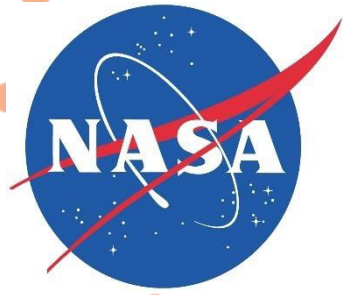
ArcGIS Pro Tutorials for Air Quality Analysis

The Holloway Group @ SAGE
Nelson Institute for Environmental Studies
University of Wisconsin-Madison
Madison, WI 53726



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Acknowledgments

Work for this tutorial was funded by the NASA Health and Air Quality Applied Sciences Team (HAQAST) "Satellite Data for Environmental Justice" Tiger Team, led by Susan Anenberg (George Washington University) and Qian Xiao (University of Texas). This tutorial was written by Colleen Heck with input from Ryan Almeida, Monica Harkey, Tracey Holloway, Lizzy Kysela, Jennifer McGinnis, and Rishika Tumula.

Introduction

This tutorial will demonstrate how to allocate gridded satellite-derived nitrogen dioxide (NO_2) data over the Continental United States (CONUS) to Chicago metropolitan area census tracts using ArcGIS Pro. It will walk through common tools that can be useful in GIS air quality analysis such as clipping, filtering and allocating data from one format to another. Upon completing this tutorial, you will have a new shapefile containing census tract average NO_2 values, a web map layer of the census tract NO_2 averages and useful skills that can be applied to other GIS air quality applications.

GIS and ArcGIS Pro

A geographic information system (GIS) is a computer system that displays geographically referenced information and has built in tools that allow users to visualize, analyze and manage this data. While there are many different GIS software packages, this tutorial was made using ESRI's ArcGIS Pro version 3.0.2 and 3.0.4 and further tested with version 3.1.2. ArcGIS Pro is a professional grade software the retails for about $700/year for the basic version and up to $3,800/year for the advanced version of the software. Future versions of this tutorial will be made with other GIS software packages, but we recommend ArcGIS Pro because it is user friendly, has greatvisualizations and is able to publish web-based maps.

Satellite data is not traditionally provided in standard GIS formats. However, it is useful to have satellite data in a GIS format, to combine with various other data products, to create visually appealing maps, and to provide the first step for the Environmental Protection Agency's (EPA) Environmental Justice (EJ) mapping tool (EJScreen). Additionalinformation on EJScreen can be found in Appendix C.

Requirements

The following are required in order to complete this tutorial:

- ArcGIS Pro v3.0.2 or later
- An ArcGIS online account

Before beginning this tutorial, you should have ArcGIS Pro installed on your computer and stepped through a basic introduction to ArcGIS Pro tutorial. If you haven't, here is one we found useful: https://pro.arcgis.com/en/pro-app/latest/get-started/get-started.htm . To use this tutorial, we do not expect proficiency or experience in ArcGIS Pro, but some level of familiarity may be helpful. If you are already very proficient in ArcGIS Pro, some of the instructions heremight be too basic, but hopefully still helpful.

Uses

While this tutorial walks through a specific example of allocating 1km x 1km gridded satellite-derived

NO_2 data to Chicago metropolitan census tracts, the steps demonstrated here can be applied to other datasets such as the satellite-derived $PM_{2.5}$ dataset provided by the Atmospheric Composition Analysis Group at Washington University in St. Louis. A list of satellite-derived datasets can be found in Appendix B.

How to Make a Map of Gridded Satellite-Derived NO_2 Data

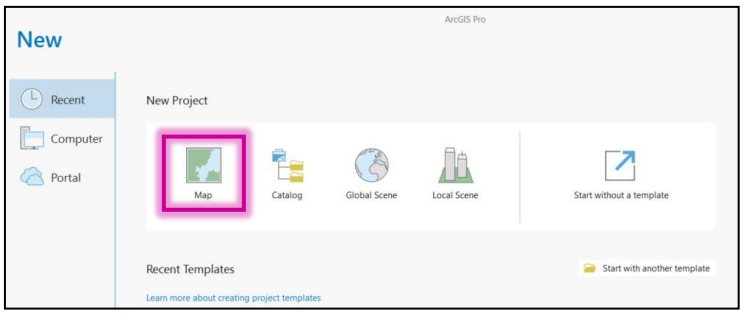
Tutorial 1 was created in November 2022 using ArcGIS Pro 3.0.2 and last tested in November 2023 using ArcGIS Pro 3.0.4. If you are using a differentversion of the software, you may encounter different functionality and results.

Getting Started

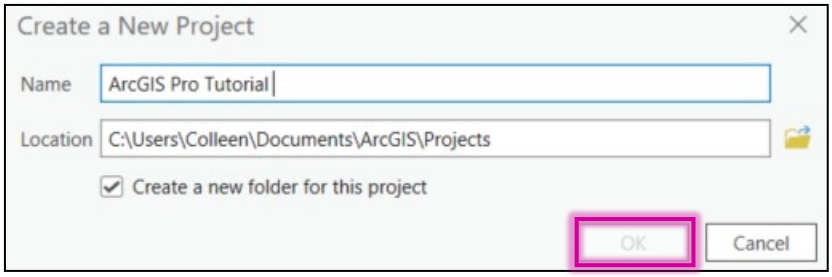
1. Download the data for this tutorial here and unzip the folder after it has been downloaded. This folder contains the 2019 census tract shapefiles for Wisconsin, Indiana and Illinois, the U.S. Metropolitan and Micropolitan Core-based Statistics Areas (CBSA) shapefile and a TIFF file of the 1km x 1km gridded 2019 TROPOMI NO_2 data over the contiguous U.S.

More information on the data used in this tutorial can be found in Appendix A.

2. Open ArcGIS Pro and create a **New Project Map**



3. **Name** the project and choose a **Location** where it will be saved. Click **OK**.

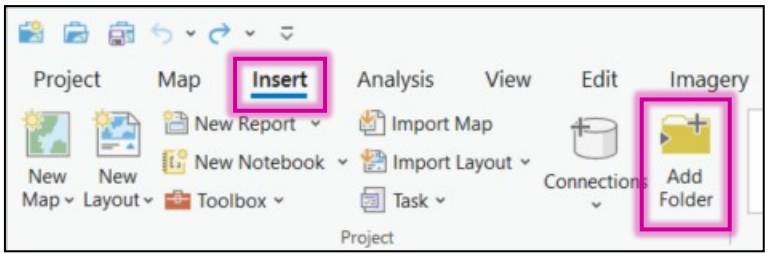


4. A new project map will open.

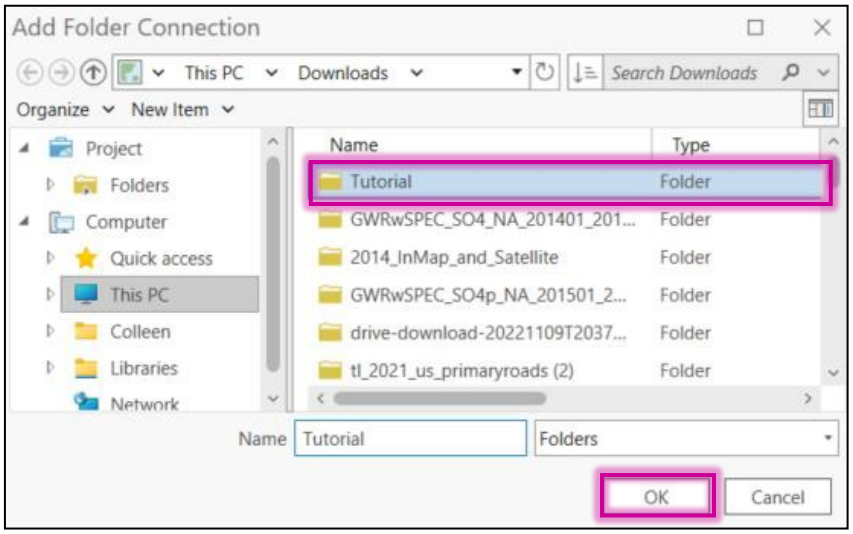
Create a Folder Connection

*Let's begin by **Adding a Folder Connection**. While there are several different ways to add data (i.e., shapefiles, netCDF files, .csv files) to a map, this way is the most efficient when all the data is in the same folder or location.*

1. From the top ribbon, click the **Insert** tab and select the **Add Folder** icon.

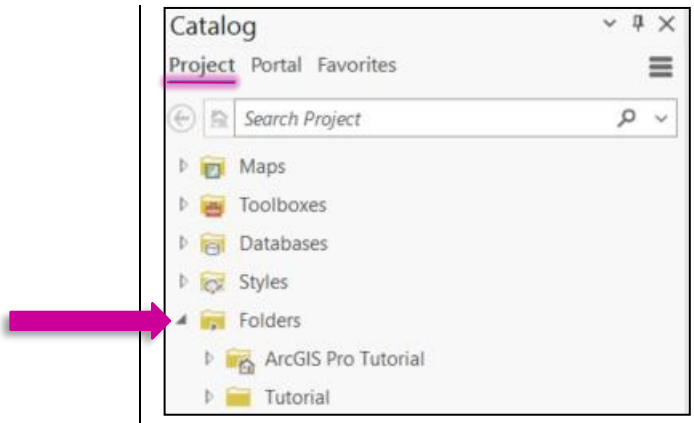


2. The **Add Folder Connection** pop-up window will appear. Navigate to where you downloaded and stored the data folder for this tutorial on your computer. Select the **Tutorial folder** and click **OK**.

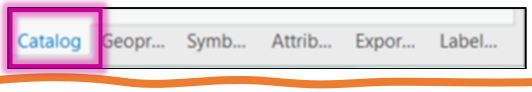


If the folder doesn't appear, check to make sure you unzipped it!

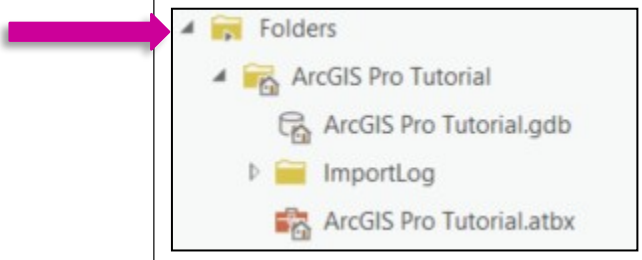
3. Go to the **Catalog** pane located to the right of the map. Under the **Project** tab, select the small arrow next to **Folders** to drop down the folder's content. You will see two separate folders. The first folder with the house icon is the project folder (I named my project **ArcGIS Pro Tutorial**) and the second folder is the **Tutorial** folder that we just added. (If the **Catalog** pane is not present, select the **View** tab on the top of screen, and click on **Catalog Pane** under **Windows**)



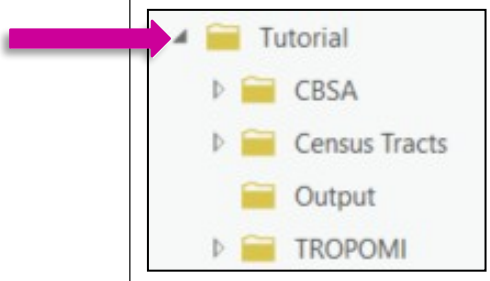
*Your project may default to another tab which is why the catalog doesn't appear. Simply click the **Catalog** tab if it happens.*



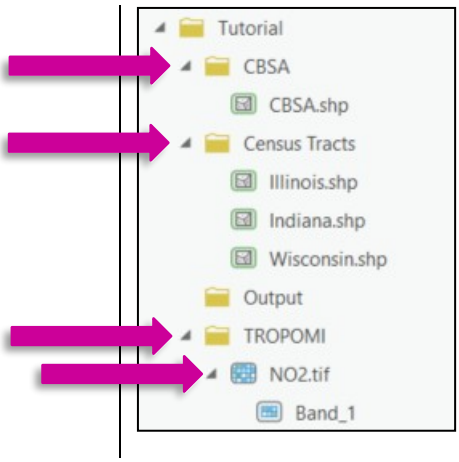
4. Click the arrow next to the project's folder to display its content. The project's geodatabase (**ArcGIS Pro Tutorial.gdb)** where we will store some of the files made during this tutorial.



5. Click the arrow next to the **Tutorial** folder to display the folder's subfolders.



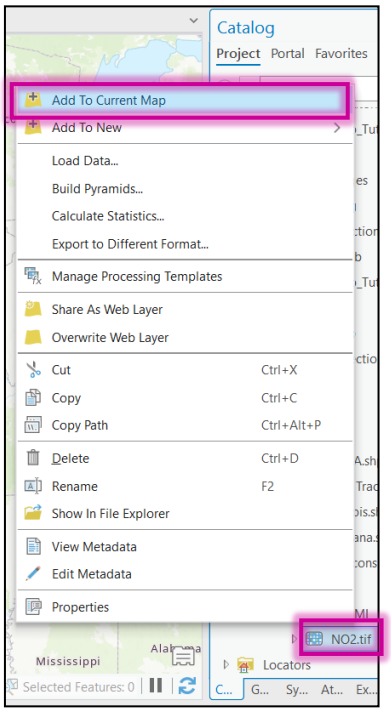
6. Continue to open the subfolders from **Tutorial** by selecting the arrows until all the content is displayed.



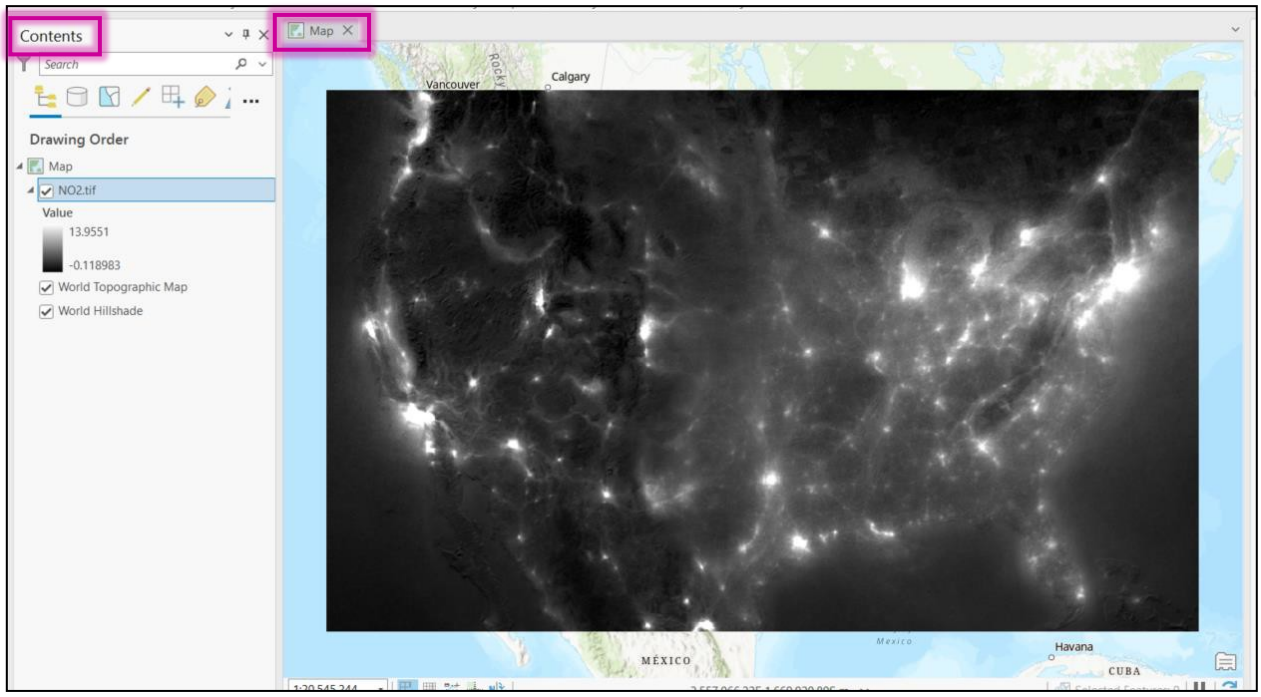
7. You will see the shapefiles (.shp) for **CBSA**, **Illinois**, **Indiana**, and **Wisconsin** as well as the **NO2.tif** raster file. The **Output** folder will be empty. This is where you will store some of the additional files made in this tutorial.

Add the Data to the Map

1. Add the **NO2.tif** file to the map. To add the files to the map, either click and drag the file onto the map, or right-click on the file and select **Add to Current Map**.

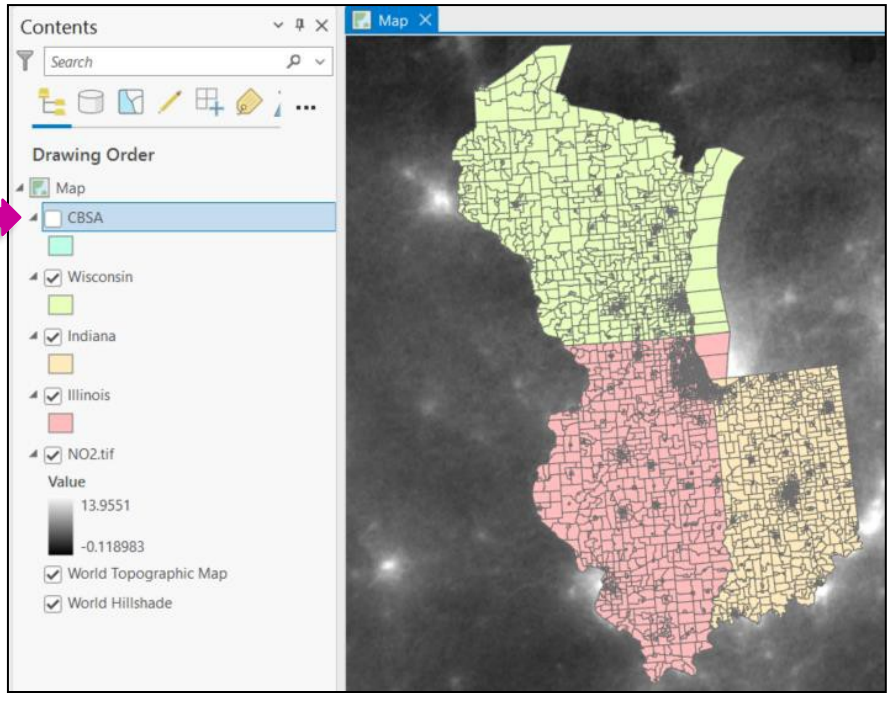


2. The **NO2.tif** layer will appear on the **Map** and in the **Contents,** pane located to the left of the map.



3. Add **Illinois.shp**, **Indiana.shp**, **Wisconsin.shp** and **CBSA.shp**

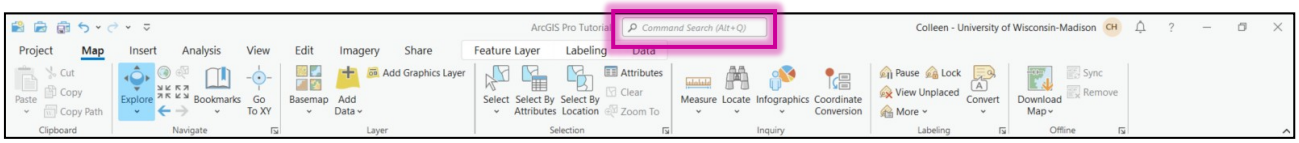
4. Hide the **CBSA** layer from being displayed on the map by clicking the box to the left of the layer.



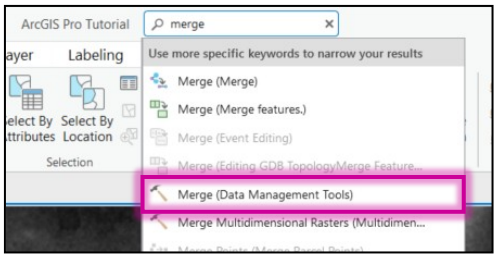
The colors of each layer may be different than the ones shown here. Do not worry about the colors of each layer!

Merging Shapefiles

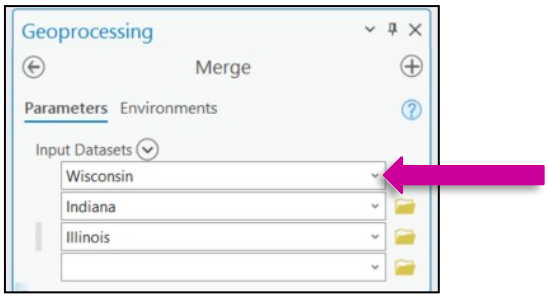
1. Merge the three census tract layers (**Wisconsin**, **Indiana**, and **Illinois**) into one layer. While there are different ways of accessing the tools used in this tutorial, it is easiest to use the **Command Search** located above the top ribbon.



2. In the **Command Search**, type “merge” and select **Merge (Data Management Tools)**.



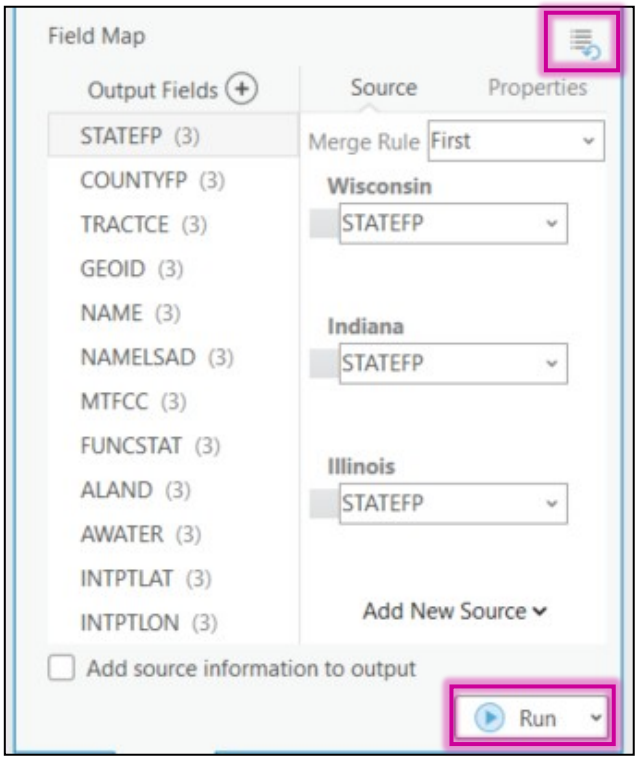
3. In the **Merge Geoprocessing** window under the **Parameters** tab, select the arrow to drop down the **Input Datasets** and select all three of the state shapefiles starting with **Wisconsin** followed by **Indiana** and **Illinois**.



4. As a result of adding the **Input Datasets**, the **Output Dataset** will update to **Wisconsin_Merge**. If you click on this box, it will show you the path where the output dataset is saved. By default, it is the project’s geodatabase (**.gdb**). We will use the default.

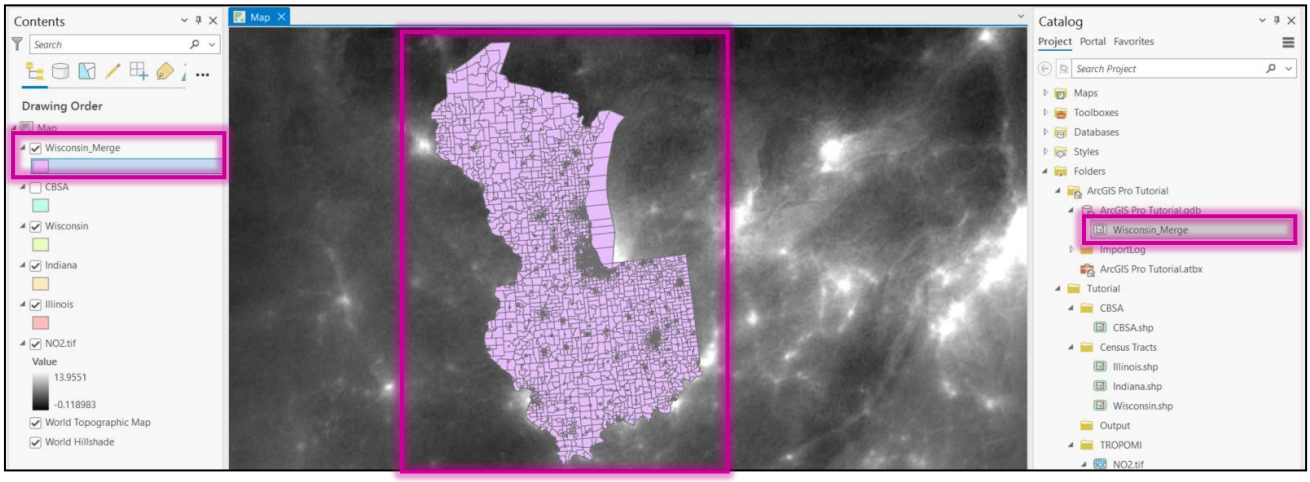
*The first state you selected as the **Input Dataset** will be the default output **_Merge** name*

5. The **Field Map** contains a list of all the fields every layer. Click the **Reset** icon to ensure that all the layer’s fields are included and click **Run**.

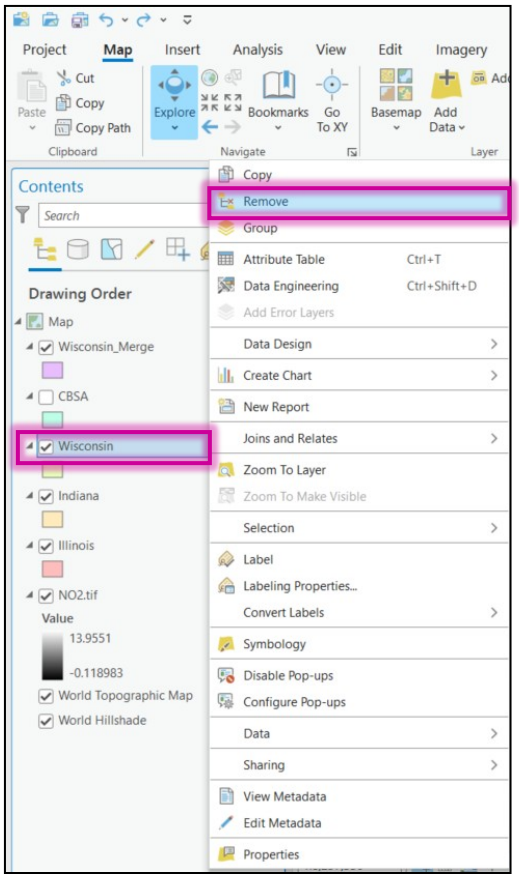


*The **(3)** next to the attributes in the **Output Fields** indicate that three layers contain fields with that name*

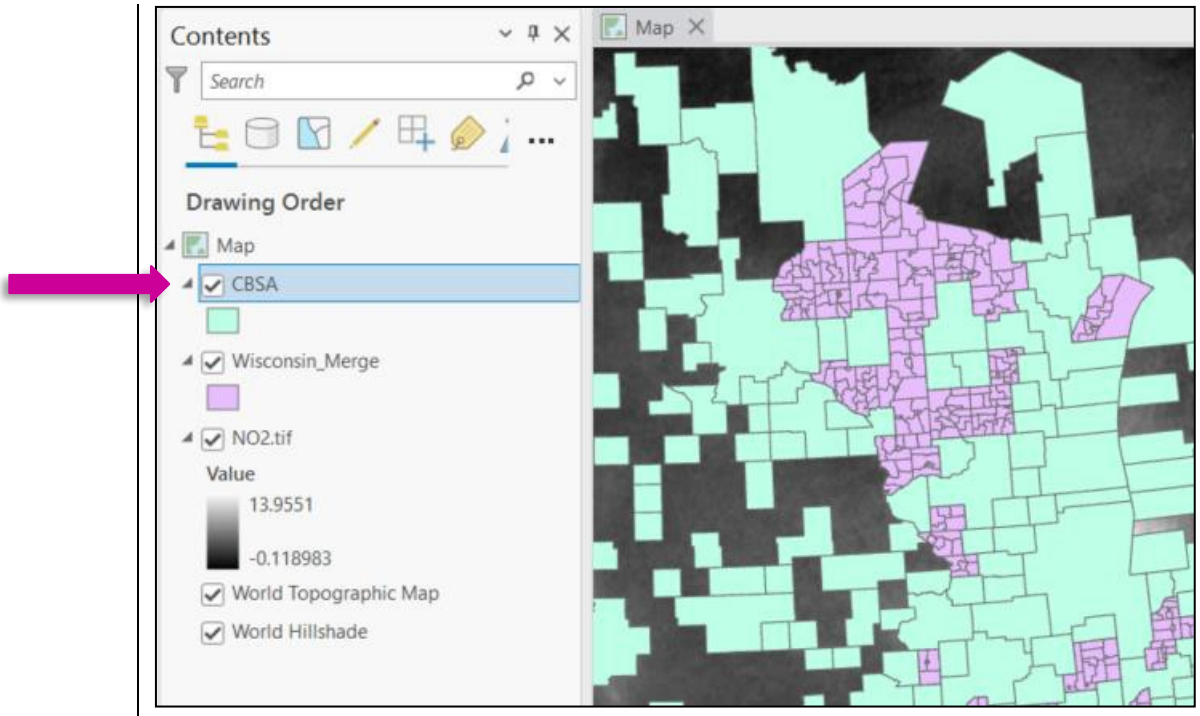
6. The new **Wisconsin_Merge** layer will be added to the **Map** and to the **Contents** pane. We can also click on the project's geodatabase in the **Catalog** and see it saved as a feature class layer there as well.



7. **Remove** the **Wisconsin**, **Indiana**, and **Illinois** layers as they will no longer be needed. To remove a layer, right-click on the layer in the **Contents** pane and select **Remove**.



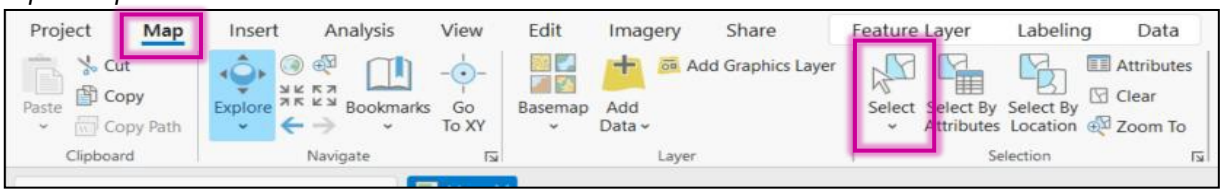
8. In the **Contents** pane, click the box next to the left of **CBSA** layer to turn it back on. Then click and drag this layer up above the **Wisconsin_Merge** and **NO2.tif** so it is on top and appears above it in the **Contents** and on the **Map**.



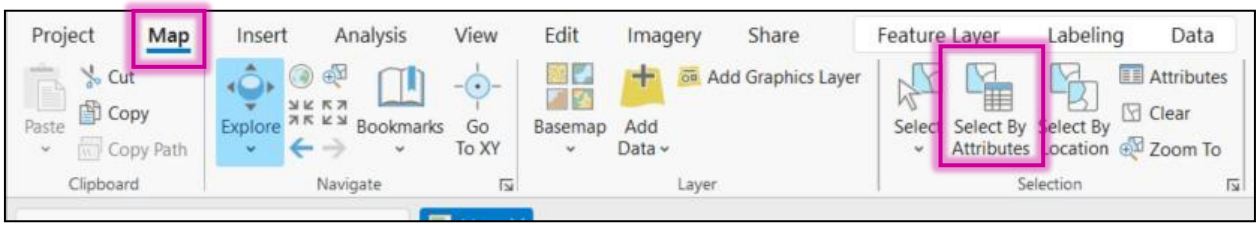
Selecting Attributes

Let's select all the census tracts from **Wisconsin_Merge** that are within the Chicago metropolitan area as defined by the **CBSA** layer.

*Note: If you already know where the "**Chicago-Naperville-Elgin, IL-IN-WI**" polygon is, from the **Map** tab, click **Select** and then click on the polygon on the Map to select and highlight it. Then skip to step 7 from this section.*

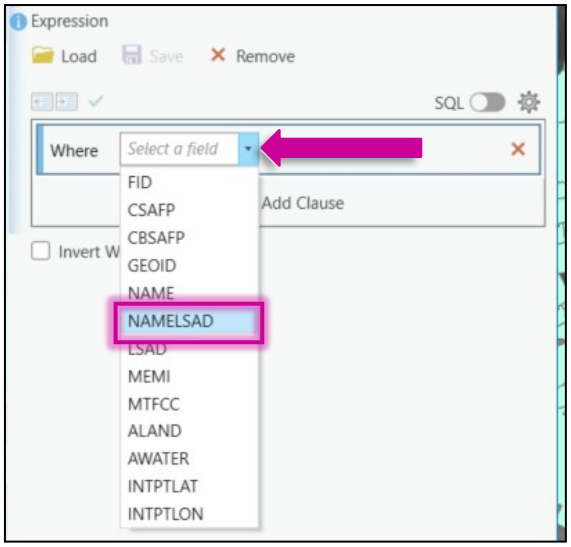


1. From the top ribbon select the **Map** tab. Under the **Selection** group, click on **Select By Attributes** .



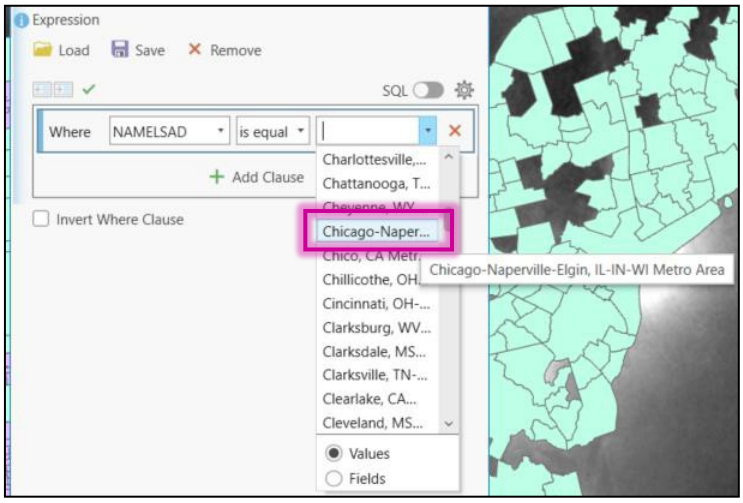
2. In the **Select By Attributes** pop-up window, for the **Input Rows**, select **CBSA** and keep the **Selection Type**, **New Selection.**

3. Under **expression**, click on **Select a field** the select **NAMELSAD**

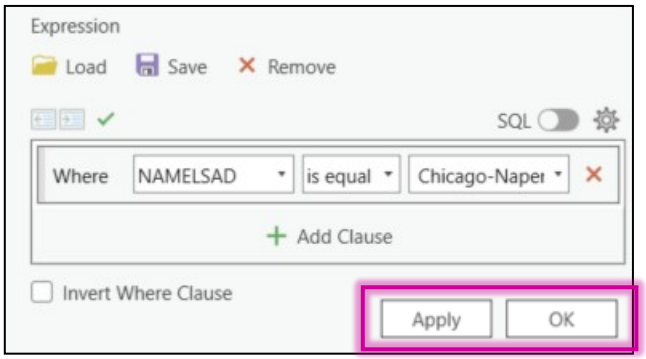


4. Keep the second box as, **is equal** and for the third box, scroll down and select "**Chicago-Naperville-Elgin, IL-IN-WI**"

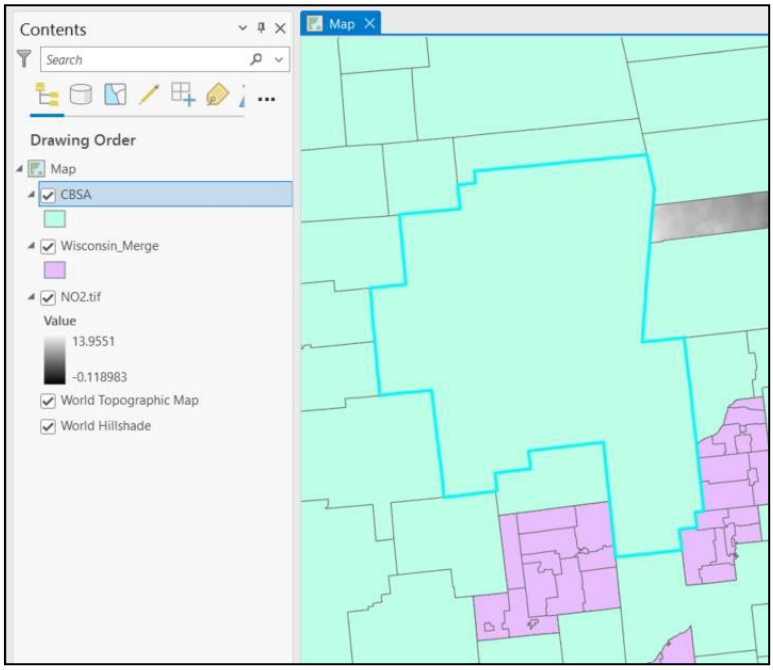
   *Note: To select more than one attribute in the future, click on **Add Clause**, change **And** to **Or** and repeat this step for all desired attributes/locations.*



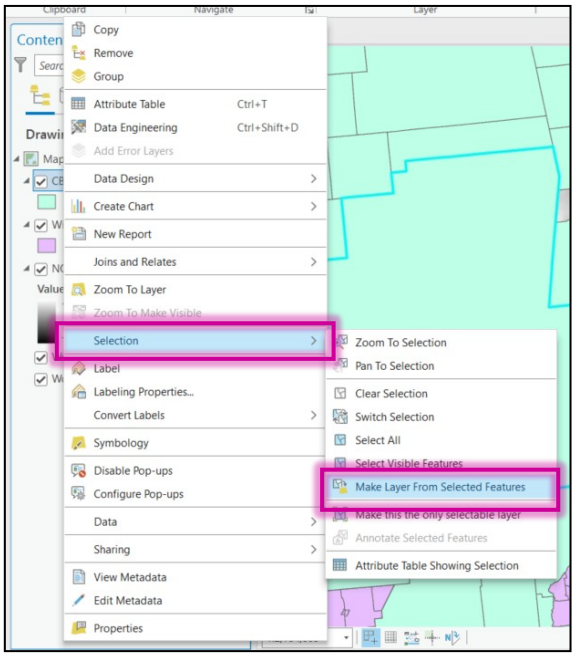
5. Click **Apply** and then **OK.**



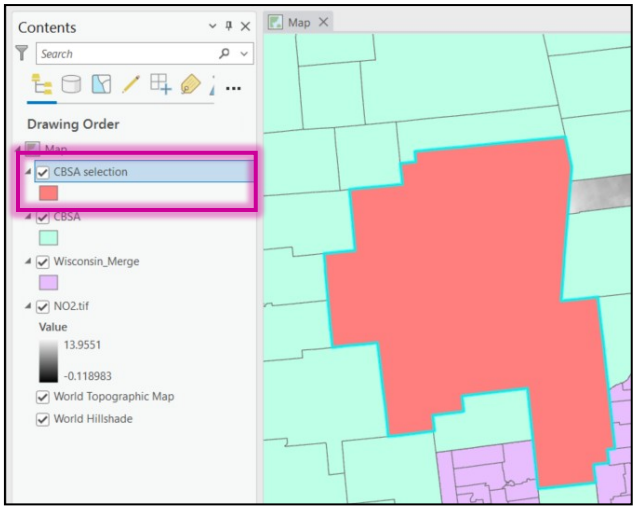
6. On the **Map** from the **CBSA** layer, click the "**Chicago-Naperville-Elgin, IL-IN-WI**" will be selected and highlighted.



7. Let's make this selection into a new layer. From the **Contents** pane, right-click on the **CBSA** layer since that is the layer we selected from. Go to **Selection** and click **Make Layer from Selected Features**.

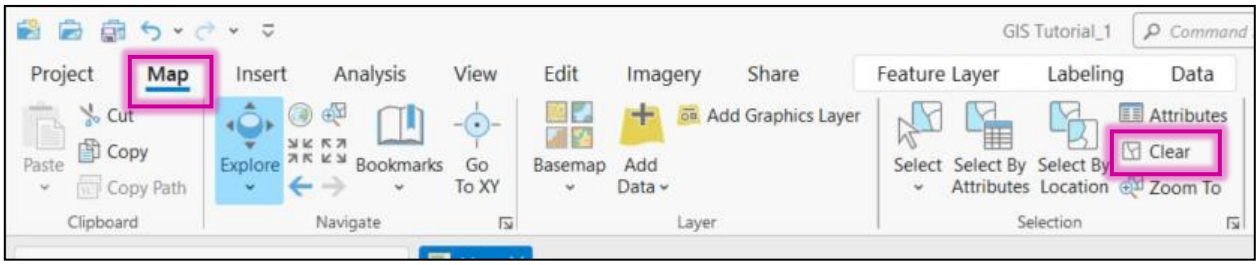


8. A new layer called **CBSA selection** will appear in the **Contents** pane and on the **Map**.



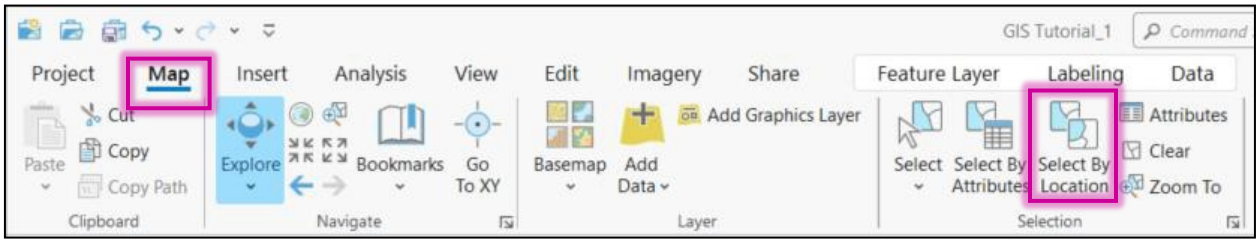
9. Hide the old **CBSA** layer by selecting the box to the right of its name in the **Contents** pane.

10. From the top ribbon, ensure you are still on the **Map** tab. Under the **Selection** group, click **Clear**. It is important to remember to clear anytime you are done with a selection.



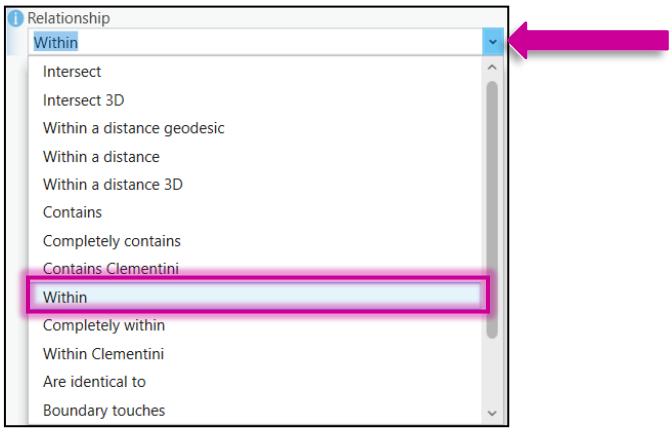
Selecting by Location

1. Now, you'll want to select all the census tracts from **Merge** that fall within the **CBSA selection** layer. From the top ribbon select the **Map** tab and under the **Selection** group, click on **Select by Location**.

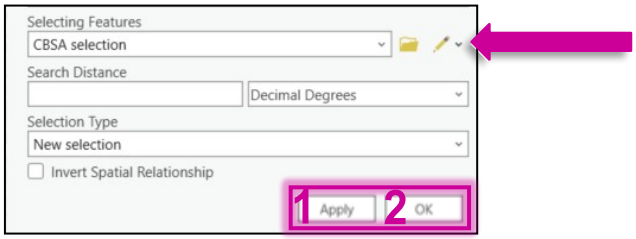


2. In the **Select by Location** pop-up window, click the arrow to drop down the input options and use **Merge** as your **Input Features**.

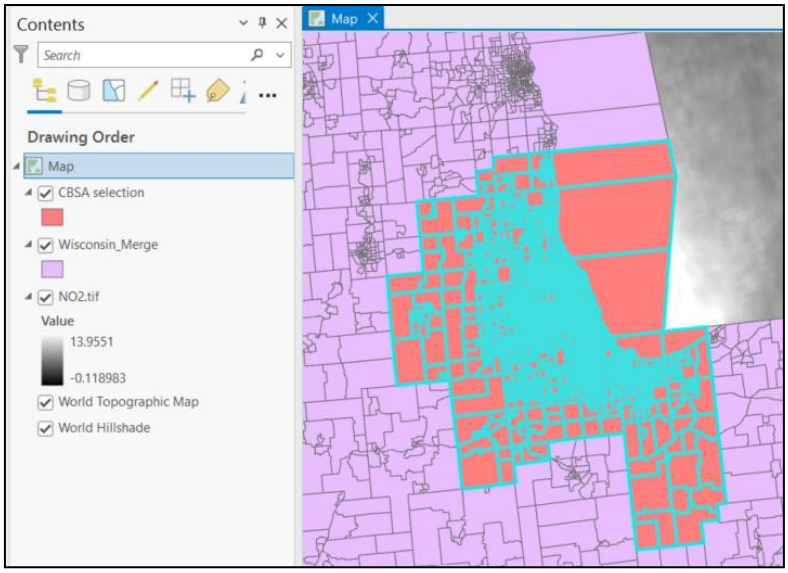
3. Under **Relationship**, click the arrow to drop down the different relationship options and select **Within**.



4. Under **Selecting Features** use the drop-down arrow to select **CBSA selection**. Leave the **Search Distance** and **Selection Type** with the default. Click **Apply** and then **OK**.



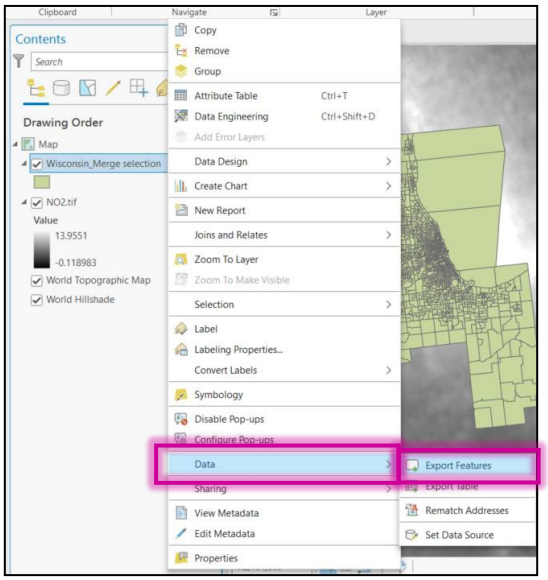
5. All the census tracts from **Wisconsin_Merge** that are within the **CBSA selection** layer will be selected and highlighted.



6. Make this selection into a new layer like before by right-clicking on **Wisconsin_Merge** from the **Contents** pane and under **Selection**, select **Make Layer from Selected Features**. Remember to **Clear** this selection after!

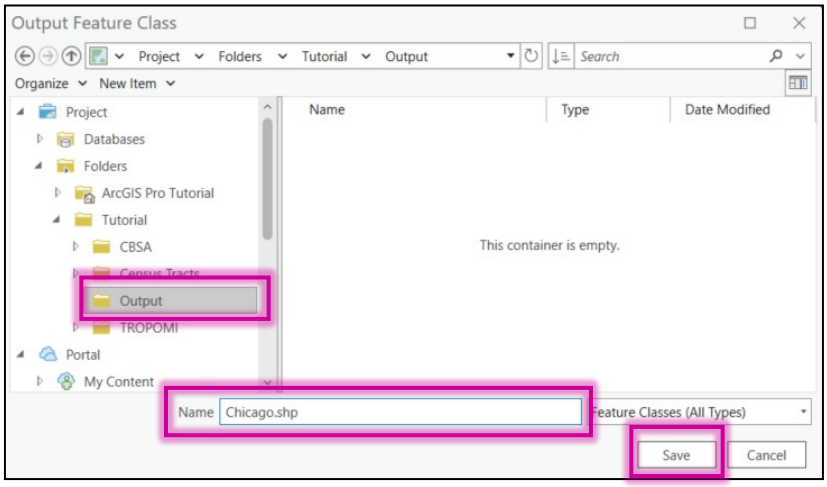
7. **Remove** the **Wisconsin_Merge**, **CBSA** and **CBSA selection** layers.

8. Let's save the **Wisconsin_Merge selection** as a shapefile. From the **Contents** pane, right-click on the layer. Select **Data** and then **Export Features.**



9. For the **Input Features**, make sure it is **Wisconsin_Merge selection**. Then click on the folder icon next to the **Output Feature Class**.

10. From the **Output Feature Class** pop-up window, navigate to the **Tutorial Output** folder. **Name** the file "**Chicago.shp**" and click **Save**.



11. Click on the **Output Feature Class** box and confirm the file is being saved in the **Output** folder and the file type is a shapefile (**.shp**). Select **OK** to finish exporting features.

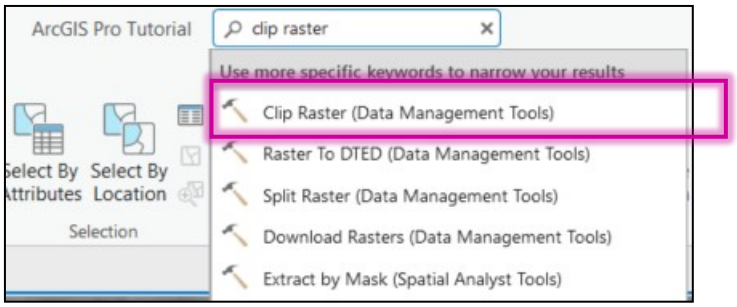
12. The **Chicago** shapefile will be added to the **Output** folder and the new layer will be added to the **Contents** pane and the **Map**.

13. Remove **Wisconsin_Merge Selection** from the **Contents** pane.

Clip the NO_2 Gridded Data

*Since the **NO2.tif** file is so large, we'll want to crop it down to cover just the Chicago metropolitan area.*

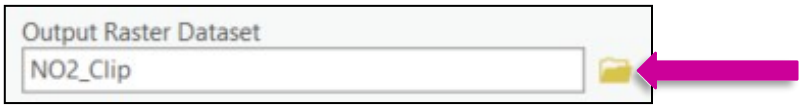
1. In the **Command Search**, type "clip raster" and select the **Clip Raster (Data Management Tool)**.



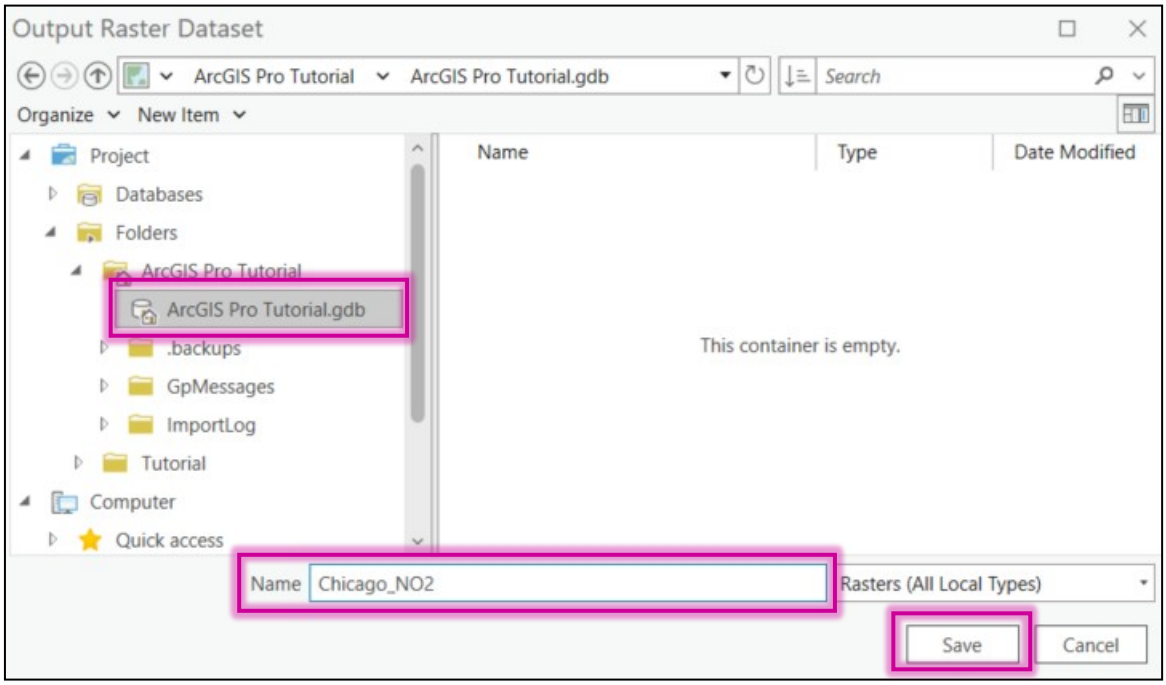
2. This will open the **Clip Raster Geoprocessing** window. For the **Input Raster,** choose **NO2.tif** and for the **Output Extent,** choose **Chicago**.

3. The **Rectangle** will automatically update. Leave the **Use Input Features for Clipping Geometry** unchecked.

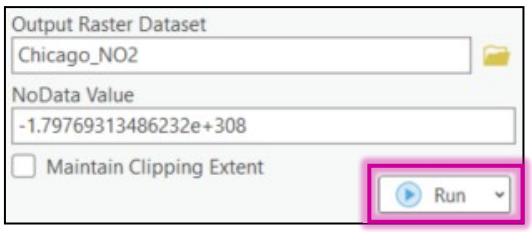
4. Click on the **Folder icon** next to the **Output Raster Dataset**



5. Navigate back to the project's geodatabase (.**gdb**) and name the file "**Chicago_NO2**". Click **Save**.



6. Leave the **NoData Value** with the default and keep the **Maintain Clipping Extent** unchecked. Click **Run**.



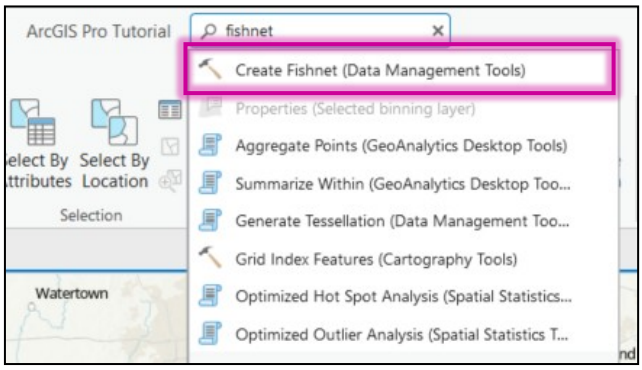
7. The new clipped **Chicago_NO2** layer will appear in the **Contents** pane, on the **Map** and in the **Catalog**.

8. Remove the **NO2.tif** layer from the map.

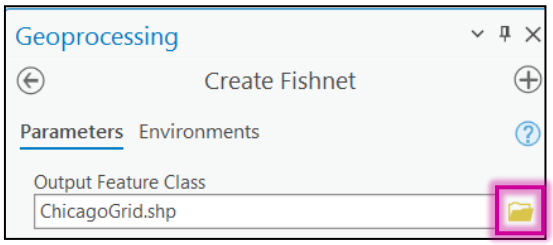
Create a Fishnet (Gridded Shapefile)

*Now you'll make a shapefile grid of **Chicago_NO2**.*

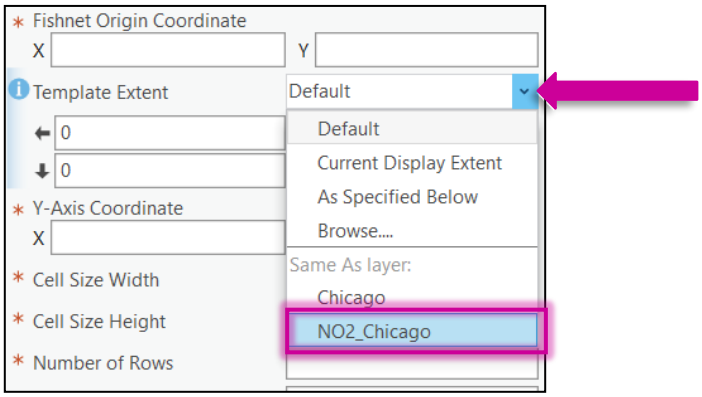
1. In the **Command Search** type "**fishnet**" and select **Fishnet (Data Management Tool)**.



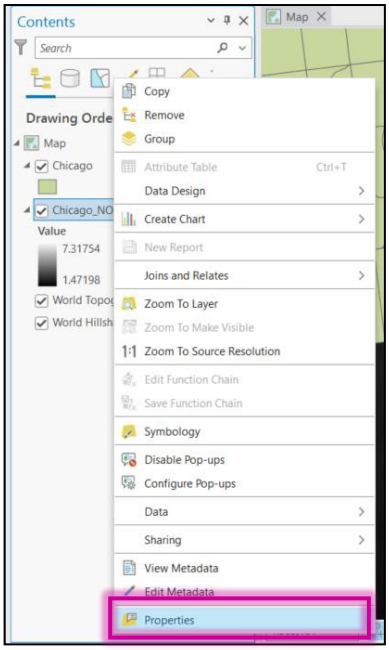
2. The **Create Fishnet Geoprocessing** window will appear. Next to the **Output Feature Class** click the **Folder** icon. Navigate to the **Tutorial Output** folder and name it "**ChicagoGrid.shp**". Click **Save**.



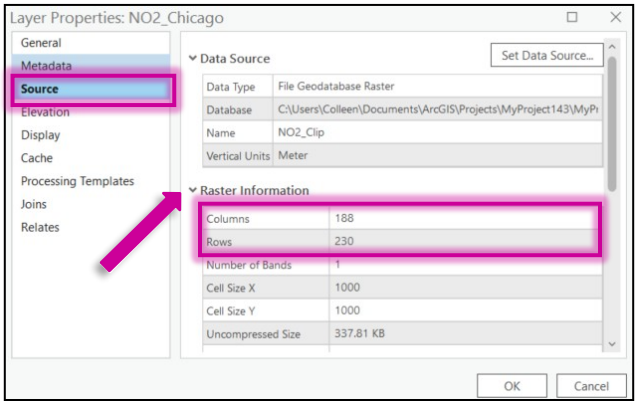
3. Under **Template Extent**, select the arrow next to **Default** and select **Chicago_NO2**. This will automatically fill in the rest of the extent, the **Y-Axis Coordinate,** and the **Opposite corner of Fishnet** groups.



4. To find the values used in **Number of Rows** and **Number of Columns**, from the **Contents** pane, right-click on **Chicago_NO2** and select **Properties**.



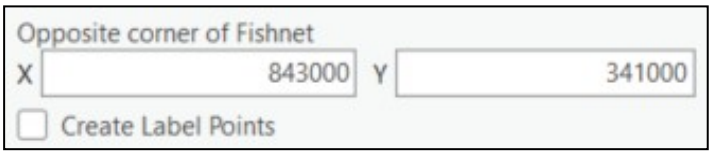
5. From the **Chicago_NO2: Layer Properties** pop-up window, click on the **Source** tab. Select the arrow to the left of **Raster Information** to see the number of **Rows** and **Columns.** Click **OK** to close out of the **Layer Properties**.



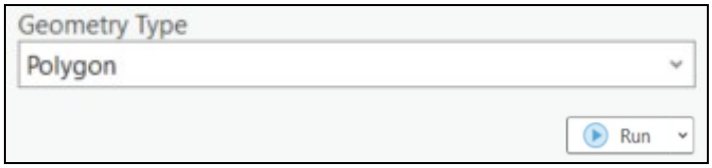
6. Return to the **Create Fishnet** tab to fill in the **Number of Rows** and **Number of Columns** values.

After you fill in the Number of Rows and Columns, the Cell Size Height and Width will disappear.

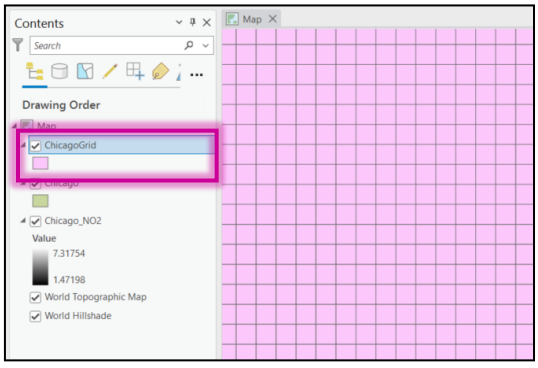
7. Under **Opposite corner of Fishnet**, keep the **X** and **Y** values and, uncheck the **Create Label Points.**



8. Under **Geometry Type**, select **Polygon**. Click **Run**.



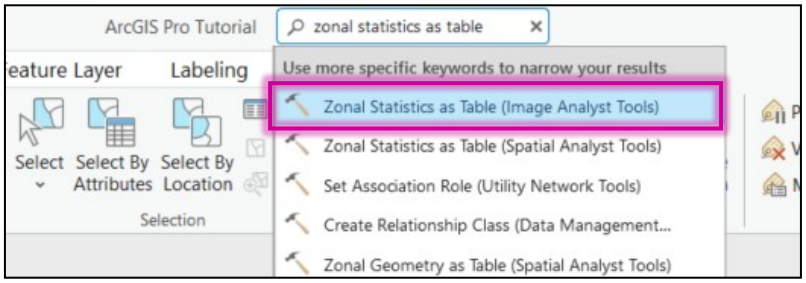
9. The new **ChicagoGrid** shapefile layer will appear on the **Map** and in the **Contents** pane.



Zonal Statistics as Table

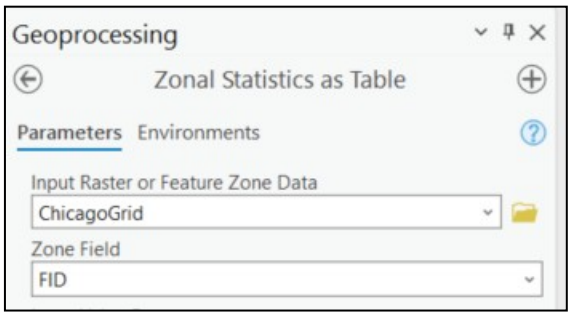
*Now you'll want to translate the values of the gridded **Chicago_NO2** raster dataset to the **ChicagoGrid** layer.*

1. In the **Command Search**, type "**zonal statistics as table**" and select **Zonal Statistics as Table (Image Analyst Tools or Spatial Analyst Tools)**



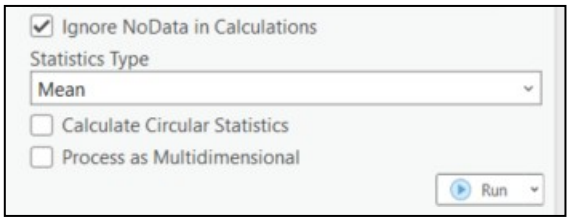
Depending on your ArcGIS Pro License, this could determine which tools you have access to and which one you select

2. In the **Zonal Statistics as Table Geoprocessing** window, for **Input Raster or Feature Zone Data**, choose **ChicagoGrid** and for **Zone Field,** select **FID**.

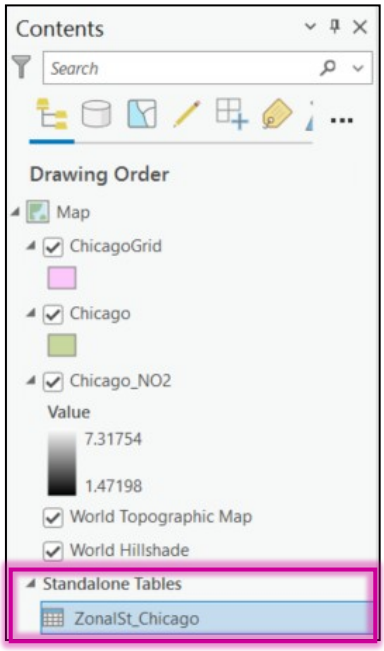


3. For the **Input Value Raster** select **Chicago_NO2** and keep the default name for **Output Table** as **ZonalSt_Chicago** (or **ZonalSt_Chicago1**). Click in the box of the **Output Table** to confirm it is being saved in the project'sgeodatabase. If not, use the **Folder** to navigate to it.

4. Use the arrow to drop down the **Statistics Type** menu and select **Mean**. Leave **Calculate Circle Statistics** and **Process as Multidimensional** unchecked. **Click Run**.



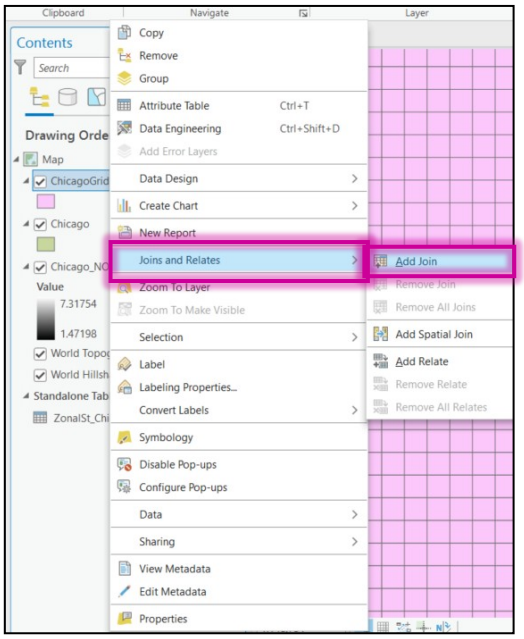
5. The **ZonalSt_Chicago** table will appear in the **Contents** pane under **Standalone Tables**.



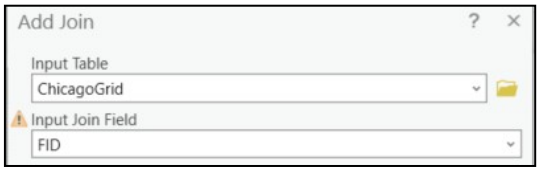
Join

*Now you'll want to join the values of the **ZonalSt_Chicago** table to the **ChicagoGrid** layer.*

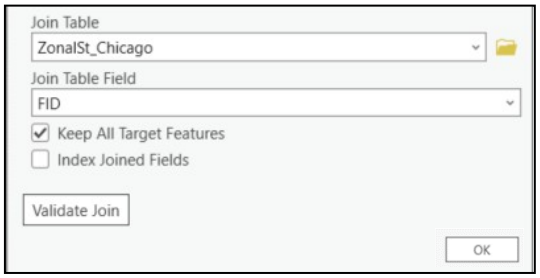
1. From the **Contents** pane, right-click on **ChicagoGrid** and select **Joins and Relates** and then click **Add Join**.



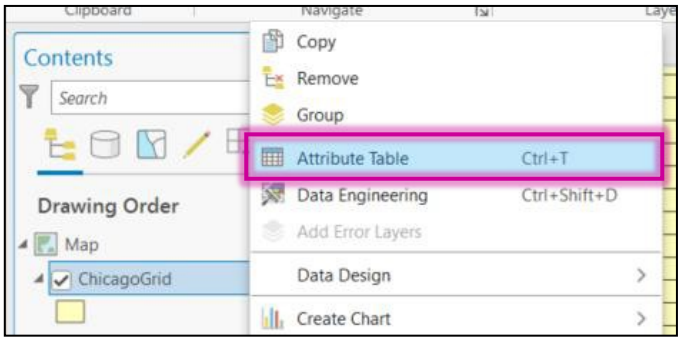
2. A new **Add Join** pop-up window will appear. For the **Input Table**, select **ChicagoGrid** if it did not default to that already. For the **Input Join Field,** choose **FID**.



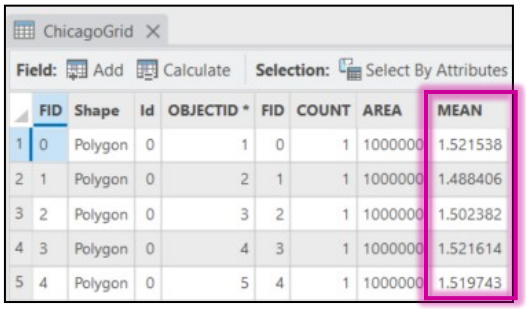
3. For **Join Table,** select **ZonalSt_Chicago** and the **Join Table Field,** as **FID**. Leave **Keep All Target Features** checked, and **Index Joined Fields** unchecked. Click **OK**.



4. Confirm the join worked by looking at the **ChicagoGrid Attribute Table**. In the **Contents** pane, right-click on **ChicagoGrid** and select **Attribute Table**.



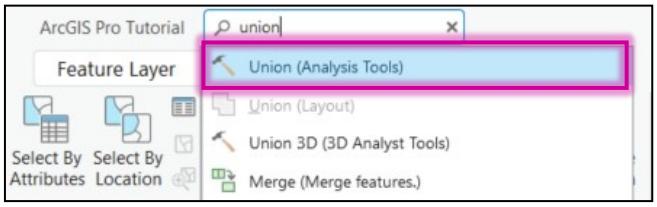
5. You will see that each attribute from the grid now contains the value from the **Chicago_NO2** raster layer as indicated by the **MEAN** column.



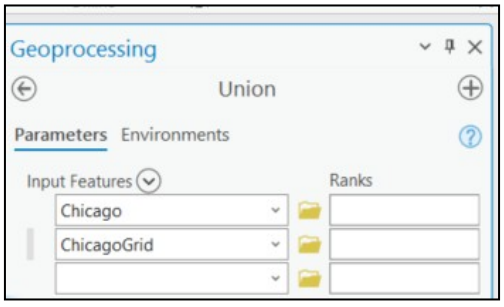
	FID	Shape	Id	OBJECTID *	FID	COUNT	AREA	MEAN
1	0	Polygon	0	1	0	1	1000000	1.521538
2	1	Polygon	0	2	1	1	1000000	1.488406
3	2	Polygon	0	3	2	1	1000000	1.502382
4	3	Polygon	0	4	3	1	1000000	1.521614
5	4	Polygon	0	5	4	1	1000000	1.519743

Union

1. You'll want to calculate how much of each census tract is within each grid cell of **ChicagoGrid**. In the **Command Search**, type "union" and select **Union (Analysis Tools)**.

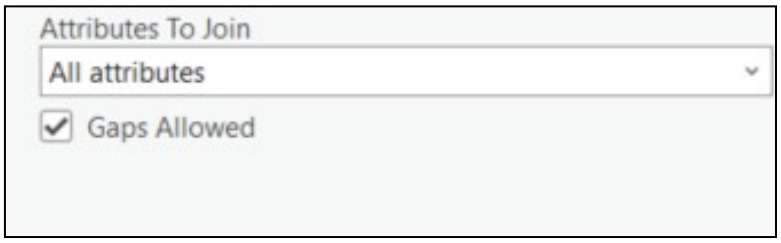


2. In the **Union Geoprocessing** window, the **Input Features** will be **Chicago** and **ChicagoGrid**. Use the default **Chicago_Union**.



3. From the **Output Feature Class**, click on the box to see the file's output location. Make sure it is the project geodatabase. Keep the default **Chicago_Union** name.

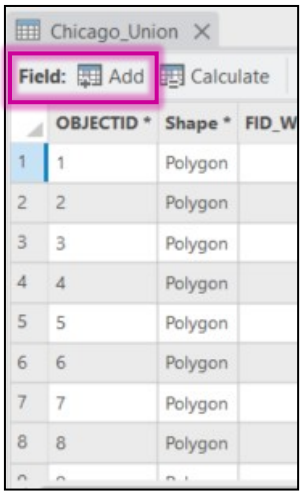
4. Keep the **Attributes To Join** as **All Attributes** and keep **Gaps Allowed** checked. **Click Run.**



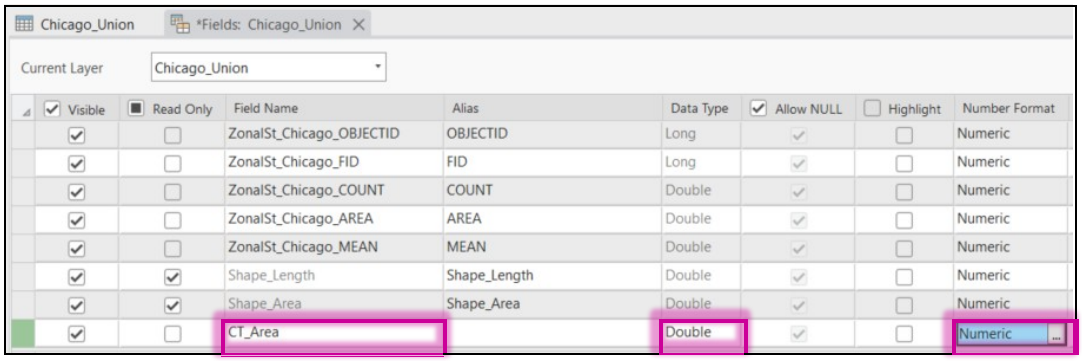
5. A new **Chicago_Union** layer will appear on the map and in the **Contents** pane.

Calculate Area

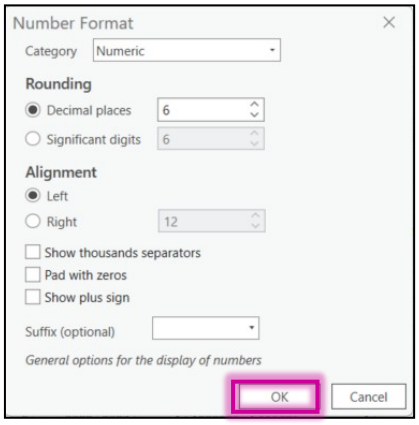
1. Next, you'll calculate the area of each of the individual pieces of the census tract from **Chicago_Union**. Open the **Chicago_Union Attribute Table** and select the **Add** icon.



2. Name the **Field Name** "**CT_Area**" which stands for "Census Tract Area". Double-click on the **Data Type** and select **Double.** Double-click in the blank box in the **Number Format** column, then click on the three dots that appear and select **Numeric**.

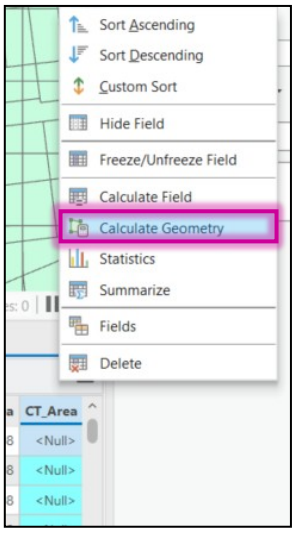


3. After selecting **Numeric**, a **Number Format** pop-up window will appear. Keep the default settings and select **OK**.

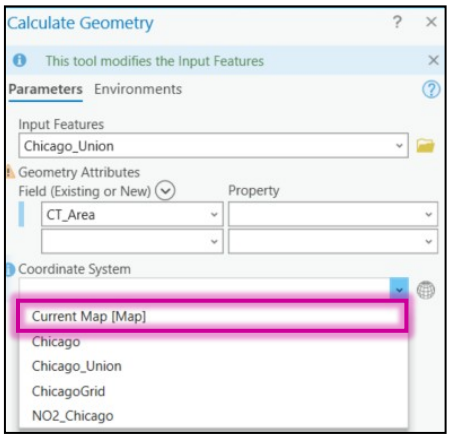


4. To save the changes, either right-click on the **CT_Area** row and select **Save** or exit out of the **Fields**:**Chicago_Union** and select **Save**.

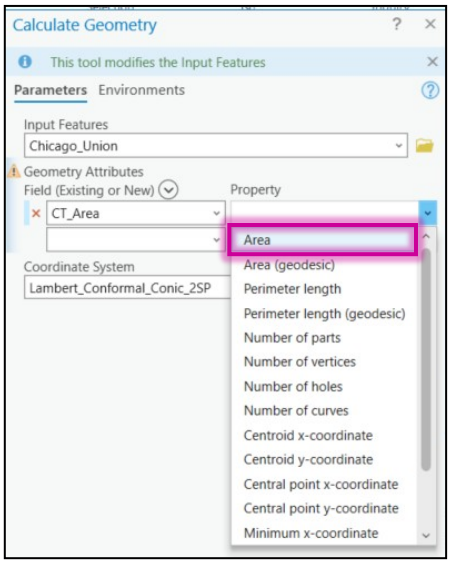
5. From the **Chicago_Union Attribute Table**, scroll over to locate the **CT_Area** column. Right-click on the **CT_Area** column header and select **Calculate Geometry**.



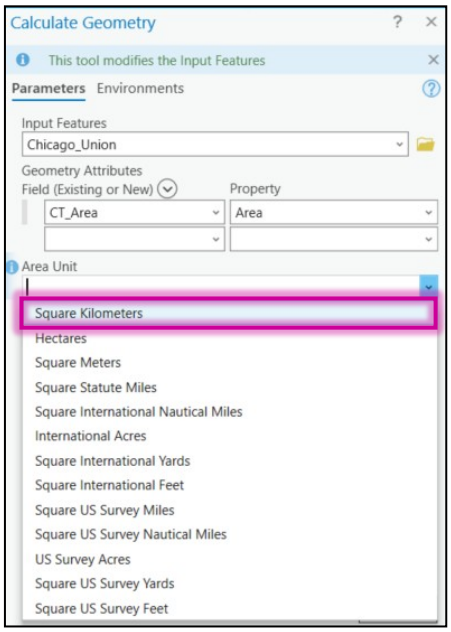
6. In the pop-up **Calculate Geometry** window, under **Coordinate System** select **Current Map [Map]**.



7. After selecting this, the **Coordinate System** will say **Lambert_Conformal_Conic_2SP** which is the projection of the data. Then from the **Geometry Attributes**, drop down the menu under **Property** and select **Area.**

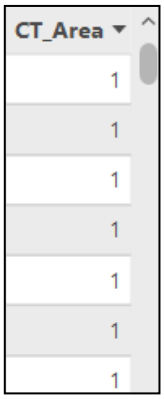


8. For the **Area Unit,** select **Square Kilometers** since this is the unit the gridded data is in. Click **OK**.



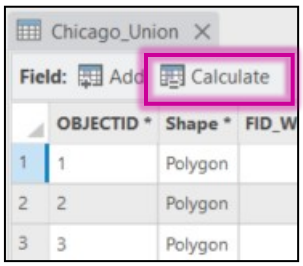
We are using Square Kilometers to match the units of the gridded data

9. The **CT_Area** column will be filled with the area.

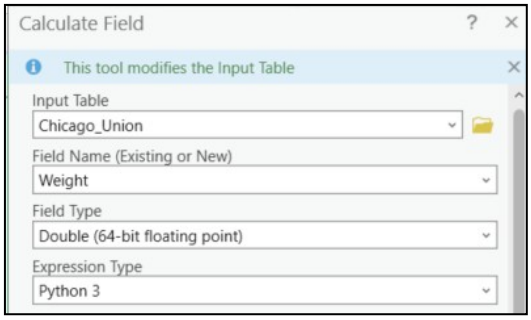


Note that the column appears with a lot of 1s. These 1's are just the area of the grid boxes that did not contain any census tracts. Right click on the **CT_Area** header to sort the data or click anywhere on the map within the Chicago metropolitan area and you will see the **CT_Area** in the pop-up window.

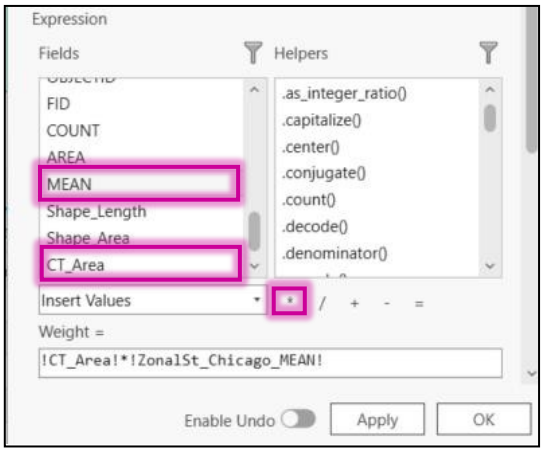
10. Now you'll calculate the weight of each area by multiplying the **CT_Area** with the **MEAN**. Select **Calculate** from the **Chicago_Union Attribute Table**



11. In the **Calculate Field** pop-up window, under **Field Name**, type "Weight". For the **Field Type**, select **Double (64-bit floating point)**. *If there is no **Field Type** box, click out of **Field Name** and then the box will appear.* Keep the **Expression Type, Python 3**.



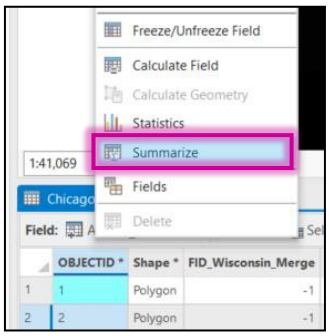
12. From **Fields**, double click on **CT_Area**. Then, click on the * next to **Insert Values**. Lastly, from **Fields** double-click on **MEAN** (it will fill in the **Weight** as **ZonalSt_Chicago_Mean**). The expression will be under the **Weight =**. Select **Apply** then **OK.**



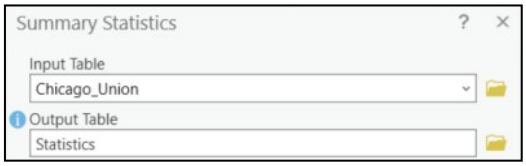
13. The new **Weight** column will be calculated and added to **Chicago Union**.

Summary Statistics

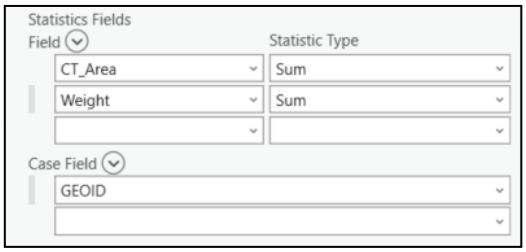
1. From the **Chicago_Union Attribute Table**, right-click on **OBJECTID** and select **Summarize.** This tool will allow you to calculate the sum of the **CT_Area** and **Weight** for each census tract from all of the individual parts.



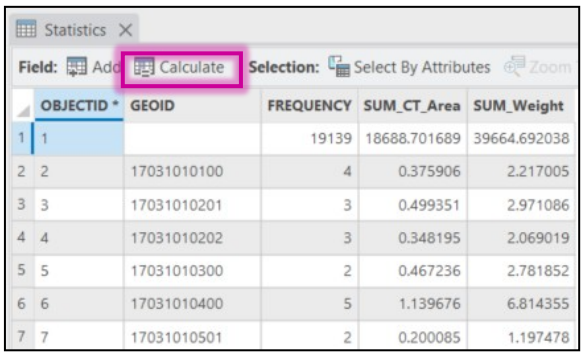
2. In the **Summary Statistics** pop-up window, ensure that the **Input Table** is **Chicago_Union**. For the **Output Table**, ensure the output path is the geodatabase and change the **Output Table** name to **Statistics**.



3. For Fields, select **CT_Area** and **Weight** and for the **Statistic Type** choose **Sum** for both. For the **Case Field** select **GEOID**. Click **OK**.



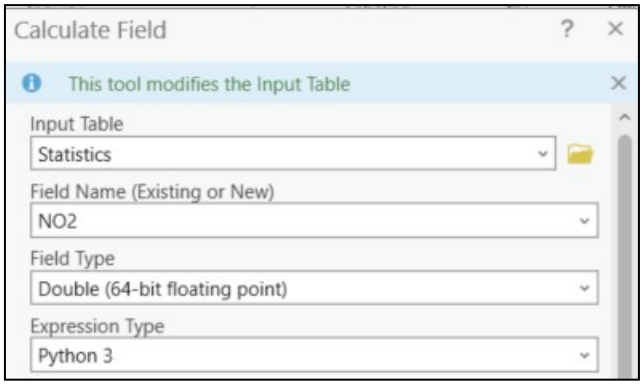
4. The **Statistics** table will appear in the **Contents** pane under the **Standalone Tables.** Right-click on it and select **Open Table** and click **Calculate**. *Note: values may be rounded differently than below.*



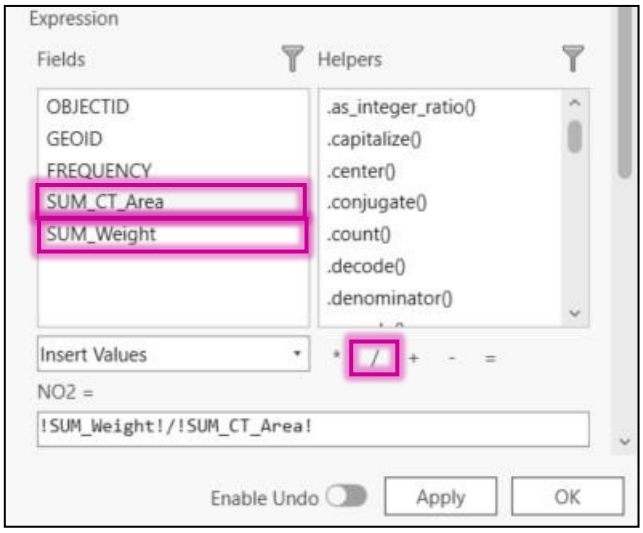
	OBJECTID *	GEOID	FREQUENCY	SUM_CT_Area	SUM_Weight
1	1		19139	18688.701689	39664.692038
2	2	17031010100	4	0.375906	2.217005
3	3	17031010201	3	0.499351	2.971086
4	4	17031010202	3	0.348195	2.069019
5	5	17031010300	2	0.467236	2.781852
6	6	17031010400	5	1.139676	6.814355
7	7	17031010501	2	0.200085	1.197478

The FREQUENCY is how many portions of a grid cells fell within the census tract and was used in the calculation

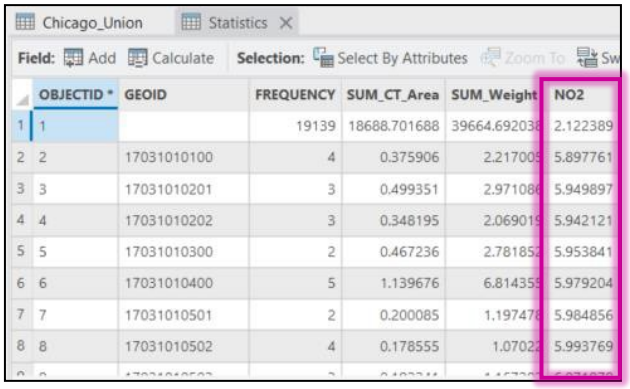
5. In the **Calculate Field** pop-up window, for the **Input Table**, make sure it is **Statistics**. For the **Field Name (Existing or New)**, type "**NO2"**. Change the **Field Type** to **Double (64-bit floating point)**. Keep the **Expression Type, Python 3**.



6. From **Fields**, double click on **SUM_Weight**. Then, click on the / next to **Insert Values**. Lastly, from **Fields** double-click on **SUM_CT_Area**. The expression will be under the **NO2 =**. Select **Apply** then **OK.**



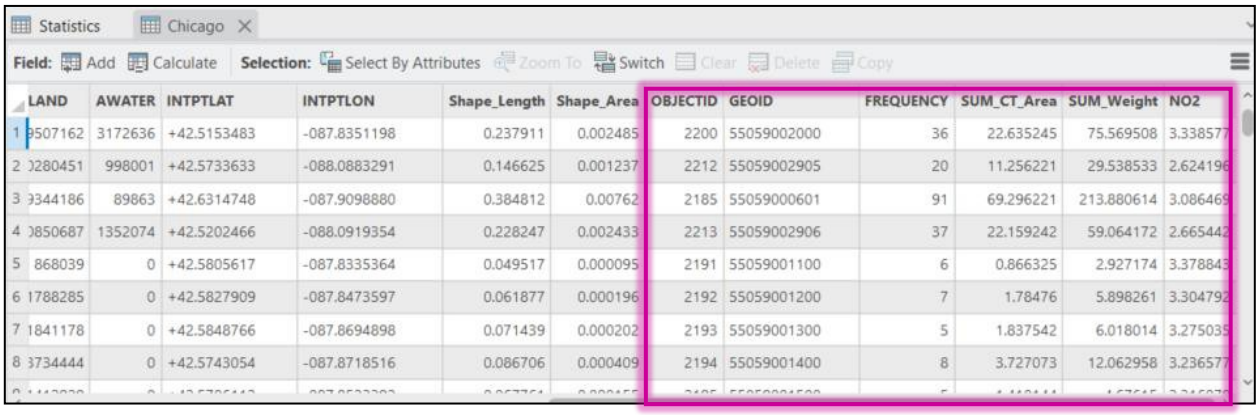
7. After the calculation is performed, you'll see the new column **NO2** appear in the **Statistics** table. *Note: Calculated values may be different.*



The first row is missing a GEOID since these are all the grid cell pieces that did not overlap with a census tract.

8. Now you'll **Join** the together the **Statistics** table with **Chicago**. In the **Contents** pane, right-click on **Chicago** and select **Joins and Relates** and then **Add Join.** Change the **Input Join Field** to **GEOID** and the **Join Table** to **Statistics**. Click **OK**.

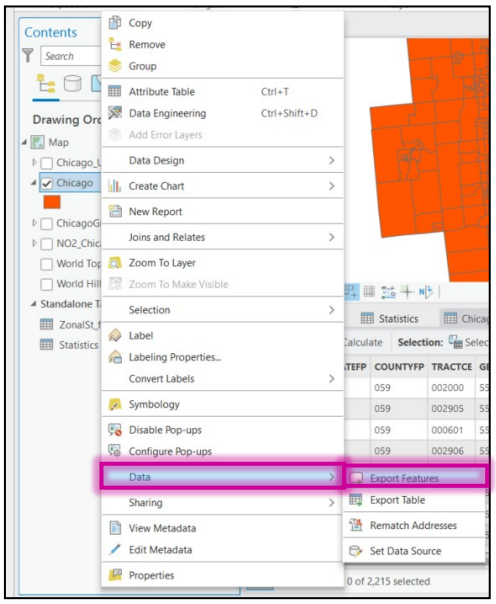
9. Open the **Chicago Attribute Table** and slide down to the end of the columns. You will see all the **Statistics** table attributes here.



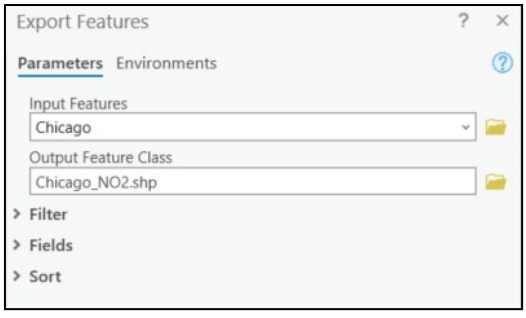
LAND	AWATER	INTPTLAT	INTPTLON	Shape_Length	Shape_Area	OBJECTID	GEOID	FREQUENCY	SUM_CT_Area	SUM_Weight	NO2
1 9507162	3172636	+42.5153483	-087.8351198	0.237911	0.002485	2200	55059002000	36	22.635245	75.569508	3.338577
2 0280451	998001	+42.5733633	-088.0883291	0.146625	0.001237	2212	55059002905	20	11.256221	29.538533	2.624196
3 9344186	89863	+42.6314748	-087.9098880	0.384812	0.00762	2185	55059000601	91	69.296221	213.880614	3.086469
4 0850687	1352074	+42.5202466	-088.0919354	0.228247	0.002433	2213	55059002906	37	22.159242	59.064172	2.665442
5 868039	0	+42.5805617	-087.8335364	0.049517	0.000095	2191	55059001100	6	0.866325	2.927174	3.378843
6 1788285	0	+42.5827909	-087.8473597	0.061877	0.000196	2192	55059001200	7	1.78476	5.898261	3.304792
7 1841178	0	+42.5848766	-087.8694898	0.071439	0.000202	2193	55059001300	5	1.837542	6.018014	3.275035
8 3734444	0	+42.5743054	-087.8718516	0.086706	0.000409	2194	55059001400	8	3.727073	12.062958	3.236577

Save as a Shapefile

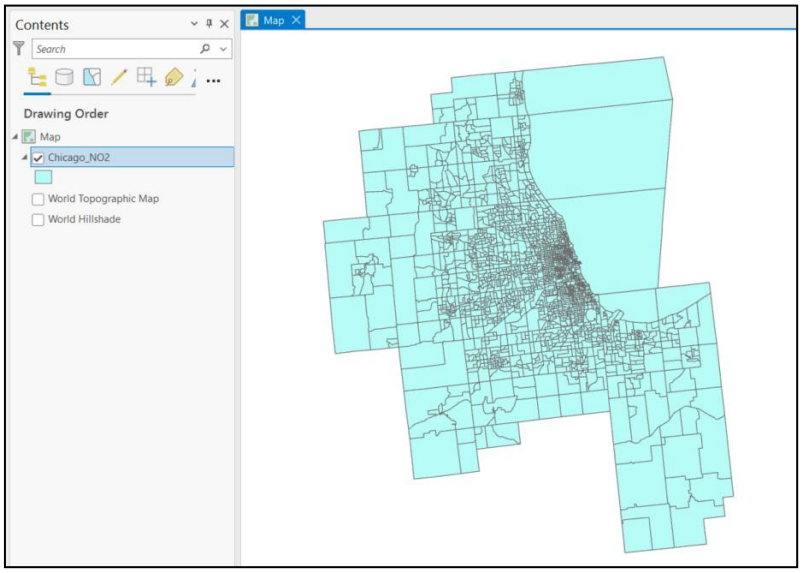
1. Now that all the data is calculated, the next step is the save this as a new shapefile. From the **Contents** pane, right-click on **Chicago**. Select **Data** and **Export Features**.



2. Make sure the **Input Features** is **Chicago**. For the **Output Feature Class**, click on the **Folder** icon. Navigate back to the **Tutorial Output** folder and name it "**Chicago_NO2.shp**".



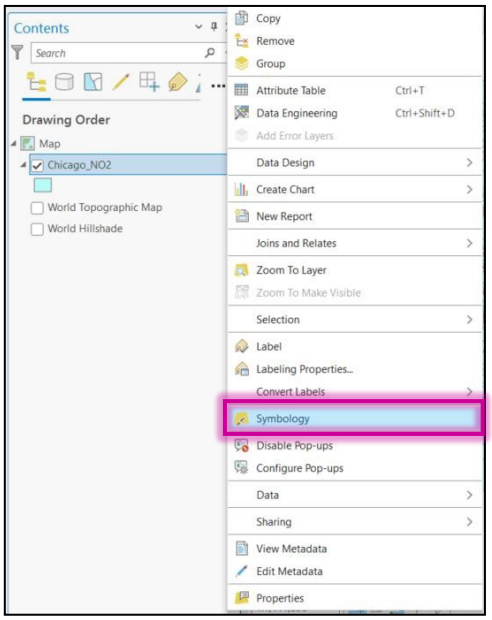
3. Click **OK**. The new **Chicago_NO2** shapefile will be added to the **Contents** pane and the Map. **Remove** all other layers and tables except for **Chicago_NO2** (You may leave World Topographic Map and World Hillside).



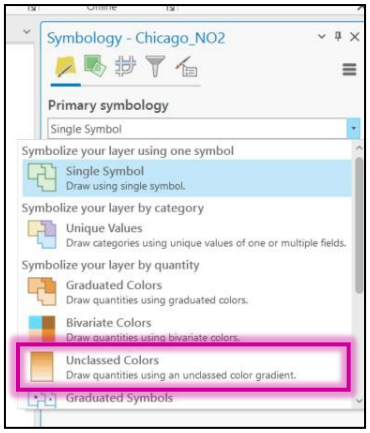
Symbology

Now that you have allocated the gridded NO_2 data onto the Chicago metropolitan area census tracts, it is time to map it. In this section of the tutorial, you will have your own creative freedom to design the map however you'd like. You'll step through different techniques and methods to help make your map visually appealing.

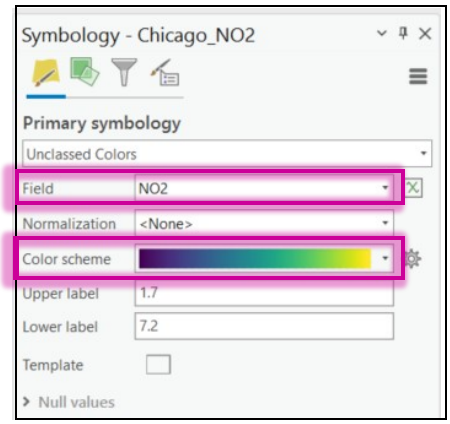
1. Right-click on the **Chicago_NO2** layer in the **Contents** pane and select **Symbology**.



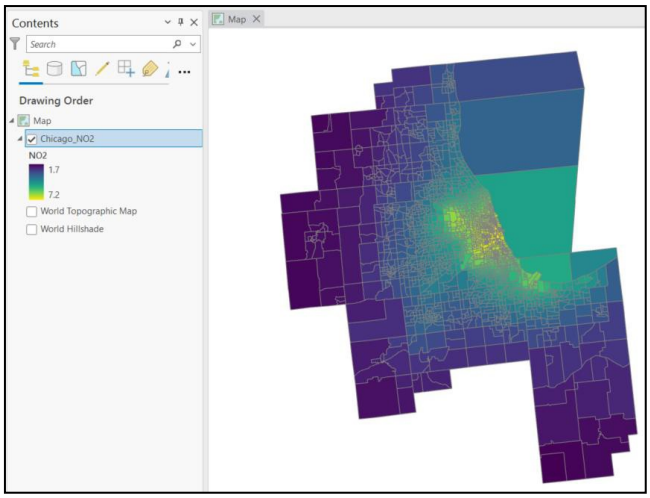
2. In the **Symbology** pane, click the arrow under **Primary symbology** to see the various mapping options. Select **Unclassed Colors**.



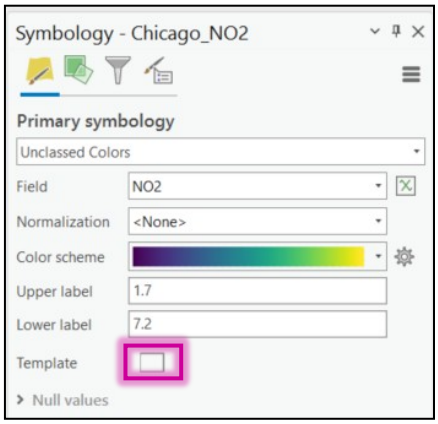
3. For the **Field**, select **NO2** and change the **Color scheme** to one that you like. For this example, I picked **Viridis**.



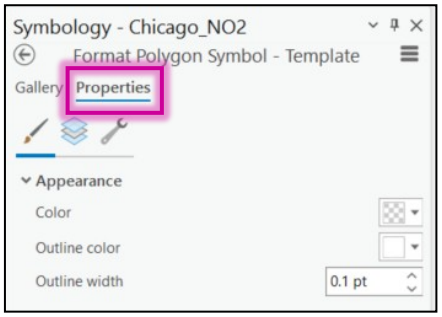
4. Your map will plot the **NO2** values by color.



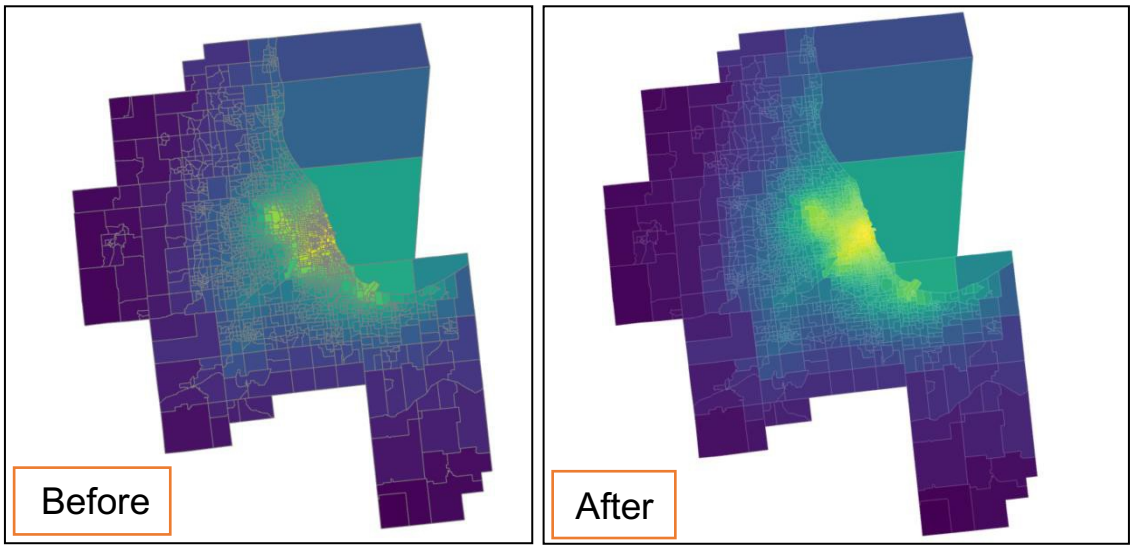
5. The thickness of the census tract border makes it difficult to see the details on the map. To change this, click the **square icon** to the right of **Template**.



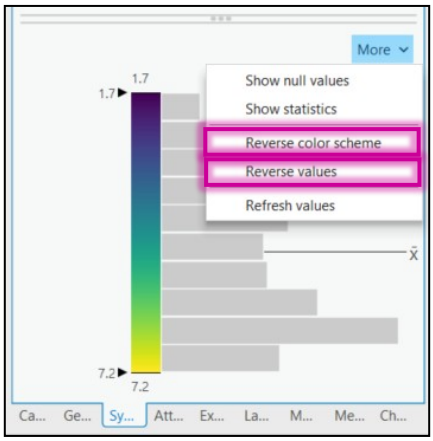
6. Under **Properties**, you can change the **Outline color** and **Outline width**. For this example, I changed the **Outline Color** to white and the **Outline width** to 0.1 pt. Click **Apply** to show these changes on the map.



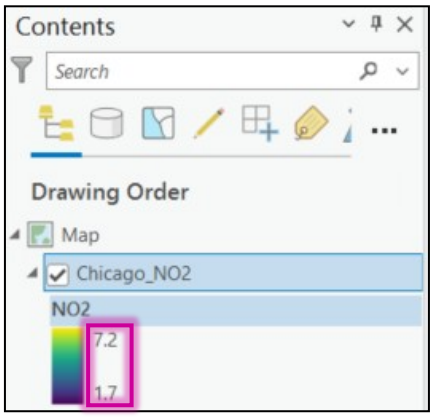
7. The map will update.



8. Notice in the **Contents** pane that the low values are labeled at the top of the color bar and the high values are labeled at the bottom. You can easily switch this by clicking **More** in the lower **Symbology** pane. Then select **Reverse color scheme** and **Reverse values**.



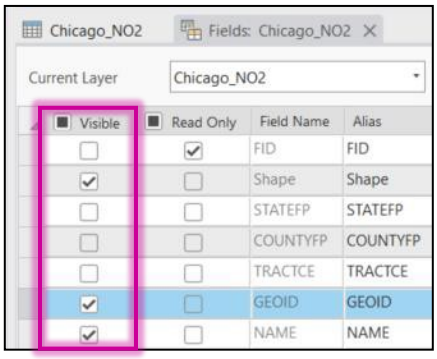
9. The map will stay the same, but the labels on the color bar will switch so the large number is on the top.



Hiding Attributes

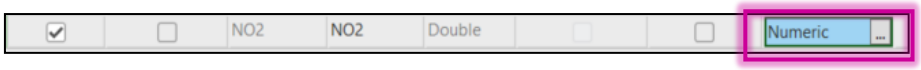
1. Open the **Chicago_NO2 Attribute Table**. Right-click on one of the column headers and select **Fields**.

2. Under the **Visible** column, I am choosing to select **Shape**, **GEOID**, **NAME**, and **NO2** to be visible. You may or may not want to select more attributes to be visible.

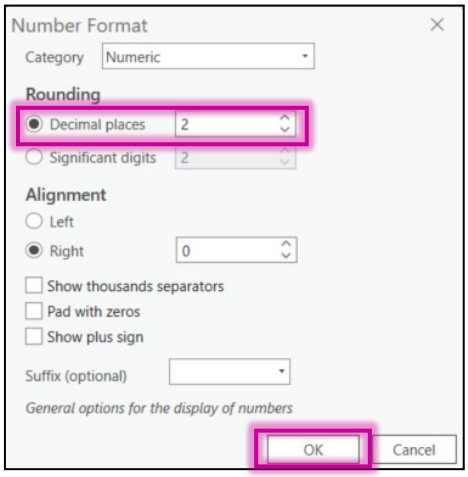


*Note that **Shape** and **Name** must be selected in order to export the map in the next step*

3. In the **NO2** row, click on the three dots next to **Numeric**.



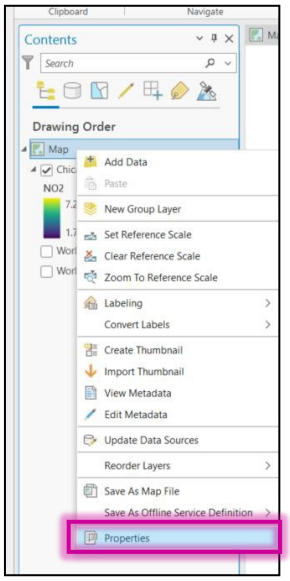
4. In the **Number Format** pop-up window, under **Rounding,** change the **Decimal places** to "2" and click **OK**.



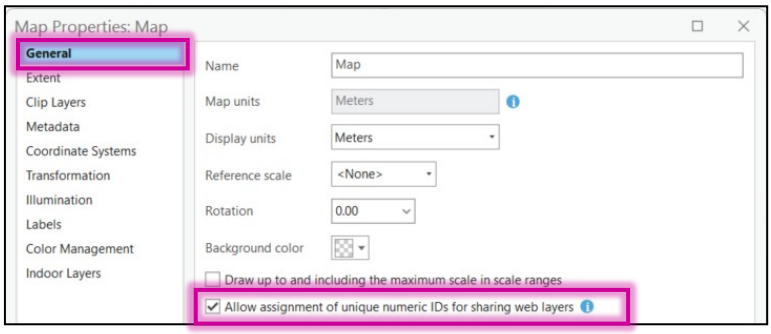
5. Exit out of the **Fields:Chicago_NO2** table and **Save** the updates. To see the changes, click on any census tract polygon from the map to open the attribute pop-up window.

Export Map as a Web Layer

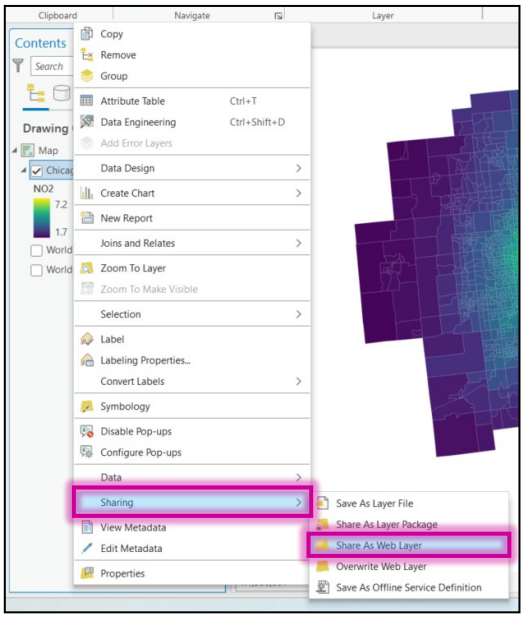
1. Now we will export the map as a web layer so it can be used online in various applications like EJSCREEN for example. From the **Contents** pane, right-click on **Map** and select **Properties**.



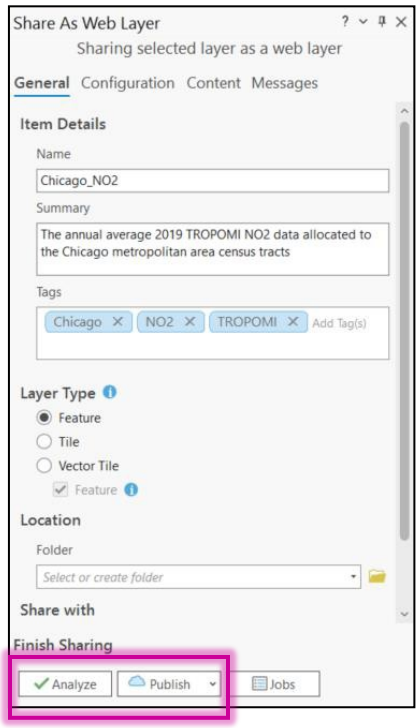
2. Under **General**, check the box next to **Allow assignment of unique numeric IDs for sharing web layers**. Select **OK**.



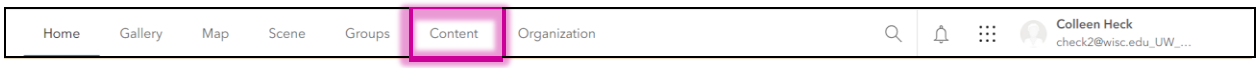
3. Right-click on **Chicago_NO2**. Select **Sharing** and then **Share As Web Layer**.



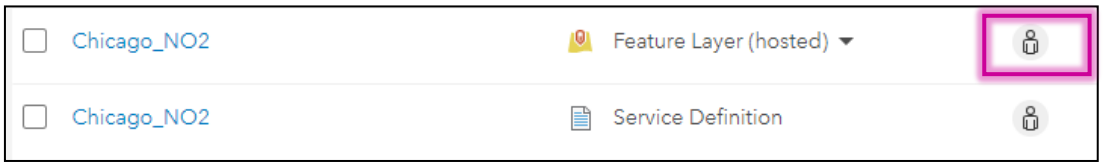
4. In the **Share As Web Layer** window to the right of the map, give the web layer a **Name**, write a brief **Summary** and a few **Tags.** Click **Analyze.** If no errors or warnings are found, click **Publish**.



5. Open a web browser to view your ArcGIS **Content** tab. (At UW Madison this can be found at https://uw-mad.maps.arcgis.com/home/index.html



6. Here you will see the Chicago_NO2 web layer we just published. Right now, the sharing level is Owner only. You can change this by clicking on the icon, but this is not required to port or view map in **EJScreen**.

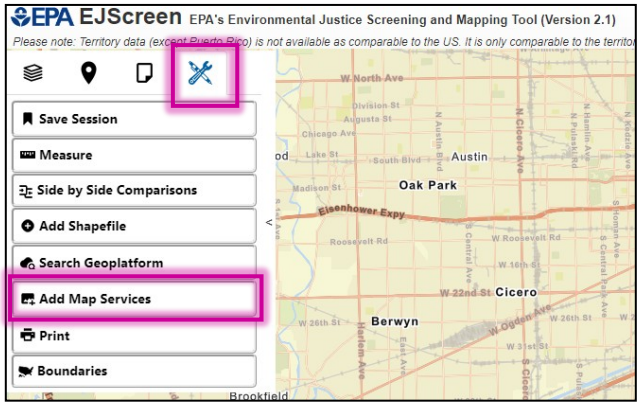


7. Click on the **Chicago_NO2 Feature Layer (Hosted)**. Scroll to the bottom of the page and locate **URL**. Copy the **URL**.

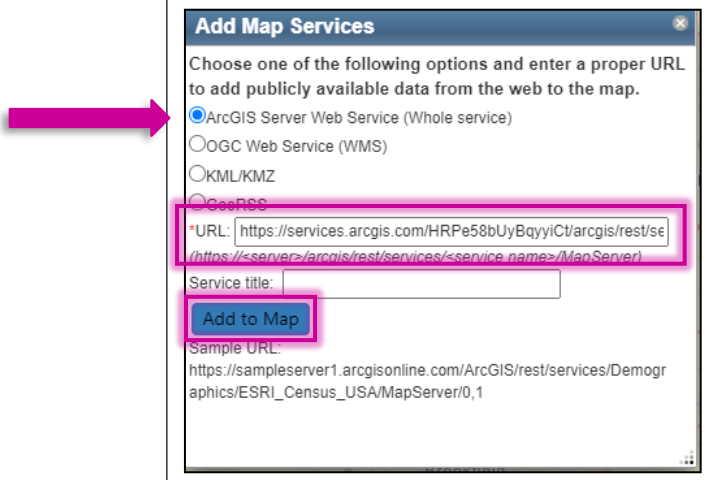
EJScreen

1. In a new tab, go to https://www.epa.gov/ejscreen and **Launch the EJScreen Tool**.

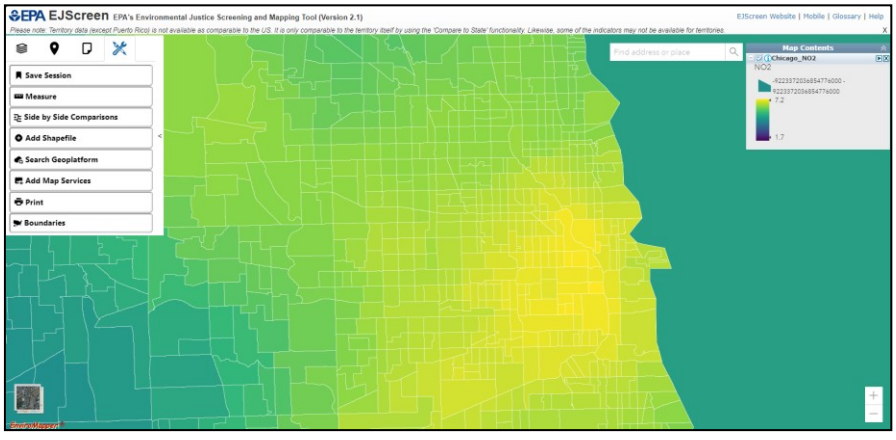
2. Click on the **Tools** icon and select **Add Map Services**.



3. In the **Add Map Services** pop-up window, paste the **URL** from the published **NO2_Chicago** web layer. Select **Add to Map**.



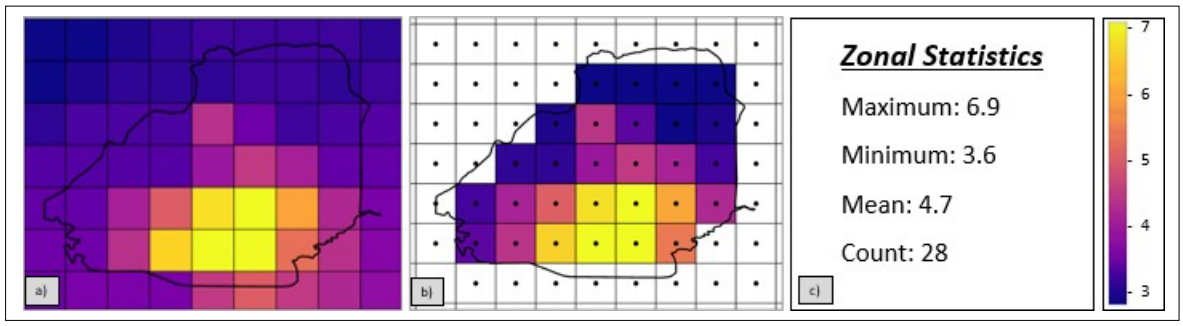
4. The **Chicago_NO2** map will be added.



FAQ

Q: Why don't we use **Zonal Statistics as Table** to directly calculate the census tract average value?

A: **Zonal Statistics as Table** is a great tool and sometimes a great solution. However, this all depends on the type of data that is being used. Zonal Statistics works by finding the centroid of each grid cell and uses that to assign a value to the polygon. Since there are census tracts that are smaller than 1km, sometimesthe gridded data's centroid doesn't fall within the census tract polygon and therefore no calculation is made. Other times, in larger polygons such as counties, the polygon boundary may include many grid cells but not the centroid of each grid cell.



Example demonstrating zonal statistics calculations. a) An example of a gridded dataset over a polygon. b) the black dots represent the center of the grid cell, and the white cells are excluded from calculations as the center does not fall within the polygon. c) The statistics are calculated. In this example 28 cells were used in the calculation.

Q: Why can't we resample the 1km x 1km data to ensure there is a centroid in each census tract?

A: While resampling the data to a finer grid would ensure that every cell has a centroid, this would introduce errors and uncertainties in the data, which are already gridded to the highest resolution appropriate for the satellite dataset.

Appendix A

Data

The data folder for this tutorial contains the 2019 census tract shapefiles for Illinois, Indiana, and Wisconsin, the U.S. Metropolitan and Micropolitan area. These files were downloaded from the U.S. Census Bureau, https://www.census.gov/cgi-bin/geo/shapefiles/index.php, originally as "tl_2019_17_tract", "tl_2019_18_tract", "tl_2019_55_tract", "tl_2019_us_cbsa", but the names were changed to Illinois, Indiana, Wisconsin and CBSA before being added to the data folder for this tutorial.

Census Tract Shapefile (Illinois, Wisconsin, Indiana)			
Field	Length	Type	Description
STATEFP	2	String	Current state Federal Information Processing Standards (FIPS) code
COUNTYFP	3	String	Current county FIPS code
TRACTCE	6	String	Current census tract code
GEOID	11	String	Census tract identifier; a concatenation of Current state FIPS code, county FIPS code, and census tract code
NAME	7	String	Current census tract name, this is the census tract code converted to an integer or integer plus 2-character decimal if the last two characters of the code are not both zeros.
NAMELSAD	20	String	Current translated legal/statistical area description and the census tract name
MTFCC	5	String	MAF/TIGER feature class code (G5020)
FUNCSTAT	1	String	Current functional Status
ALAND	14	Number	Current land area
AWATER	14	Number	Current water area
INTPTLAT	11	String	Current Latitude of the internal point
INTPTLON	12	String	Current Longitude of the internal point

Source: TIGER/Line Shapefiles Technical Documentation

Metropolitan Statistical Area/Micropolitan Statistical Area (CBSA)			
Field	Length	Type	Description
CSAFP	3	String	Current combined statistical area code, if applicable
CBSAFP	5	String	Current metropolitan statistical area/micropolitan statistical area code
GEOID	5	String	Metropolitan statistical area/micropolitan statistical area identifier, metropolitan statistical area/micropolitan statistical area code
NAME	100	String	Current metropolitan statistical area/micropolitan statistical area name
NAMELSAD	100	String	Current name and the translated legal/statistical area description for metropolitan statistical area/micropolitan statistical area
LSAD	2	String	Current legal/statistical area description code for metropolitan statistical area/micropolitan statistical area
MEMI	1	String	Current metropolitan/micropolitan status indicator
MTFCC	5	String	MAF/TIGER feature class code (G3110)
ALAND	14	Number	Current land area
AWATER	14	Number	Current water area

INTPTLAT	11	String	Current Latitude of the internal point
INTPTLON	12	String	Current Longitude of the internal point

Source: TIGER/Line Shapefiles Technical Documentation

The **NO2.tif** provides a 2019 average of the tropospheric vertical column density (VCD) of NO_2 from the TROPOMI instrument. These data have a native resolution of 3.5 km x 7 km (January – August 2019) and 3.5 km x 5 km (August – December 2019) and were regridded to 1 km x 1 km using the Wisconsin Horizontal Interpolation Program for Satellites (WHIPS, https://sage.nelson.wisc.edu/data-and-models/wisconsin-horizontal-interpolation-program-for-satellites-whips/). TROPOMI NO_2 data were filtered with a quality assurance value of 0.75 or greater. More information about TROPOMI NO_2 can be found in the product User Manual (https://sentinel.esa.int/documents/247904/2474726/Sentinel-5P-Level-2-Product-User-Manual-Nitrogen-Dioxide.pdf).

Citing the Data

The following are citations for the datasets:

2019 TIGER/Line Shapefiles (machine readable data files) / prepared by the U.S. Census Bureau, 2019

We wish to thank the University of Wisconsin-Madison for the use and development of the Wisconsin Horizontal Interpolation Program for Satellites (WHIPS). WHIPS was developed by Tracey Holloway, Jacob Oberman, Peidong Wang, Eliot Kim, and other students and staff, with funding from the NASA Air Quality Applied Science Team (AQAST), the NASA Health and Air Quality Applied Sciences Team (HAQAST), and the State of Texas Air Quality Research Program (AQRP).

Appendix B

Where to Download Satellite Data for Air Quality

Gridded tropospheric NO_2 from OMI and TROPOMI instruments, from 2006 onward

- https://sage.nelson.wisc.edu/data-and-models/datasets/satellite-data-for-air-quality/

Gridded estimates of surface PM2.5

- https://sites.wustl.edu/acag/datasets/surface-pm2-5/

As more satellite data for air quality become available, we do our best to keep an up-to-date list of products on the Holloway Group page,
https://hollowaygroup.org/data-models

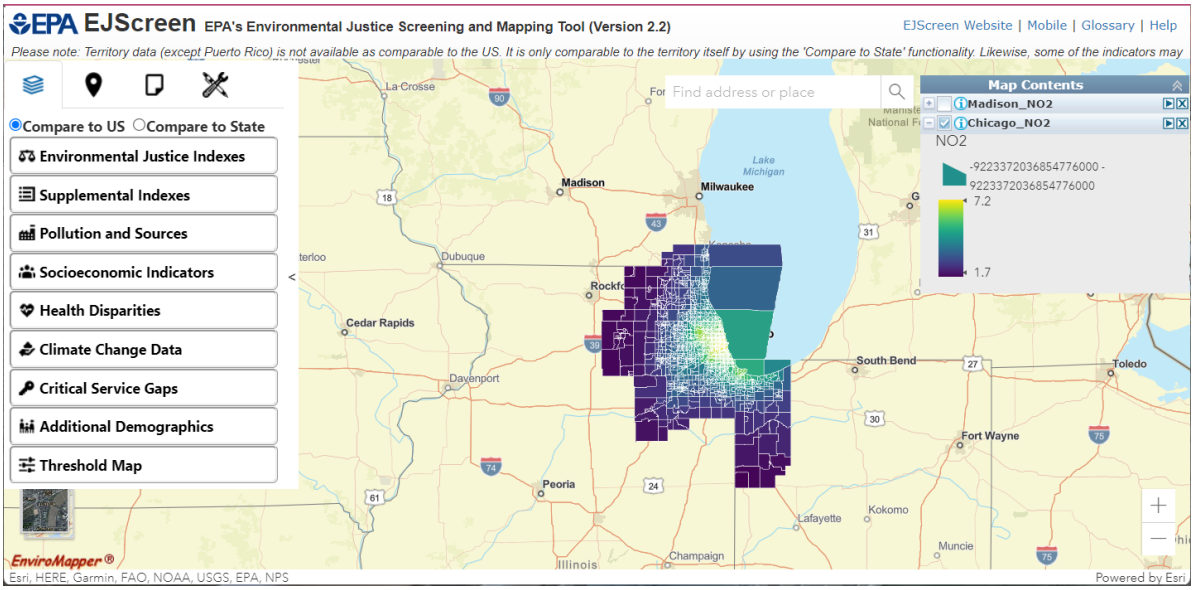
Additional NASA and satellite-related products can be found through HAQAST,
https://haqast.org/data-and-tools/

Appendix C

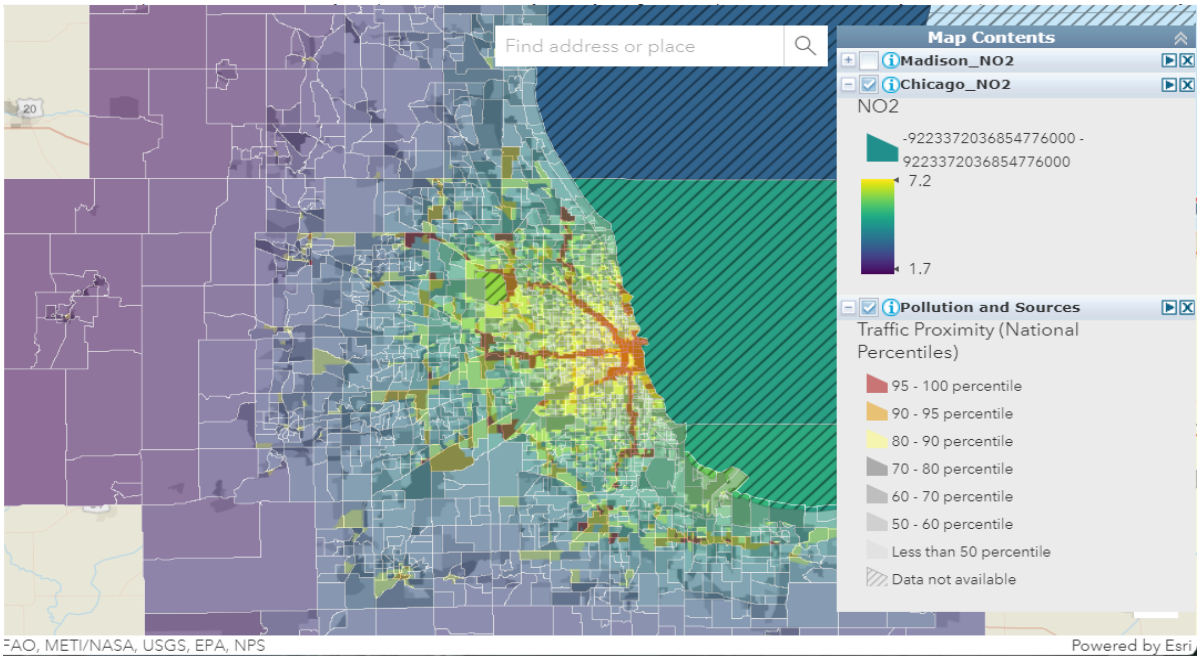
EJScreen

The Environmental Protection Agency (EPA) created an online mapping tool that allows users to visualize environmental and demographic socioeconomic indicators in a selected area within the U.S.

https://www.epa.gov/ejscreen/what-ejscreen



EJScreen Homepage (with created map layer)



Example of EJScreen “Traffic Proximity” layer and created map layer “Chicago_NO2.”

Glossary

CBSA	Core-Based Statistical Area
Coordinate System (Geographic)	Uses latitude and longitude to identify locations.
Coordinate System (Projected)	Used feet and meters to express x and y coordinates.
Double (64-bit floating point)	How many bits represent a floating-point number.
Geodatabase	Primary data structure for ArcGIS and used for editing and data management.
NetCDF File	Network Common Data Form. Support sharing of array-oriented scientific data.
Raster file	Spatial data models that define space as an array of equally sized cells, arranged in rows and columns, and composed of single or multiple bands.
Shapefile	A simple, nontopological format for storing the geometric location and attribute information of geographic features.
TIFF	“Tag Image File Format,” computer file for storing raster graphics and other image related information. TIFF files are more complex than shapefiles.
TROPOMI	Tropospheric Monitoring Instrument aboard the Copernicus Sentinel-5 Precursor satellite. Collects data on trace gases and aerosols.
VCD	Vertical Column Density, useful in interpreting the concentration of trace gases.