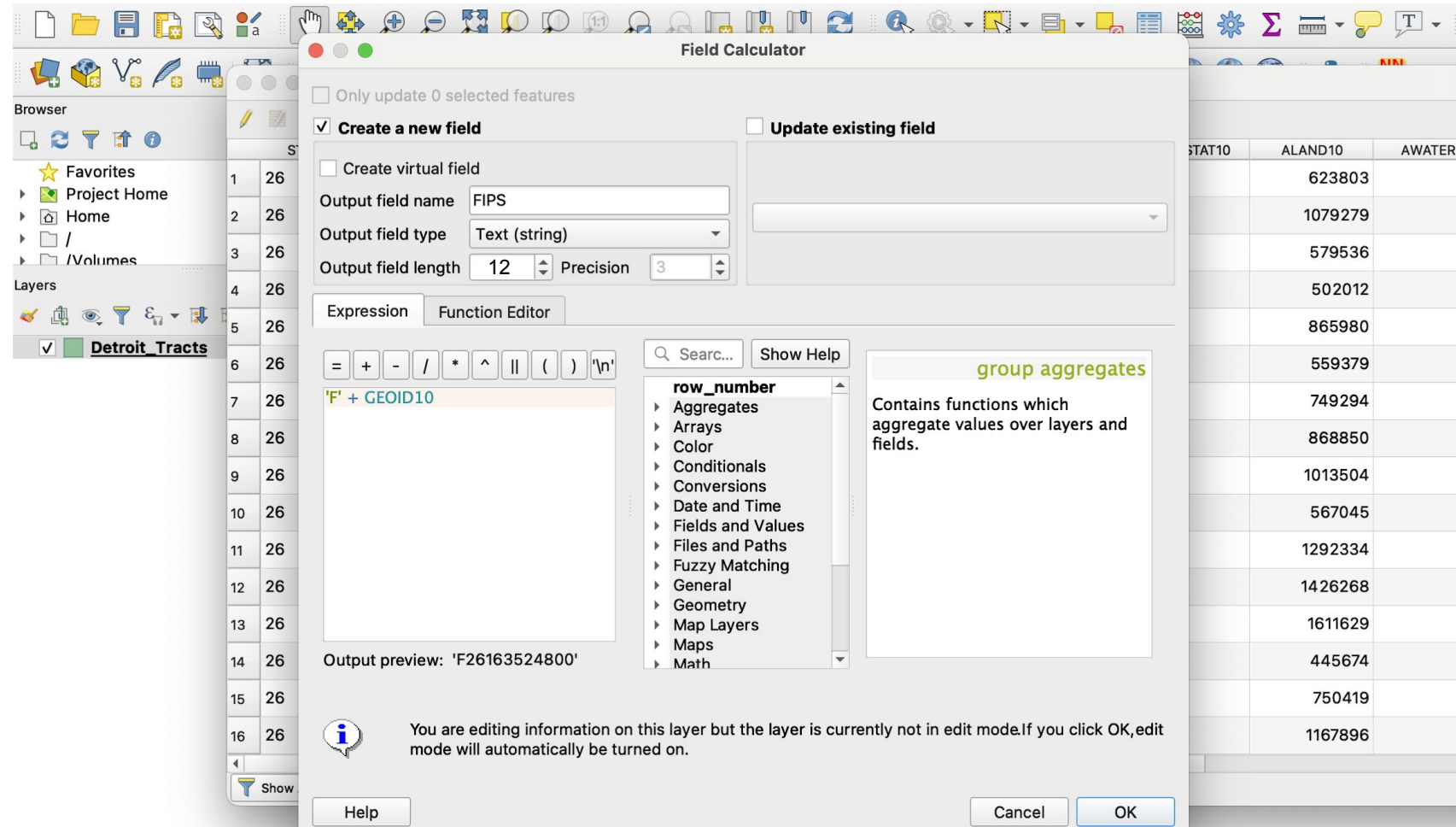
Creating a Key to Join Data



GEOID = FIPS

Convert to string
for easier joining
later

'F' + GEOID10



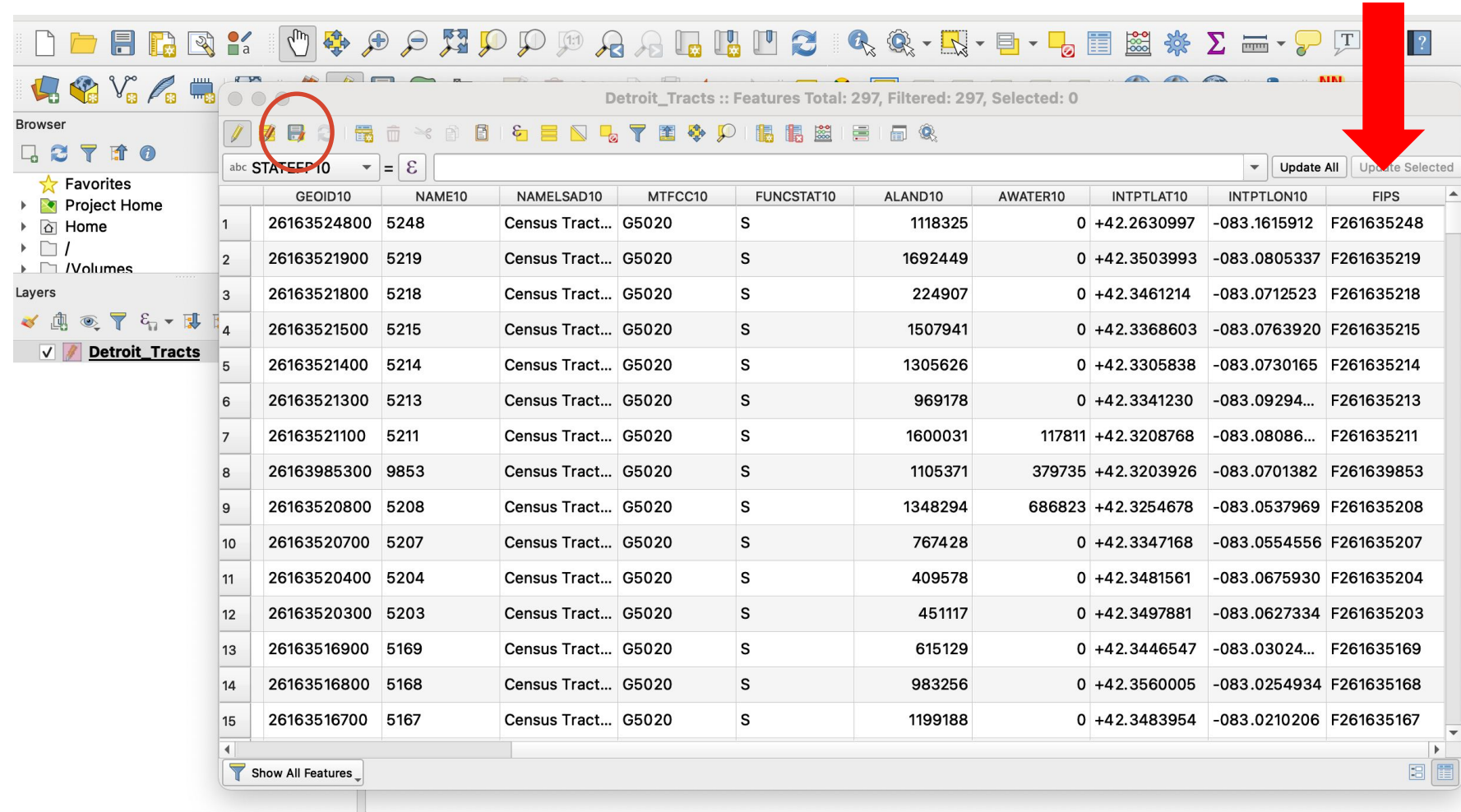
Creating a Key to Join Data



FIPS is now a string that will not drop leading zeroes.

Repeat in your additional data tables to ensure a clean join.

Don't forget to save your edits using the save button.






Creating a Key to Join Data

FIPS	HVI Indicator

Use the concatenate function to place an "F" before your Geo_FIPS code.

This forces the data into a string format to match the FIPS code in QGIS attribute table.

SUM					=CONCATENATE("F",A3)
	A	B	C		
2	GEOID	Geo_FIPS_calc	Geo_FIPS		
3	26163985200	"F",A3)	F26163985200		
4	26163985300	F26163985300	F26163985300		
5	26163985400	F26163985400	F26163985400		
6	26163985500	F26163985500	F26163985500		
7	26163985600	F26163985600	F26163985600		
8	26163985700	F26163985700	F26163985700		
9	26163985900	F26163985900	F26163985900		



Copy your key field and paste as values to preserve your key (Column C)

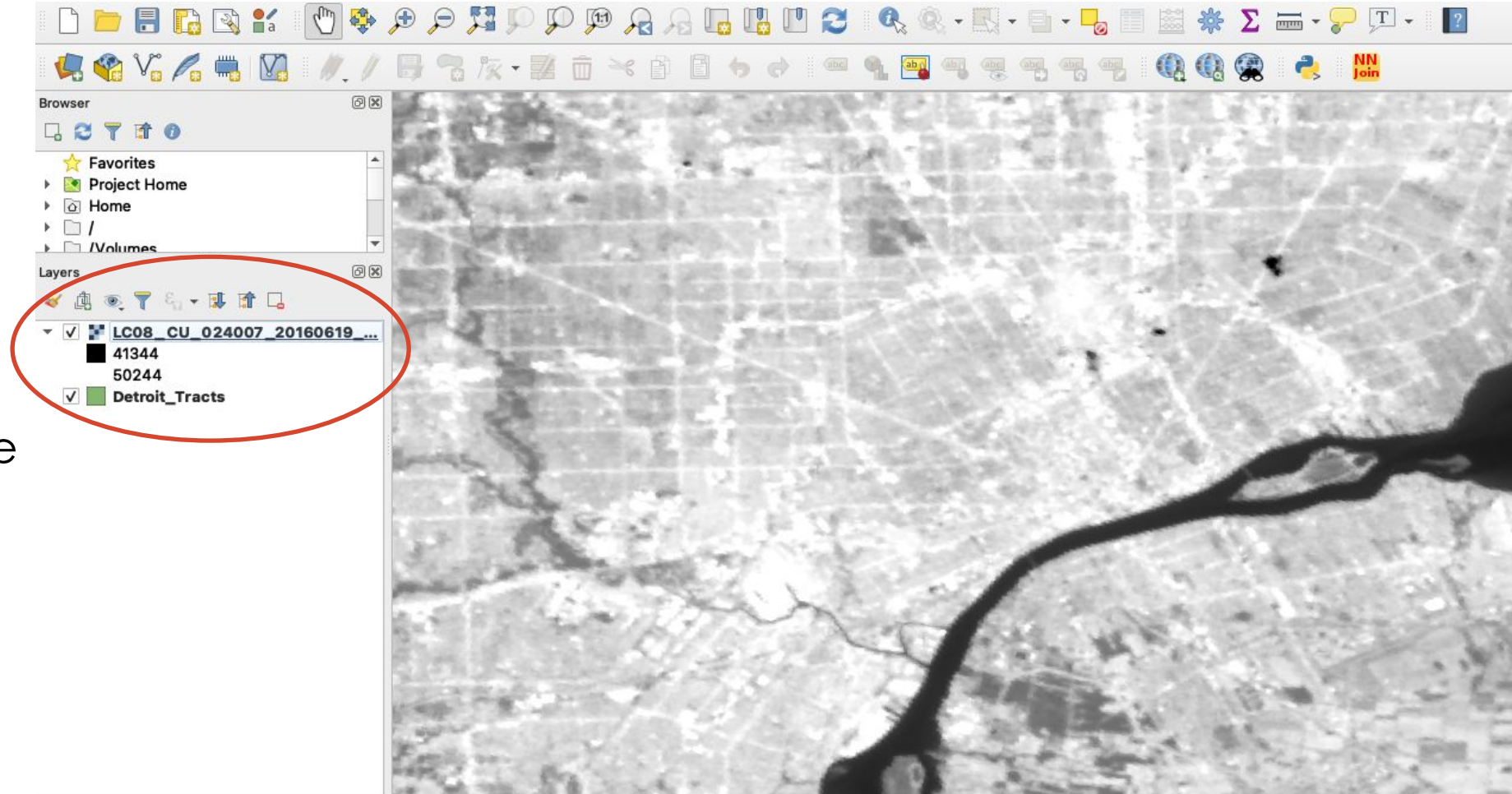


Processing Spatial Components – Exposure Rasters



Data such as Land Surface Temperature may not come in familiar units

Review all product documentation for scale factors and units before use.



Processing Spatial Components – Exposure Rasters



Data such as Land Surface Temperature may not come in familiar units

Review all product documentation for scale factors and units before use.



Scale factors, fill values, data type, and valid range for Landsat Collection 1 and Collection 2 science products

Science Product	Scale Factor	Fill Value	Data Type	Valid Range
Collection 1				
Surface Reflectance	0.0001	-9999	Signed 16-bit integer	0-10000
Provisional Surface Temperature	0.1	-9999	Signed 16-bit integer	0-10000
Collection 2				
Surface Reflectance	0.0000275 + -0.2	0	Unsigned 16-bit integer	1-65455
Surface Temperature	0.00341802 + 149.0	0	Unsigned 16-bit integer	1-65455

<https://www.usgs.gov/faqs/how-do-i-use-scale-factor-landsat-level-2-science-products>

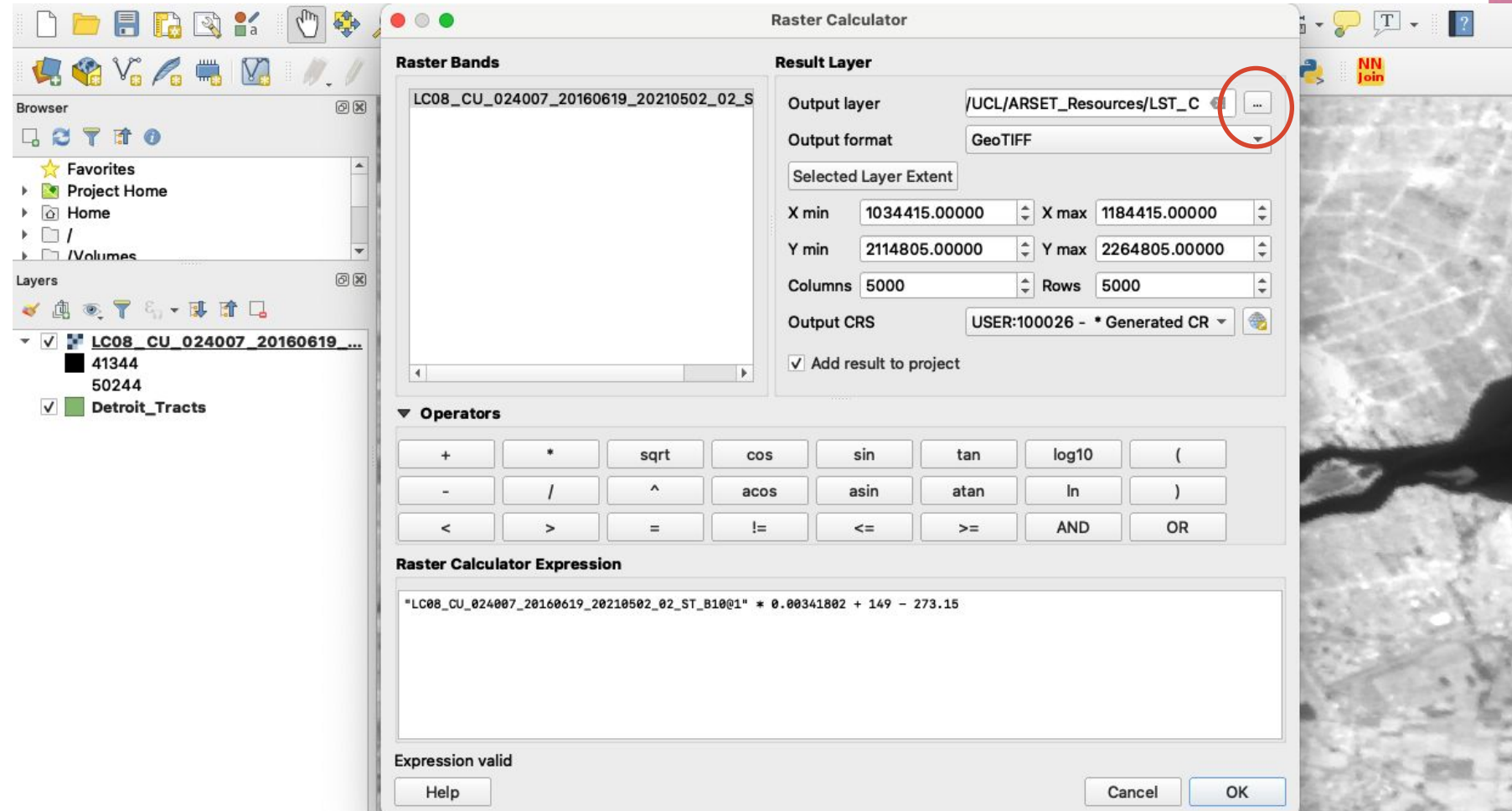


Processing Spatial Components – Exposure Rasters



Data such as Land Surface Temperature may not come in familiar units

Review all product documentation for scale factors and units before use.



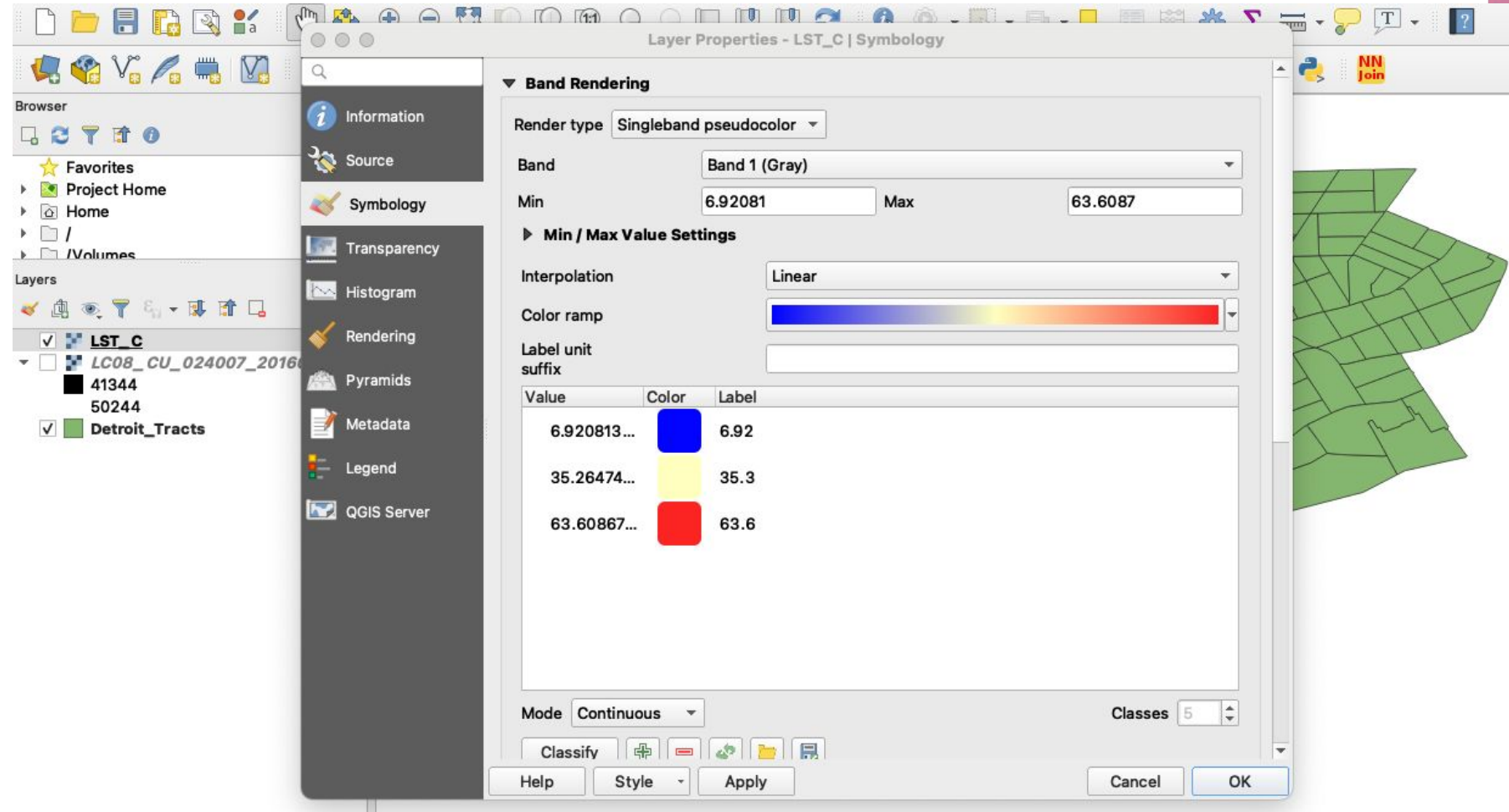
$$\text{LST_C} = \underbrace{[\text{LST Raster}] * 0.00341802 + 149}_{\text{Raw value to Kelvin}} \underbrace{- 273.15}_{\text{Kelvin to Celsius}}$$



Processing Spatial Components – Exposure Rasters



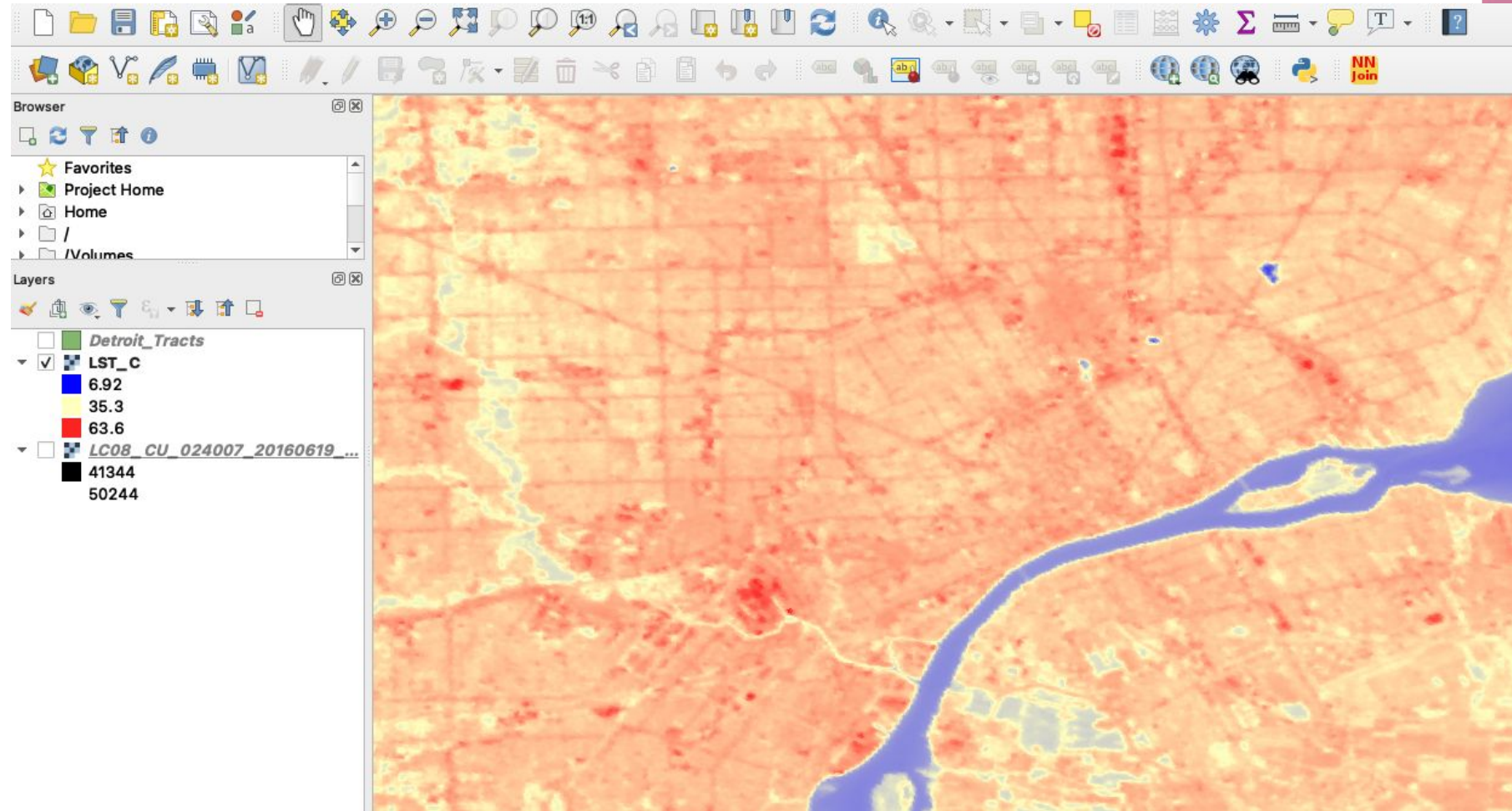
Change the symbology in the layer properties for a more familiar color scheme.



Processing Spatial Components – Exposure Rasters



Change the symbology in the layer properties for a more familiar color scheme.



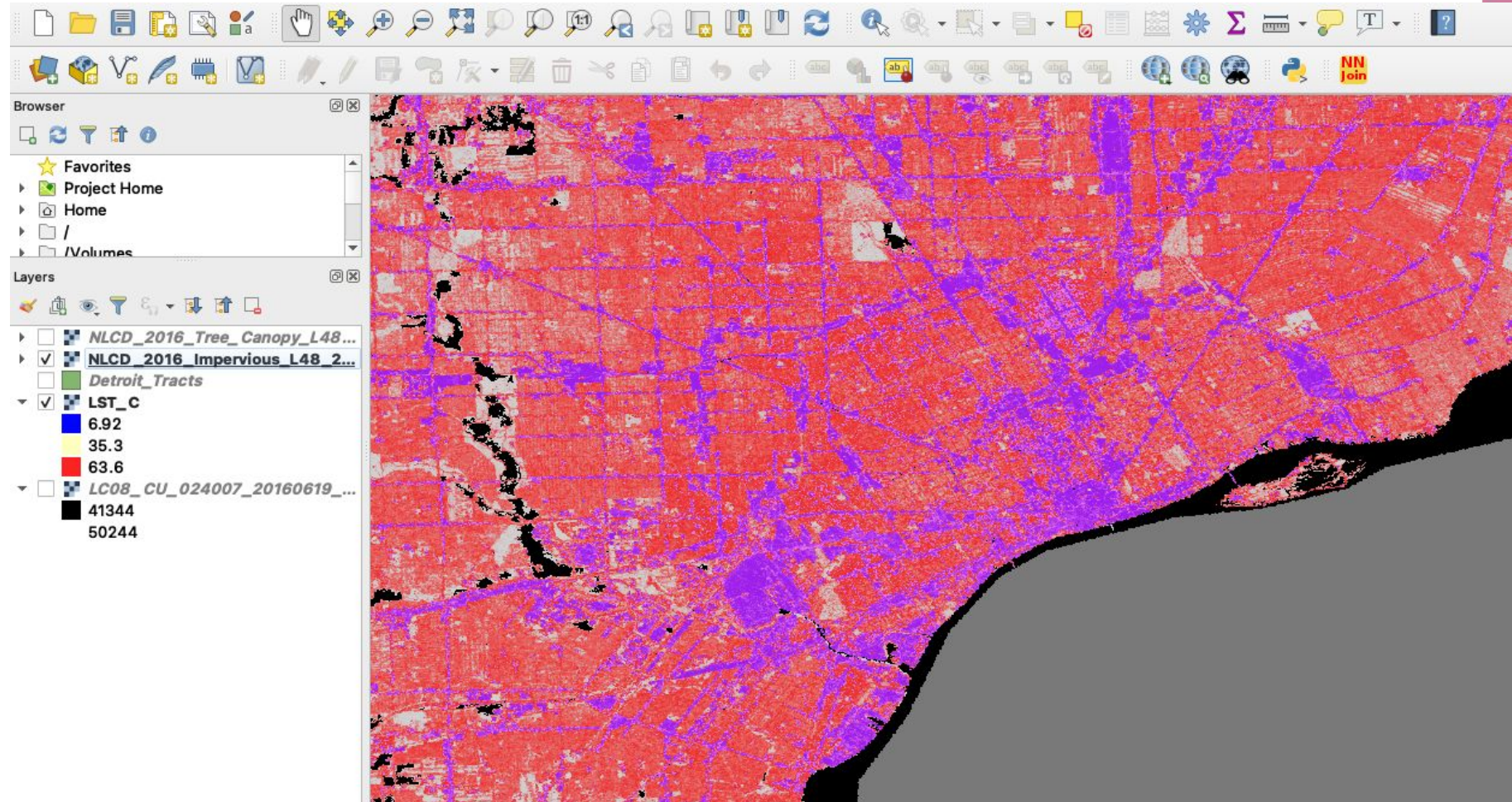
Processing Spatial Components – Exposure Rasters



Repeat with alternative exposure rasters if available

Listed here:

1. Tree canopy
2. Impervious surface



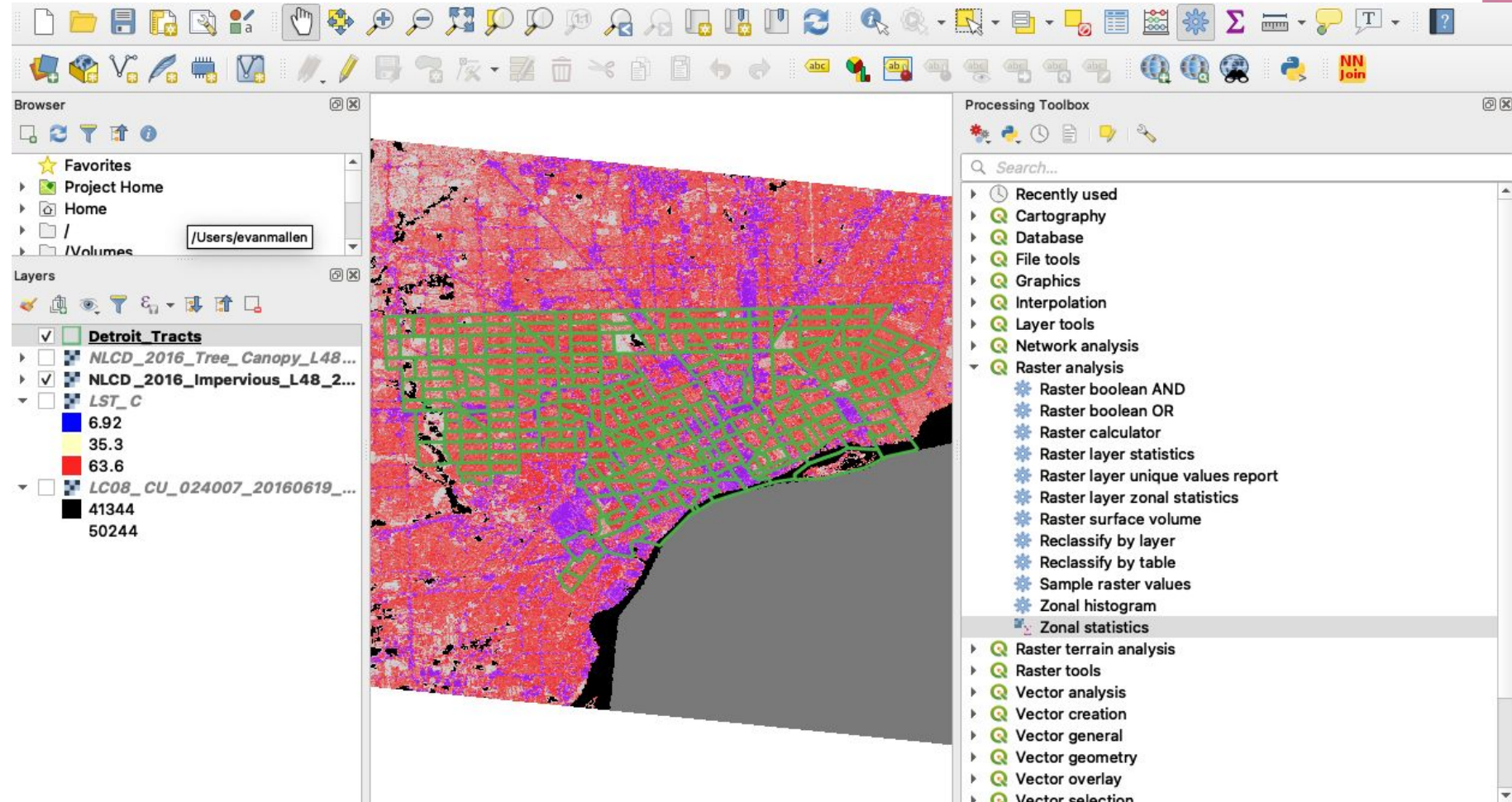
Summarizing Exposure – Zonal Statistics



Zonal Statistics summarizes the values of the raster layer by each unit of geography in the shapefile, or "zone."

Here, we'll use the mean for each exposure raster.

Access the **Zonal Statistics** tool using the **Processing Toolbox**.



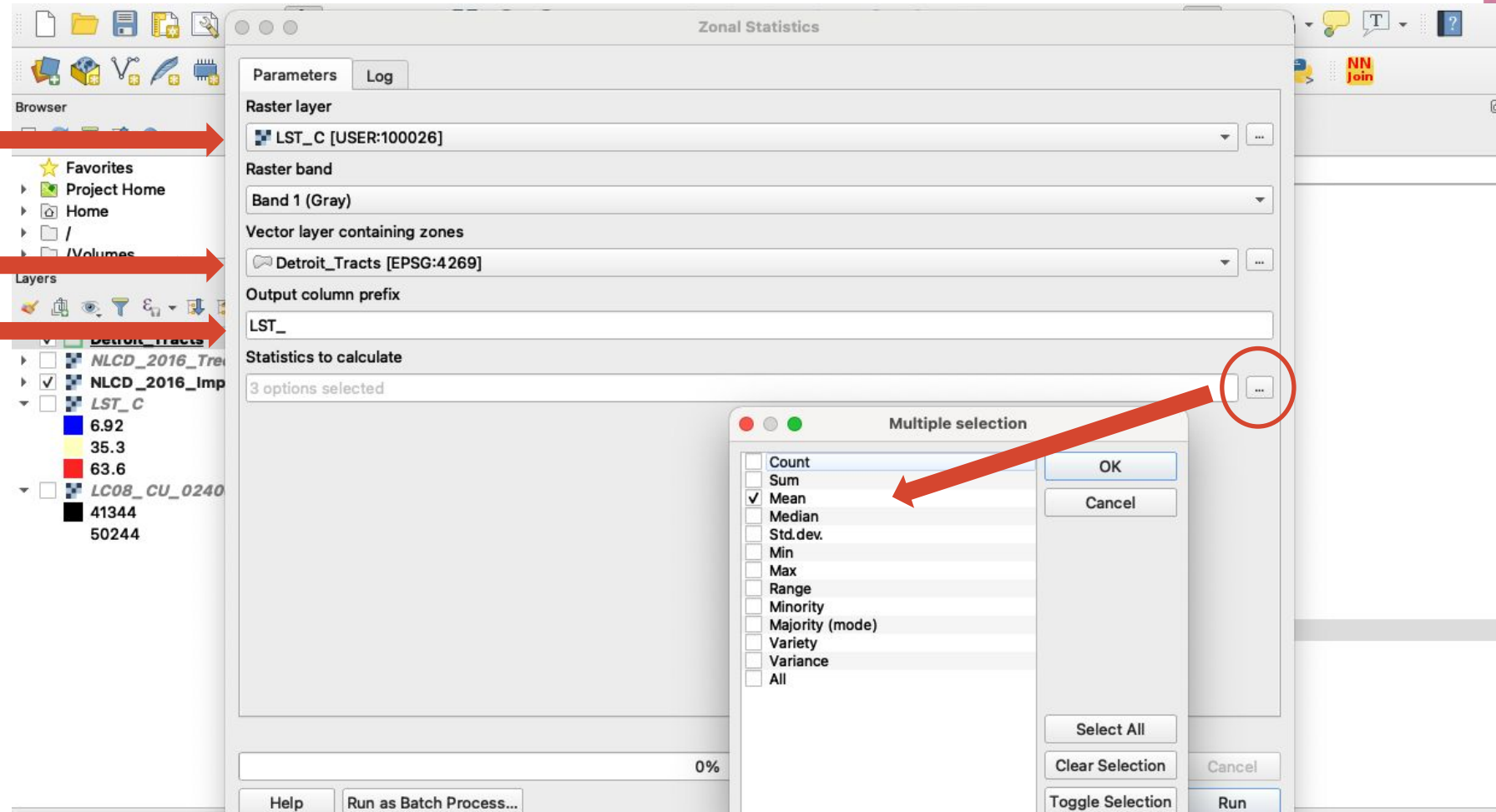
Summarizing Exposure – Zonal Statistics



Exposure data

Boundary shapefiles

Select label for your input variable



Summarizing Exposure – Zonal Statistics



LST_mean is now placed directly into your input shapefile attribute table

Repeat with other input exposure variables as needed

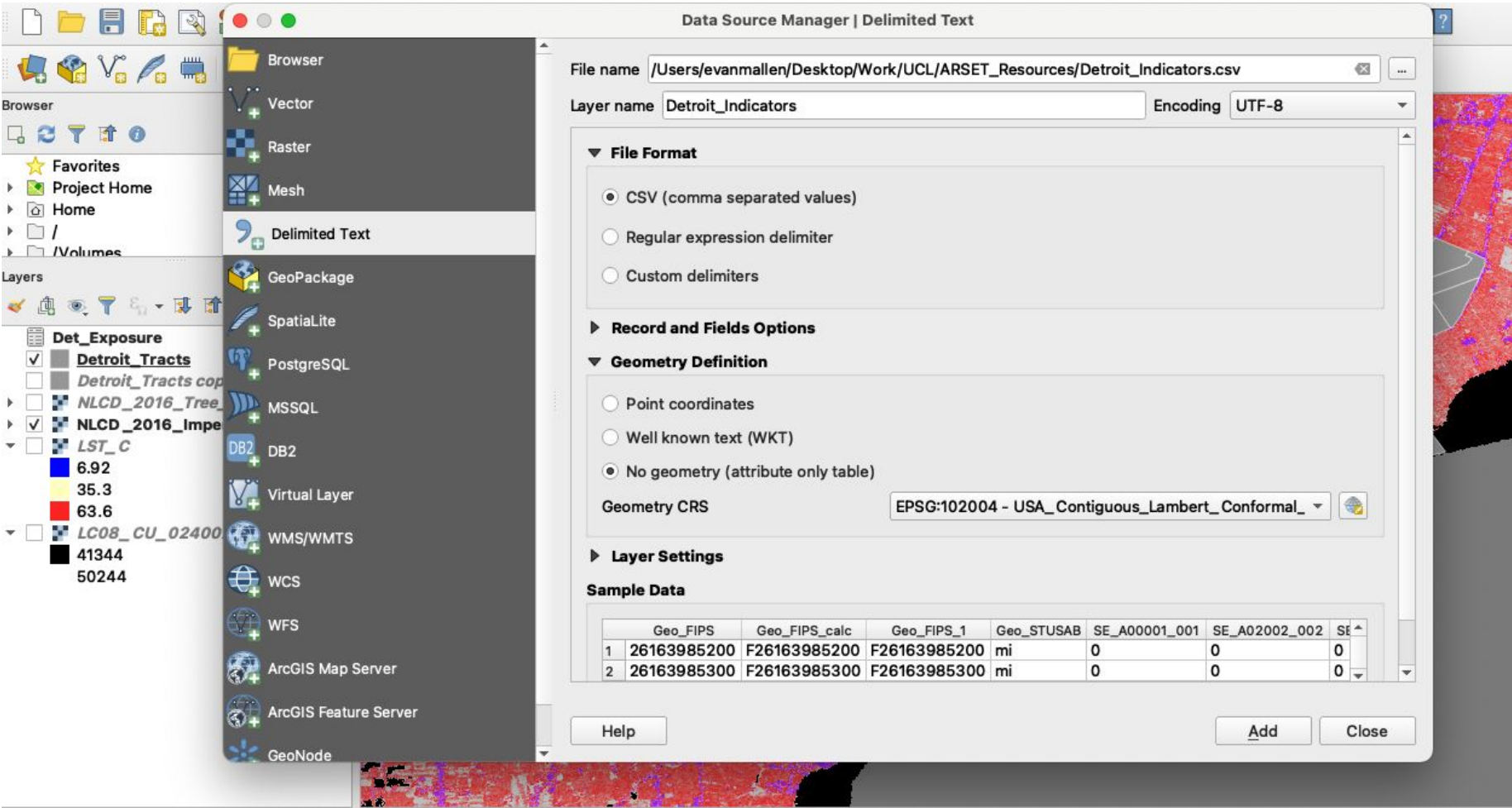
	NAME10	NAMELSAD10	MTFCC10	FUNCSTAT10	ALAND10	AWATER10	INTPTLAT10	INTPTLON10	FIPS	LST_mean
1	5311	Census Tract...	G5020	S	623803	0	+42.3748819	-083.1152689	F261635311	43.1464663...
2	5312	Census Tract...	G5020	S	1079279	0	+42.3788297	-083.1020097	F261635312	42.2081244...
3	5313	Census Tract...	G5020	S	579536	0	+42.3833022	-083.1097921	F261635313	43.31168108...
4	5314	Census Tract...	G5020	S	502012	0	+42.3803842	-083.1189728	F261635314	43.3415864...
5	5315	Census Tract...	G5020	S	865980	0	+42.3870970	-083.1235622	F261635315	43.7937896...
6	5316	Census Tract...	G5020	S	559379	0	+42.3941530	-083.1282997	F261635316	43.5281954...
7	5317	Census Tract...	G5020	S	749294	0	+42.3980117	-083.1171527	F261635317	43.6934145...
8	5318	Census Tract...	G5020	S	868850	0	+42.3903871	-083.1146956	F261635318	42.9092905...
9	5263	Census Tract...	G5020	S	1013504	0	+42.3390784	-083.1384863	F261635263	43.3945226...
10	5264	Census Tract...	G5020	S	567045	0	+42.3405358	-083.1309829	F261635264	43.6871224...
11	5301	Census Tract...	G5020	S	1292334	0	+42.4096746	-083.1216653	F261635301	43.4191440...
12	5302	Census Tract...	G5020	S	1426268	0	+42.4111231	-083.1341948	F261635302	44.3844459...
13	5303	Census Tract...	G5020	S	1611629	0	+42.4008029	-083.1306653	F261635303	44.6468627...
14	5304	Census Tract...	G5020	S	445674	0	+42.3909517	-083.1361282	F261635304	43.66106138...
15	5305	Census Tract...	G5020	S	750419	0	+42.3844331	-083.1340130	F261635305	43.0280061...
16	5308	Census Tract...	G5020	S	1167896	0	+42.3716662	-083.1339332	F261635308	42.59214782...



Joining Your Data



Save your additional data tables as CSV and load into QGIS using the "Delimited Text" option.

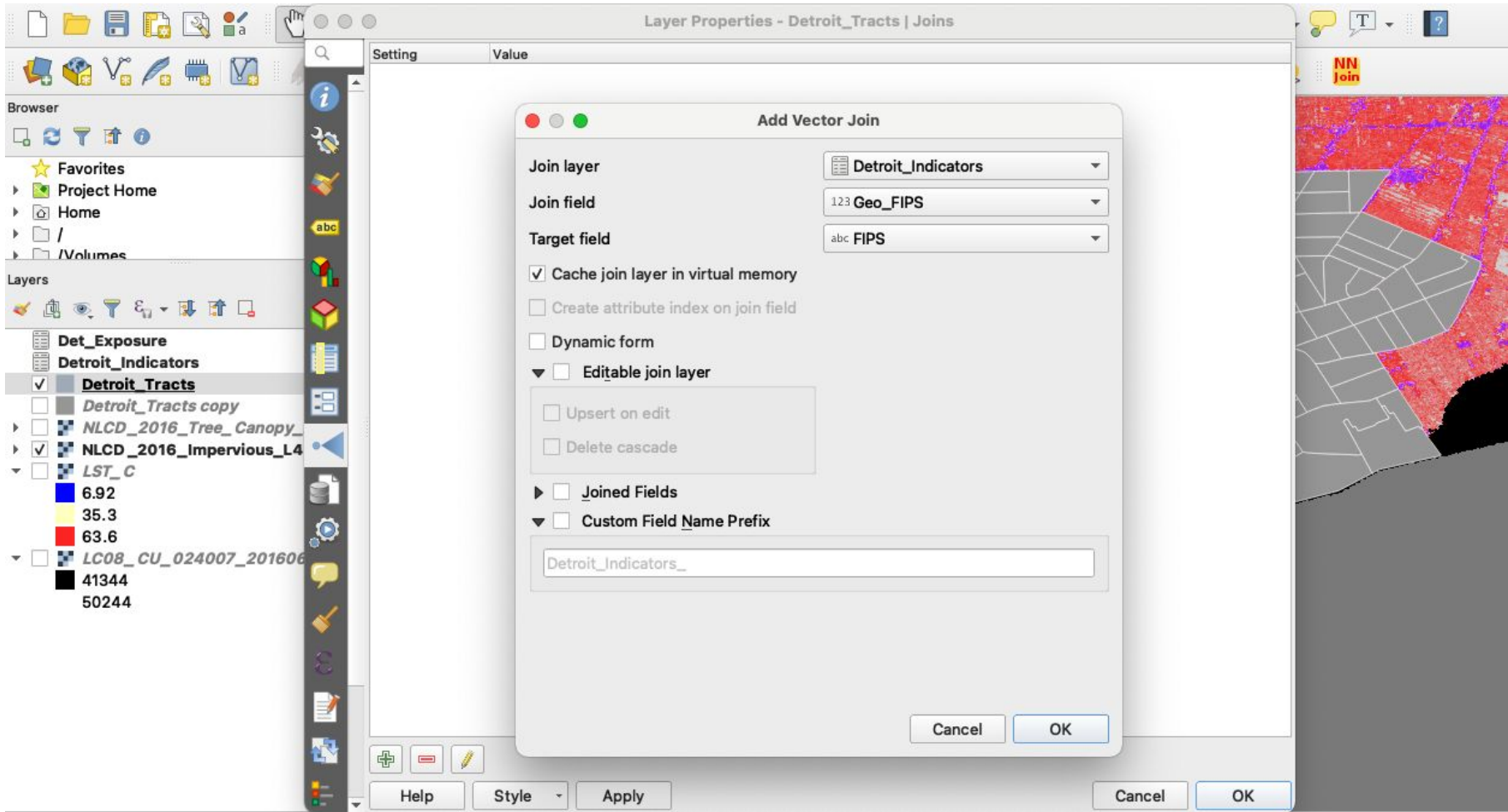


Joining Your Data



Right-click your shapefile and select **Layer Properties**, then the **Join** tab.

Click the + button to add a new join to your shapefile's attribute table.



Joining Your Data

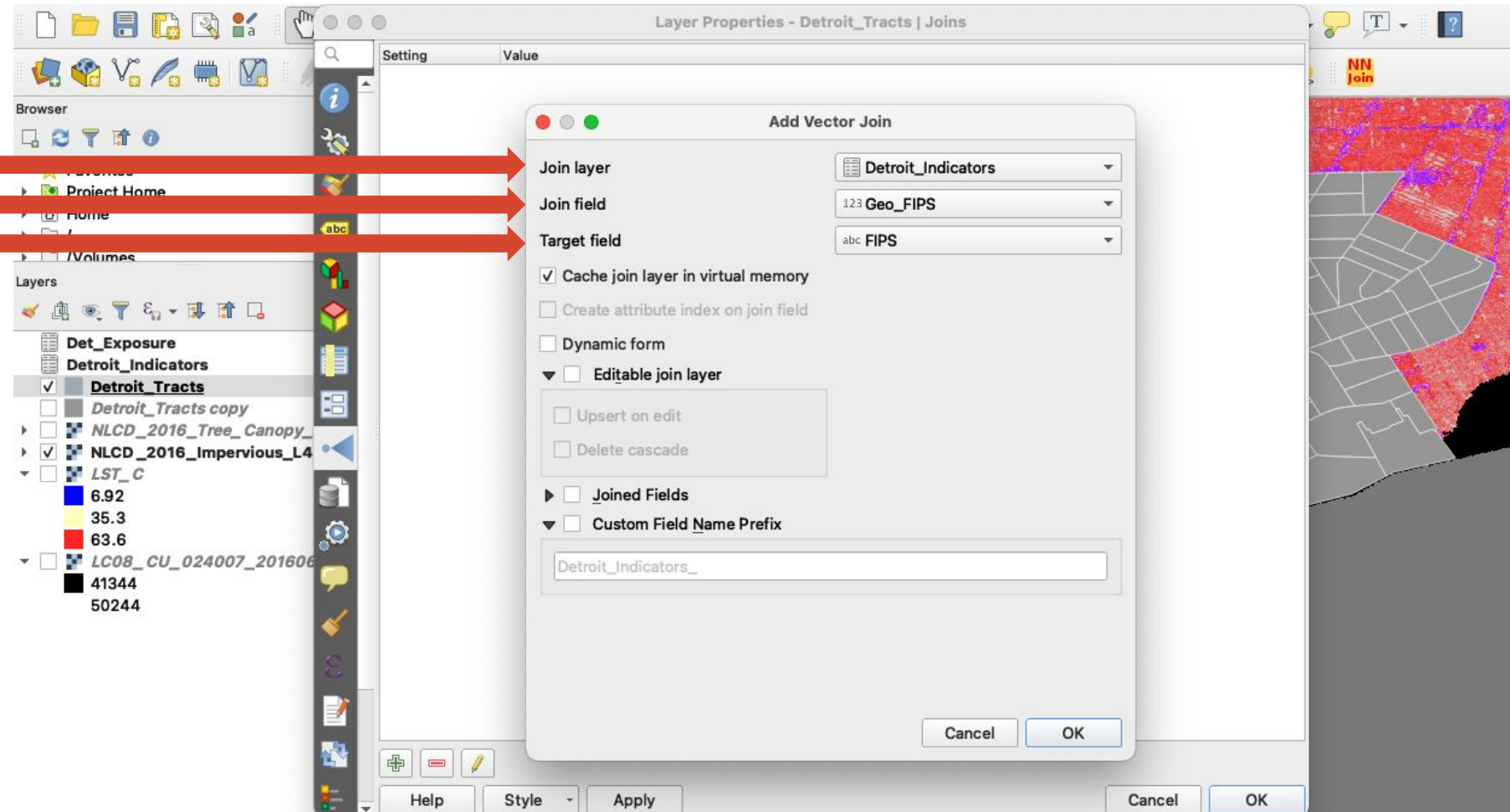


Table we will add to shapefile table

Key field in new table

Key field in shapefile table

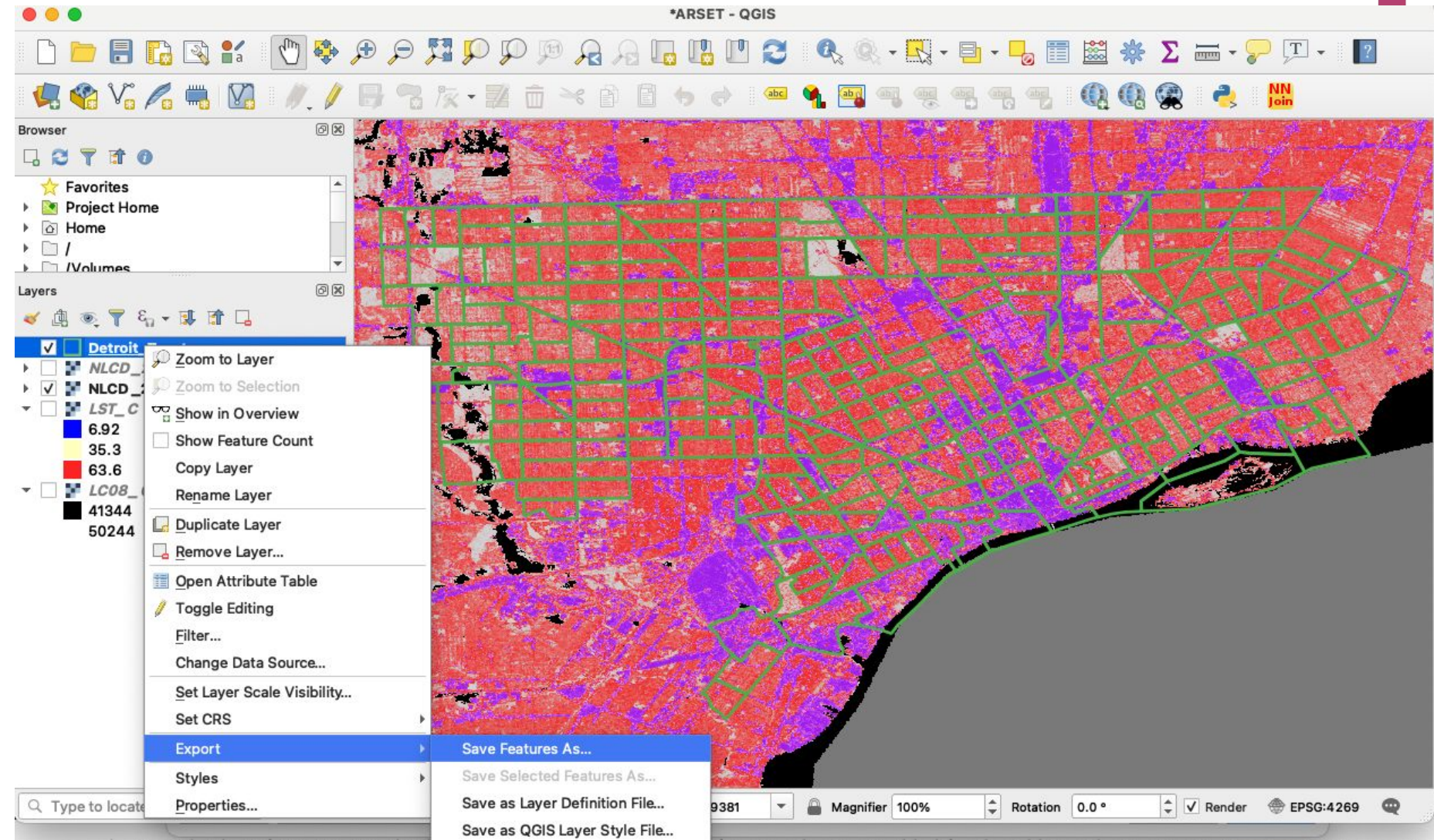
Repeat this process for any new data tables you'd like to add to your HVI dataset.



Exporting Joined Data Table



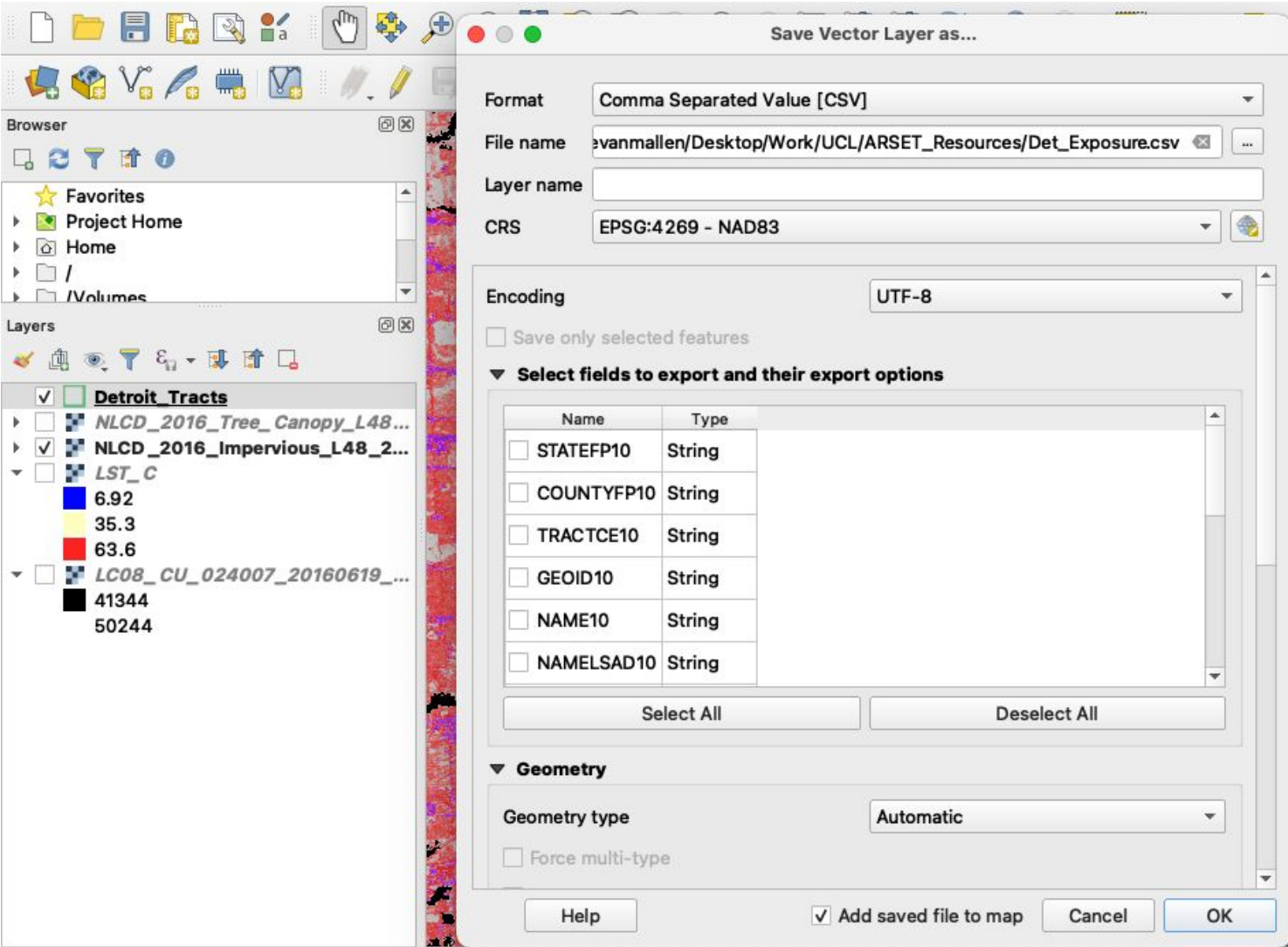
Export data as **Comma Separated Value (CSV)** to combine with other variables in spreadsheet editor.

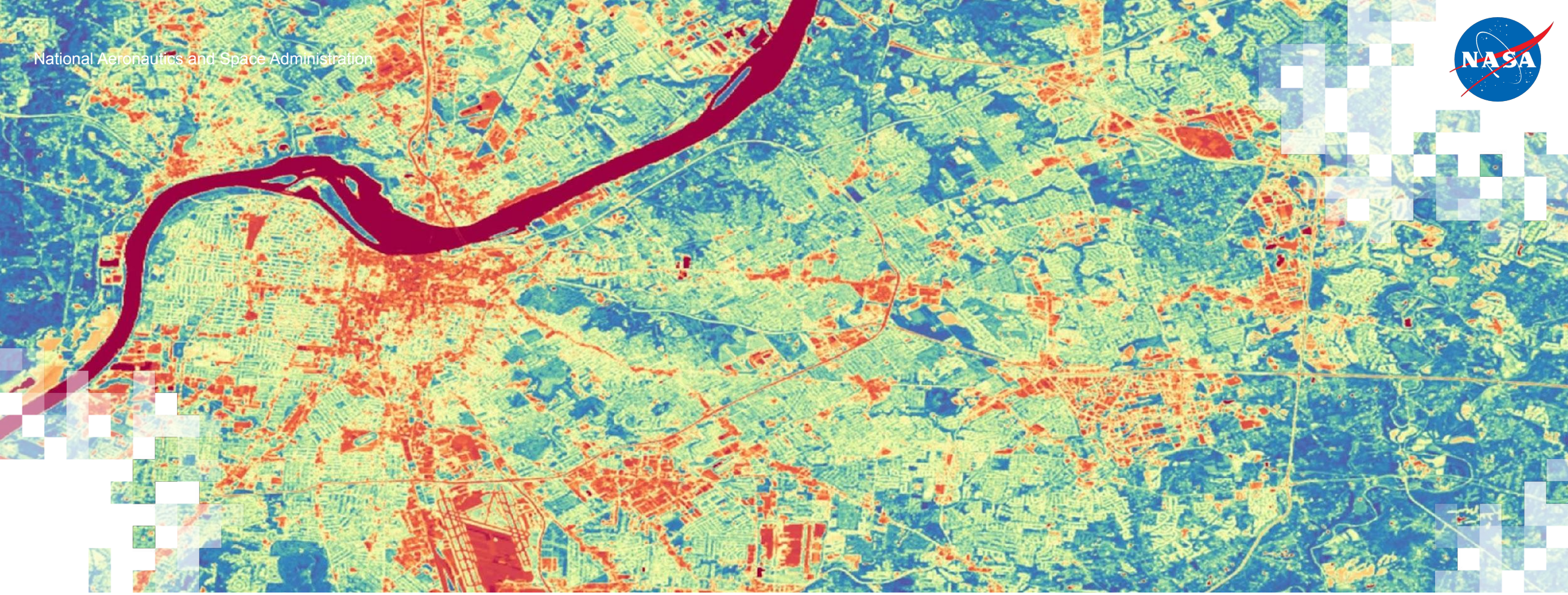


Exporting Joined Data Table



Export data as **Comma Separated Value (CSV)** to combine with other variables in spreadsheet editor.



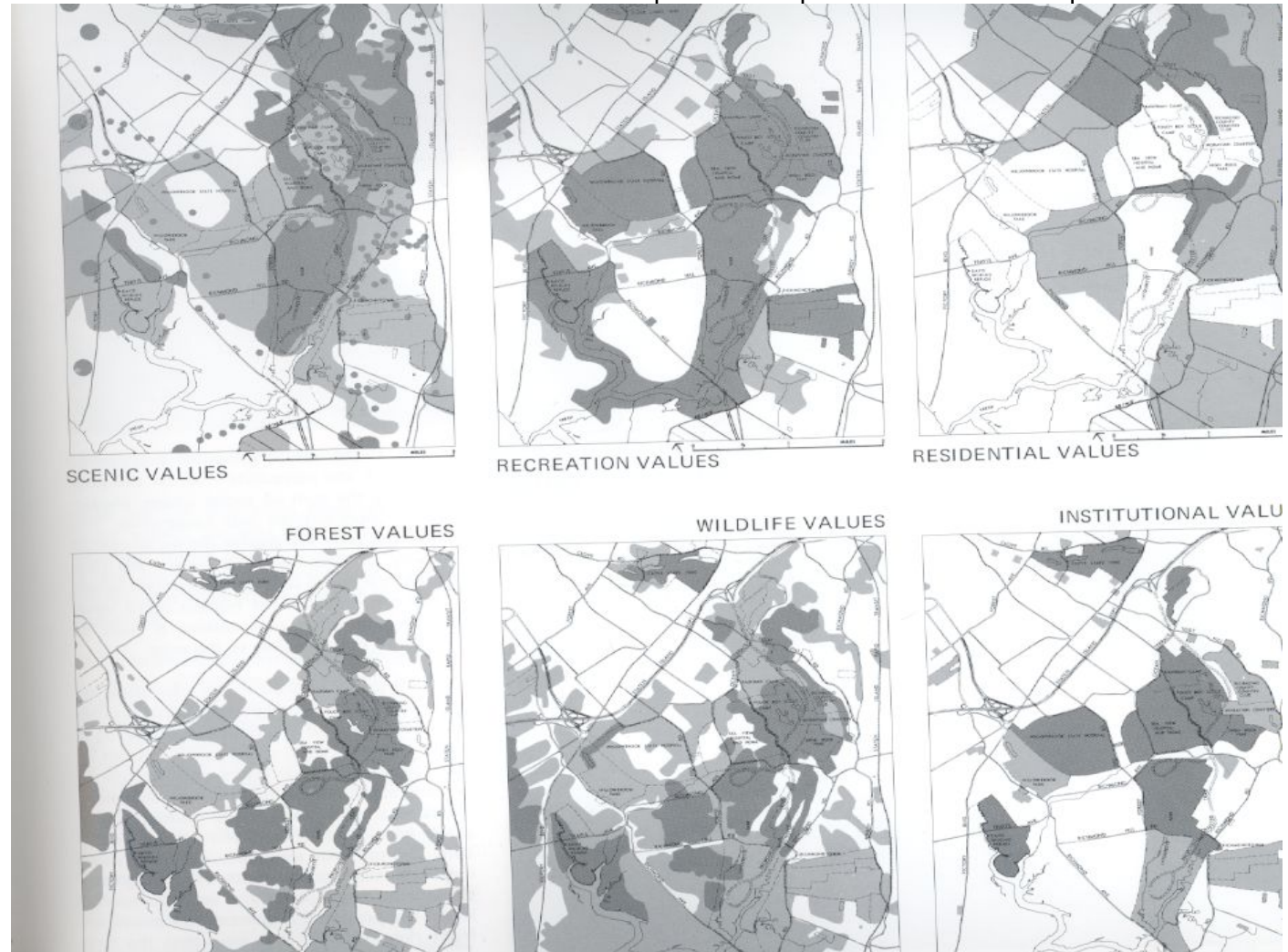


Constructing Your Heat Vulnerability Index

HVI Construction Considerations

- What intervention do you want to implement?
- Which indicators will help locate high-priority areas for this intervention?
- Do you have (or need) a mix of vulnerability components?
- Are your indicators independent?
- Will you weight your indicators?

FIPS	HVI Indicator



McHarg (1969)



HVIs and Heat Interventions

Credit: Las Vegas Review-Journal



Cooling Centers

Credit: Trees Atlanta



Tree Planting

Sensitivity

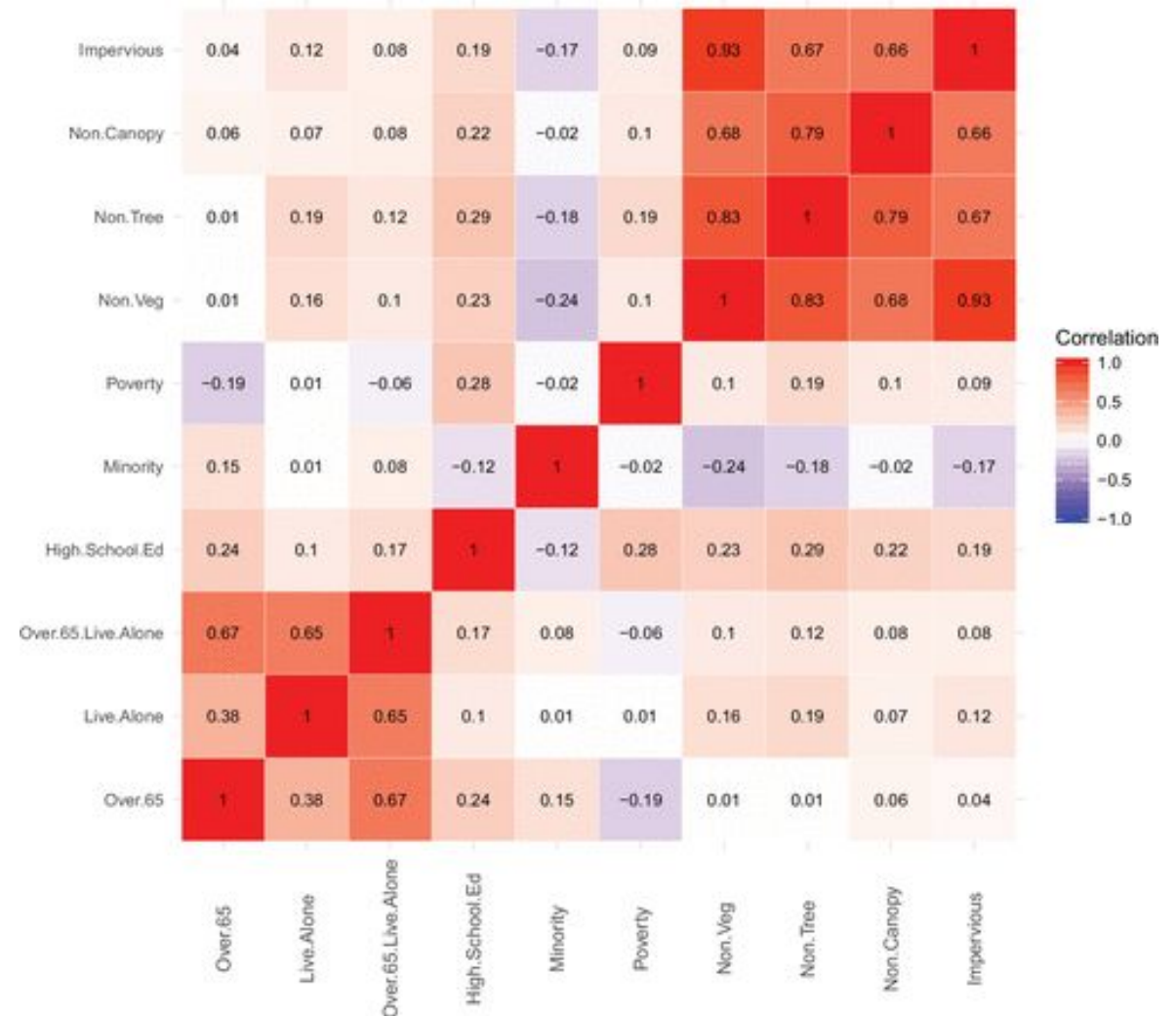
Adaptive
Capacity

Exposure



Weighting Considerations

- Are your indicators independent?
- Correlation matrix
 - Highly correlated variables could be dropped



Conlon et al. (2020)



Cleaning the Dataset

Remove any rows with a total population of zero

- Cannot divide by zero in normalization steps
- Avoids #Div/0! errors



	C	D
2	Geo_FIPS	Total_Population
3	F26163985200	0
4	F26163985300	0
5	F26163985400	0
6	F26163985500	0
7	F26163985600	0
8	F26163985700	0
9	F26163985900	0
10	F26163990100	0
11	F26163990200	0
12	F26163985000	72
13	F26163985100	150
14	F26163518400	425
15	F26163545400	600
16	F26163518800	624

FIPS	HVI Indicator



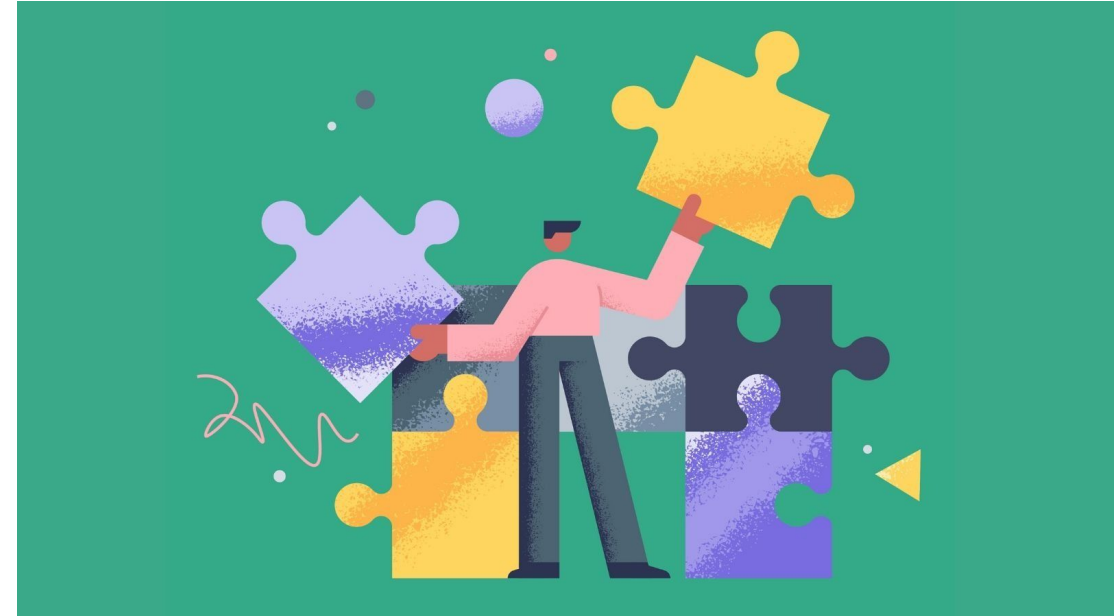
Normalization

FIPS	HVI Indicator

Identify your numerator and denominator

Numerator: Intervention population

Denominator: Total eligible population



Credit: [Sales Layer](#)



Eligible population is not always total population in the geography



Normalization

FIPS	HVI Indicator

Example:

Population over age 65

Numerator: Population cohorts with age > 65

Denominator: Total Population

	BX	BY	BZ
2	O65_pop	Total_Population	O65_p
3	226	3719	0.061
4	226	2985	0.076
5	133	2720	0.049
6	80	1306	0.061
7	171	1795	0.095
8	196	3366	0.058
9	219	4349	0.050
10	133	2795	0.048
11	225	4018	0.056



Eligible population is not always total population in the geography



Normalization

FIPS	HVI Indicator

Example:

Less than High School Education

Numerator: Population over age 25 who did not graduate high school

Denominator: Population over age 25

	CS	CT	CU
2	LHS_pop	O25_pop	LHS_p
3	340	1879	0.181
4	243	1672	0.145
5	227	1353	0.168
6	196	725	0.270
7	281	1206	0.233
8	327	1858	0.176
9	391	2288	0.171
10	171	1659	0.103
11	442	2464	0.179



Eligible population is not always total population in the geography



Checking Unidirectionality

Ensure higher values means higher vulnerability for all indicators in your HVI.

Example:

Land surface temperature and impervious surfaces

FIPS	HVI Indicator

	A	B	C
1	FIPS	LST_mean	Imp_mean
2	F261635248	43.71	59.67
3	F261635219	43.51	67.99
4	F261635218	44.97	69.93
5	F261635215	44.00	69.30
6	F261635214	45.76	82.10
7	F261635213	44.02	70.30
8	F261635211	43.11	73.39

Higher values → Higher heat exposure → More vulnerable ✓



Checking Unidirectionality

FIPS	HVI Indicator

Ensure higher values means higher vulnerability for all indicators in your HVI.

Example:
Tree Canopy

Need to flip this indicator!

	A	D
1	FIPS	TreeCan_mean
2	F261635248	3.41
3	F261635219	3.28
4	F261635218	0.06
5	F261635215	1.71
6	F261635214	0.80
7	F261635213	2.06
8	F261635211	5.54

Higher values → Lower heat exposure → Less vulnerable



Checking Unidirectionality

Ensure higher values means higher vulnerability for all indicators in your HVI.

Use complement of indicator to flip orientation.

NoCan = 100 - TreeCan

FIPS	HVI Indicator

SUM ↕ ✖ ✓ fx =100 - D2			
	A	D	E
1	FIPS	TreeCan_mean	NoCan_mean
2	F261635248	3.41	=100 - D2
3	F261635219	3.28	96.72
4	F261635218	0.06	99.94
5	F261635215	1.71	98.29
6	F261635214	0.80	99.20
7	F261635213	2.06	97.94
8	F261635211	5.54	94.46

Higher values  Higher heat exposure  More vulnerable



Construction Mechanisms – Scoring

FIPS	HVI Indicator

Z-score: Number of standard deviations from the mean

$$\text{Z-score} = \frac{[\text{Observed value} - \text{mean}_x]}{\text{Std. deviation}}$$

Range of Z-Score	HVI Component Score
-2 or lower	1
-2 to -1	2
-1 to 0	3
0 to 1	4
1 to 2	5
2 or higher	6

Reid et al. (2009)



Construction Mechanisms – Scoring

FIPS	HVI Indicator

	BZ	CA	CB
2	O65_p	O65_z	O65_HVI
3	0.061	-1.285	2
4	0.076	-1.008	2
5	0.049	-1.505	2
6	0.061	-1.276	2
7	0.095	-0.645	3
8	0.058	-1.332	2
9	0.050	-1.478	2
10	0.048	-1.530	2

Range of Z-Score	HVI Component Score
-2 or lower	1
-2 to -1	2
-1 to 0	3
0 to 1	4
1 to 2	5
2 or higher	6

Reid et al. (2009)



Construction Mechanisms – Scoring

FIPS	HVI Indicator

Repeat scoring scheme for each vulnerability indicator and combine.

Unweighted HVI is simply the sum of all individual HVI indicator scores.

SUM						
=SUM(CB3:CF3)						
	CB	CC	CD	CE	CF	CG
2	LST_HVI	Diabetes_HVI	LHS_HVI	O65_HVI	Pov_HVI	UnWeight_HVI
3	1	2	6	2	3	=SUM(CB3:CF3)
4	4	2	3	2	4	15
5	4	2	4	2	2	14
6	3	5	5	2	2	17
7	2	4	2	3	2	13
8	6	3	1	2	6	18
9	4	2	3	2	4	15
10	2	3	3	2	3	13

Exposure

Sensitivity

Adaptive Capacity



Construction Mechanisms – Scoring

FIPS	HVI Indicator

Weighted HVI will need to add weights to each indicator or collection of indicators.

Example: Each vulnerability **component** is equally weighted in this HVI.

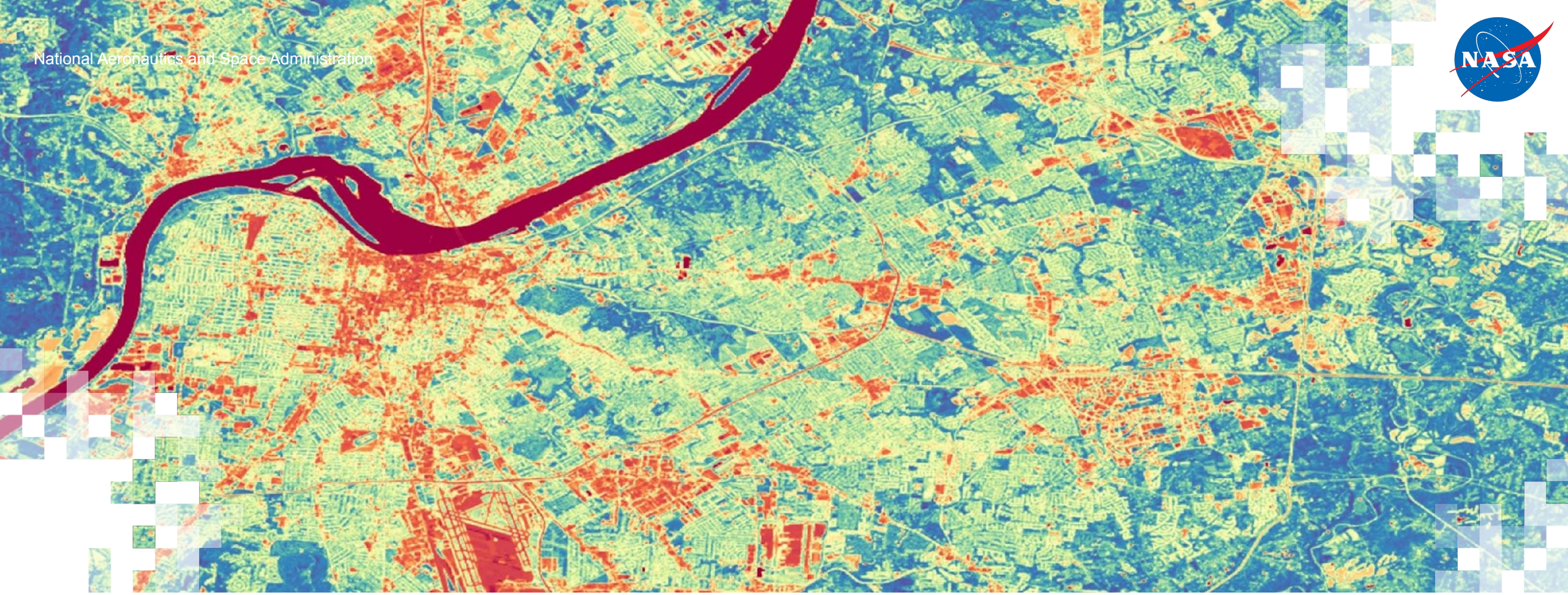
SUM							
	CB	CC	CD	CE	CF	CH	
2	LST_HVI	Diabetes_HVI	LHS_HVI	O65_HVI	Pov_HVI	Weight_HVI	
3	1	2	6	2	3	CF3)/3)	
4	4	2	3	2	4	9	
5	4	2	4	2	2	9	
6	3	5	5	2	2	11	
7	2	4	2	3	2	8	
8	6	3	1	2	6	12	
9	4	2	3	2	4	9	
10	2	3	3	2	3	8	

Exposure

Sensitivity

Adaptive Capacity





Mapping the Heat Vulnerability Index

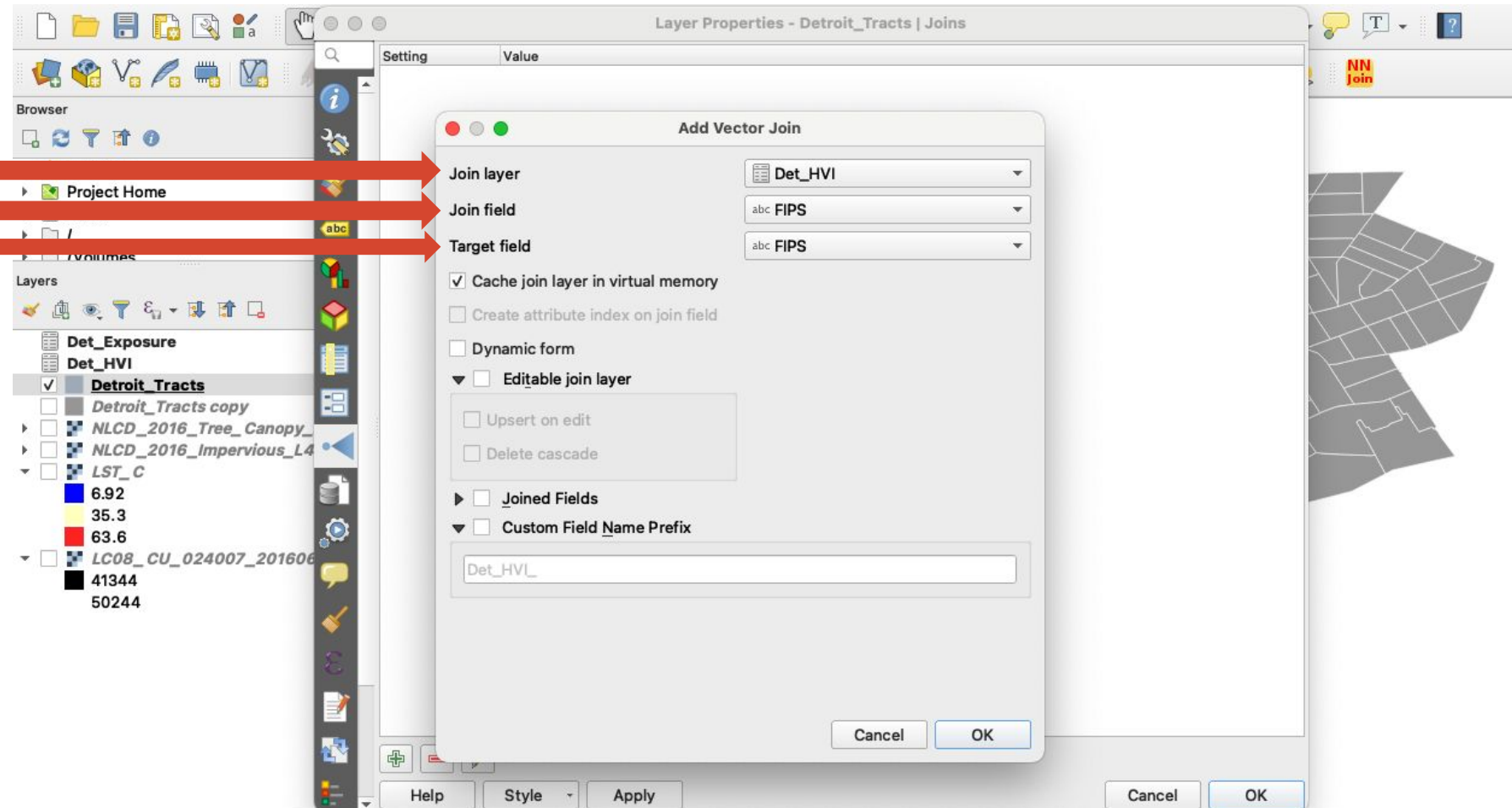
Joining Your Data for Mapping



Processed HVI table as CSV

Key field in HVI table

Key field in shapefile table

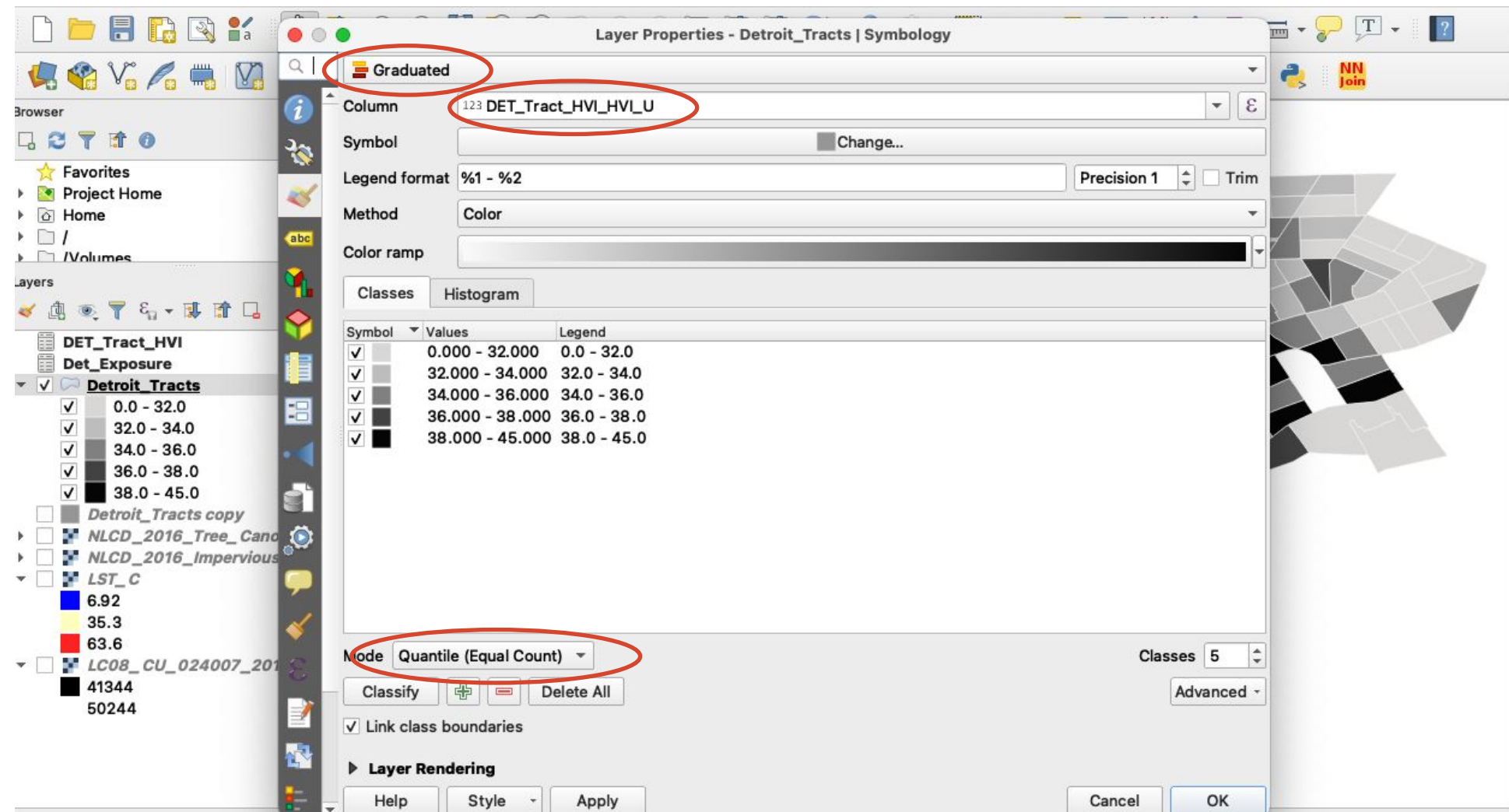


Joining Your Data for Mapping



Design your map using the **Symbology** tab in **Layer Properties**.

We recommend "Quantile" mode to indicate areas of highest relative priority.

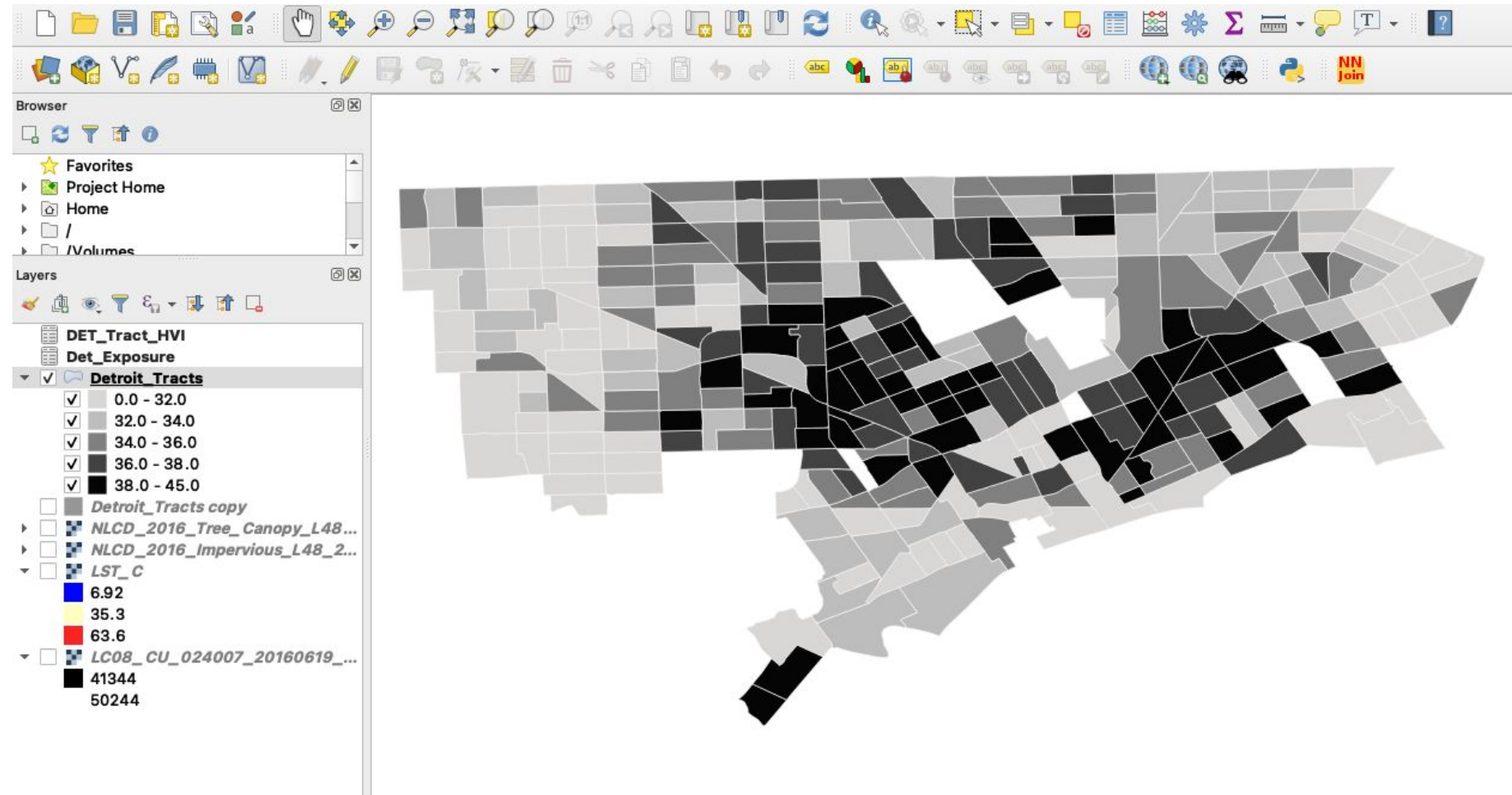


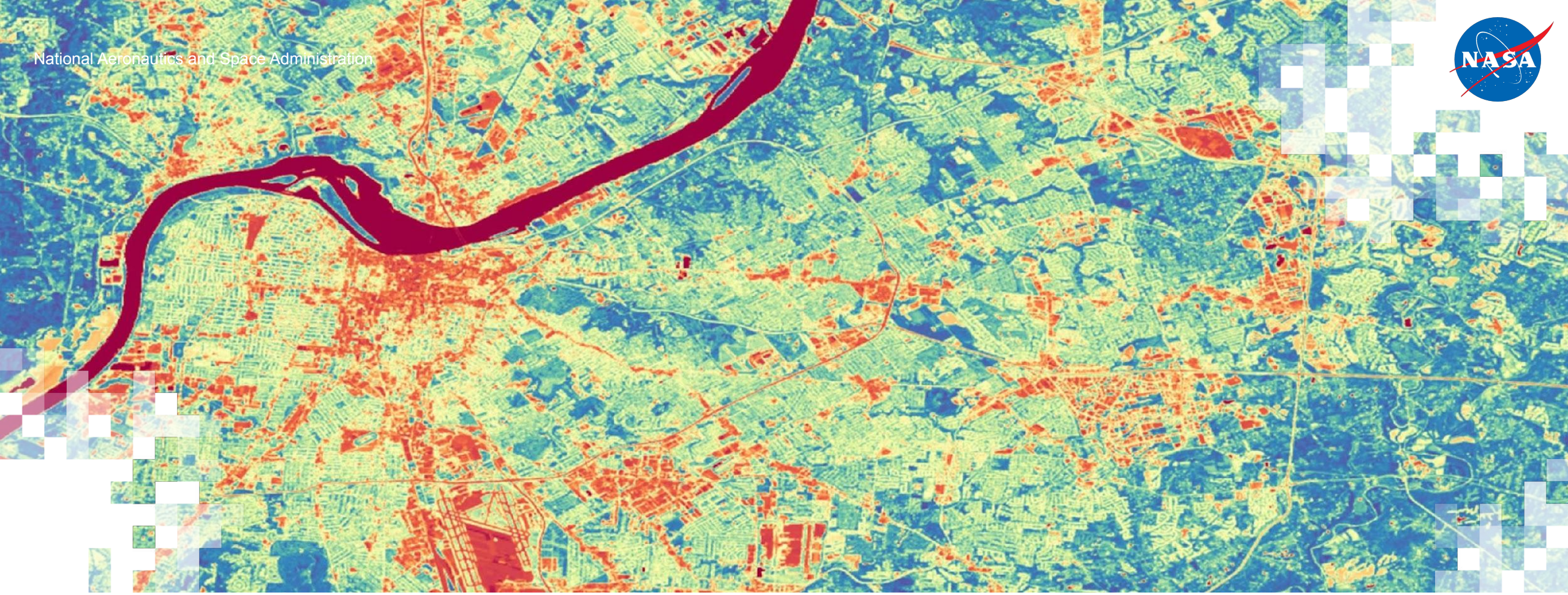
Your HVI Map



Your map is complete!

Now how will you use it?





Time to Practice!

Homework Materials

1. Provided dataset of heat vulnerability characteristics for Detroit, MI USA
 1. Demographic data
 2. Land use data
 3. Temperature data
2. Slide deck with step-by-step guidance

Note: Dataset is organized such that variables confer vulnerability



Homework Questions

1. What is your intervention?
2. Which indicators will you use?
3. How will you weight your indicators?
4. Map of HVI
5. Based on your HVI results, where will you deploy your intervention?



Works Cited

- Conlon KC, Mallen E, Gronlund CJ, Berrocal VJ, Larsen L, O'Neill MS. Mapping human vulnerability to extreme heat: a critical assessment of heat vulnerability indices created using principal components analysis. *Environmental Health Perspectives*. 2020 Sep 2;128(9):097001.
- McHarg, I. L., & American Museum of Natural History. (1969). *Design with nature*. Garden City, N.Y: Published for the American Museum of Natural History [by] the Natural History Press.
- Reid, C., O'Neill, M., Gronlund, C., Brines, S., Brown, D., Diez-Roux, A., Schwartz, J. (2009). Mapping community determinants of heat vulnerability. *Environmental Health Perspectives*, 117(11), 1730–1736. <http://doi.org/10.1289/ehp.0900683>



Questions?

- Please enter your questions in the Q&A box. We will answer them in the order they were received.
- We will post the Q&A to the training website following the conclusion of the webinar.



Credit: NASA



Contacts

- Trainers
 - Kathryn Conlon, PhD, MPH: kcconlon@ucdavis.edu
 - Evan Mallen, PhD, MUP: emallen3@gatech.edu
- Training Webpage:
 - <https://appliedsciences.nasa.gov/join-mission/training/english-arset-satellite-remote-sensing-measuring-urban-heat-islands-and>
[d](https://appliedsciences.nasa.gov/join-mission/training/english-arset-satellite-remote-sensing-measuring-urban-heat-islands-and)
- ARSET Website:
 - <https://appliedsciences.nasa.gov/what-we-do/capacity-building/arset>





Thank You!

