Green in the City

Atlanta, Georgia, USA

Worksheets

Colophon

Imagery

Landsat, USGS and NASA

Sentinel-2, Copernicus program, ESA

Introduction

In this workshop, you will map urban green in the **City of Atlanta** and analyze relationships between the presence of urban green, temperature, and various socio-economic data.

In **Part 1** of the workshop, you will produce a vegetation map of the city based on satellite images and investigate how green the city is and how urban green is distributed within the city. In **Part 2**, you will continue the analysis by comparing the distribution of green within the city with data on temperature. In **Part 3**, you will look at green and temperature in relation to different socio-economic data.

To start, we assume that QGIS is correctly installed on your computer, that all the files you need are available in a folder that you have created on your PC or that your teacher has prepared for you, and that the data you will be working with has already been loaded into QGIS. If you have not already done so, first go through the technical manual to install QGIS and/or download and load the data you need into QGIS.

Using these worksheets, you should be able to complete the workshop independently and step by step. Each set of exercises in part 1 of the workshop starts with a video that prepares you for the exercises that follow. The video numbers correspond to the numbers indicated in the worksheets.

Guidelines:

Watch the video with the corresponding number

Read the boxes with technical explanations – they will help you move forward

Mini post-its are provided throughout the exercises and questions to give helpful tips

Let's start with a simple question: What percentage of the total area of the City of Atlanta do you think is covered by urban green?

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Have fun!

PART 1 – Make a vegetation map of Atlanta

EXERCISE 1.1

Open the Atlanta project by double clicking on the ***QGS Atlanta*** icon.

In the layers panel on the left, check only the ***Atlanta_spectral_bands*** layer to make this image visible in QGIS. If necessary, deactivate the other layers by unchecking them and keep them deactivated.

1) Inspect different parts of the image and try to identify different features and how they are represented as pixels using the *pan map*, *zoom in*, *zoom out*, and *zoom full* tools.

2) Click on specific pixels with the *Identify features* tool and observe the pixel values in the *identify results* window for each spectral band. Make sure the ***Atlanta_spectral_bands*** layer is checked, and the other layers are unchecked. Otherwise, you will not be able to see the pixel values in this layer.

3) Choose three pixels in different parts of the image for each of the three land cover types in the table below and record the values for these pixels in each of the four spectral bands. Each pixel in the image has four values and corresponds to one row in the table below. You can use Google Earth to get a better view of the land cover types in different locations.
4) Calculate the average of the three pixel values for each of the three land cover types per band.

	Band3_blue	*Band2_green*	*Band1_red*	*Band4_NIR*
water				
average				
vegetation (park, forest, meadow, …)				
average				
buildings				
average				

5) Plot the mean values for each spectral band for each land cover type with a point in the graph below. Assign a letter to each point to indicate whether it represents water (W), vegetation (V), or buildings (B). This will help you distinguish the mean values in each band for the three land cover types.

Then connect the points of the same land cover type with straight line segments.

EXERCISE 1.2

Each pixel has a value per spectral band.
What is the physical meaning of a) a low pixel value and b) a high pixel value?

a) ....

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b) ....

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EXERCISE 1.3

Based on your answers to the previous two exercises, how does water interact with electromagnetic radiation? And what happens with electromagnetic radiation that comes into contact with vegetation and buildings?

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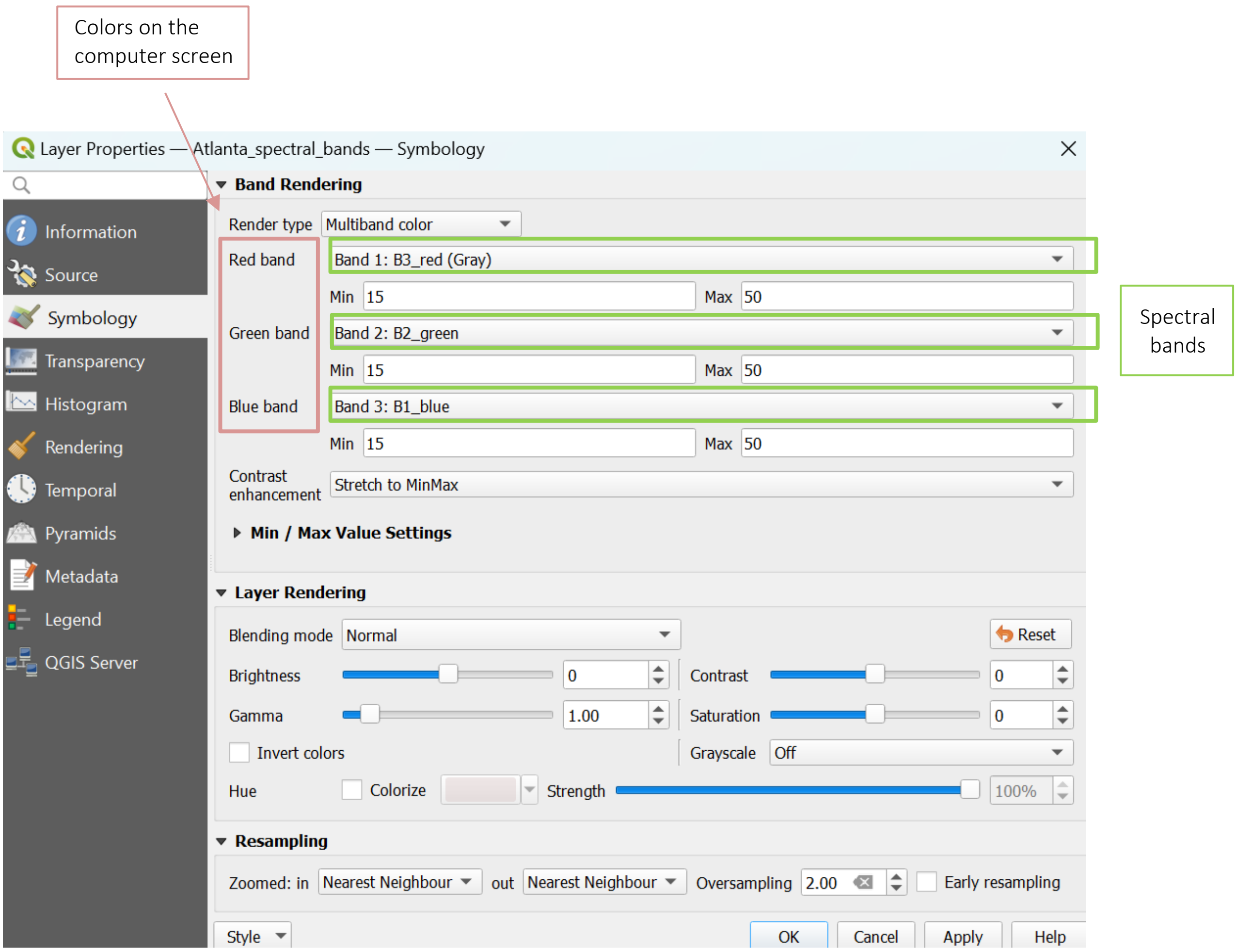
EXERCISE 2.1

The ***Atlanta_spectral_bands*** layer is shown as a true-color image. As you have just seen in the video, we obtain such an image by linking the value of each pixel in the blue, green, and red bands of the image to the intensity of the primary colors blue, green, and red on our computer screen.

To see how this was done, double-click on the ***Atlanta_spectral_bands*** layer and select the *Symbology* tab on the left. You can see that the blue band (Band 3), the green band (Band 2), and the red band (Band 1) are associated with the three basic colors in the image.

"Red band", "Green band", and "Blue band" on the Symbology window refer to the colors that are used to visualize the spectral reflectance in each of the three bands. Band 1, Band 2, and Band 3 correspond to the layers containing the spectral values for each pixel.



Take another look at the image. What color do water, vegetation, and buildings appear in the true-color image?

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Now take a look at the graphs you made in Exercise 1.1. Can you explain why water, vegetation, and buildings have the color they do? If needed, use the <u>*identify features*</u> tool again to understand the difference in spectral band values for different types of features.

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EXERCISE 2.2

We will now create a false-color image as shown in the video. In the layers panel, right-click the ***Atlanta_spectral_bands*** layer and select *Duplicate Layer*. This will create a new map layer with the name ***Atlanta_spectral_bands_copy***. Right-click the newly created map layer and select *Rename Layer*. Change the name to ***Atlanta_spectral_bands_false_color***.

STEP 1

Double-click on the ***Atlanta_spectral_bands_false_color*** layer and select the *Symbology* tab on the left.

STEP 2

Assign three of the four available satellite bands to the red, green, and blue color of your screen to obtain a false-color image. Assign "Band 4: B4_NIR" to the red color (Red band) of your display, "Band 1: B3_red (Gray)" to the green color (Green band), and "Band 2: B2_green" to the blue color (Blue band).

STEP 3

Click on the "*Style*" tab at the bottom of the Symbology window, click "*Load Style,*" and open the ***Atlanta_style_fcc*** file in the Atlanta folder. Confirm with "OK".

EXERCISE 2.3

Which features appear red in the false-color image you have created? Why? Think carefully about which satellite band you have assigned to the red color of your screen. If necessary, use the *identify features* tool again to understand this better. (Also look back at the graph you made in Exercise 1.1.)

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Tip: In QGIS, click on the top left to save your project. This is useful in case QGIS unexpectedly closes or becomes unresponsive. Do this regularly from now on to avoid losing your work.

EXERCISE 3.1

Create an NDVI map.

Calculating with grids in QGIS

Each pixel or cell in a raster image has a value, allowing all kinds of calculations to be performed on the pixels to create a new map.

In QGIS, performing calculations with raster images is very easy. Go to *Raster* in the menu bar and select *Raster calculator*. A new window will open. Simply follow the steps in the figure on the next page:

1- To calculate the NDVI value of a pixel we will make use of the formula below.

$$\frac{(NIR - \mathrm{RED})}{(NIR + \mathrm{RED})}$$

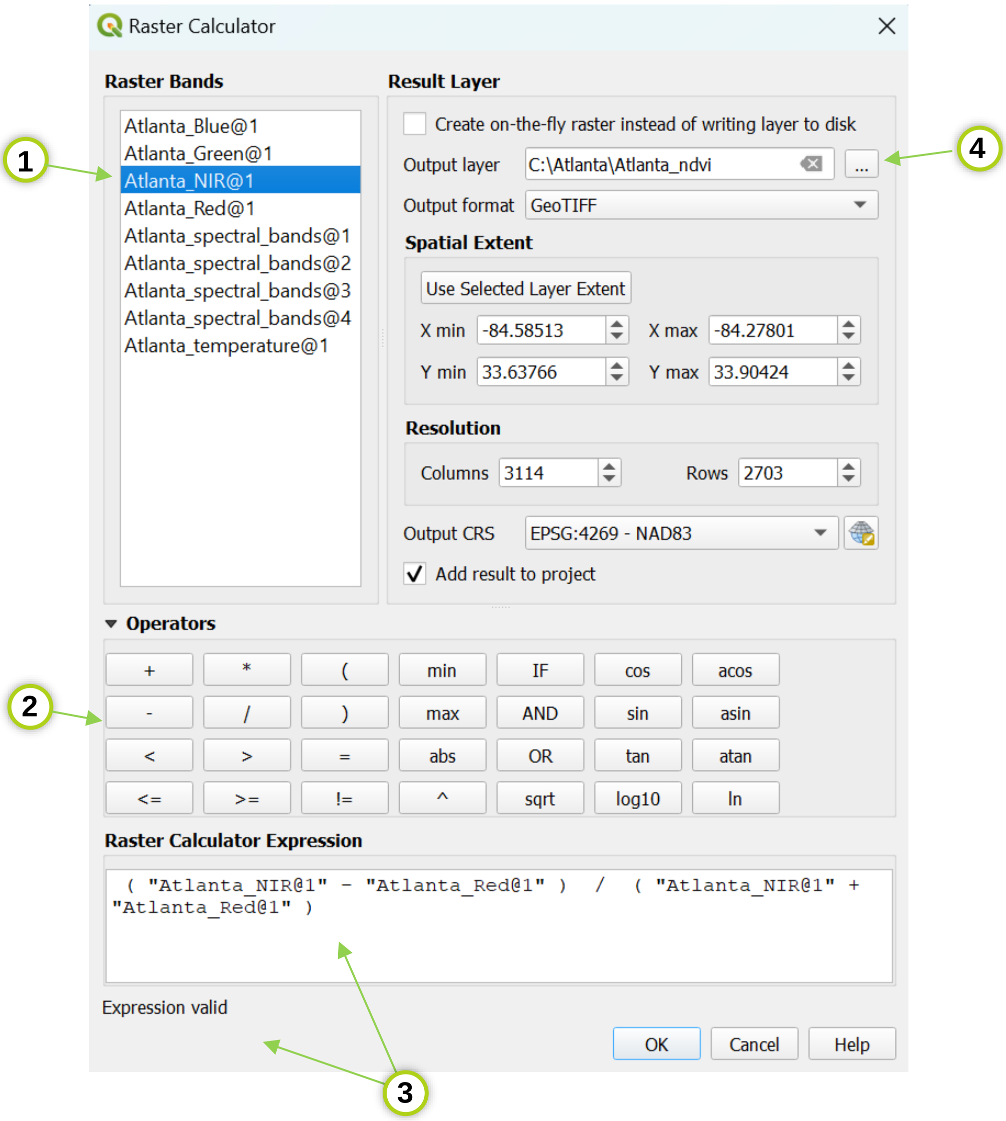
Enter the formula for the operation in the white field under the "*Raster calculator expression*." To add a raster as a calculation element to the formula, double-click the item in the list under "*Raster bands*."

2- To insert an operator (+, -, *, /) into the formula, click on the buttons under "*Operators*".

3- Make sure you define the formula correctly (don't forget the parentheses!). At the bottom left, you can see if the formula is mathematically correct or not.

4- To name the output layer that will contain the result of your calculation, first click on ... and go to the ***Atlanta*** folder, type **Atlanta_ndvi** as the file name, and confirm with OK.

The **Atlanta_ndvi** layer will be added to the layers panel. Double click on the new layer and click on the "*Style*" tab at the bottom of the Symbology window, click "*Load Style,"* and open the **Atlanta_style_NDVI** file in the Atlanta folder. Confirm with "OK".



EXERCISE 3.2

Which land cover types have the highest NDVI values? Which types have the lowest NDVI values? Can you explain why this is the case?

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EXERCISE 4.1

Creating a vegetation map

The vegetation map consists of pixels with a value of 1 for vegetation and 0 for non-vegetation. Using an NDVI threshold value, you can determine whether a pixel corresponds to vegetation or not. You select that threshold value based on the histogram of the NDVI map.

Show the histogram of a raster map

To display the histogram or frequency plot of the NDVI map, double-click the ***Atlanta_ndvi*** layer and select the *Histogram* tab on the left. If you cannot see the histogram, click the *Compute Histogram* button below the graph.

Move the mouse over the graph and use the magnifying glass to draw a rectangle around the area you want to zoom in on. You can return to the original image by right clicking.

Read the threshold value and record it here: ....

To check whether a pixel should be classified as vegetation, the following reasoning is used:

IF pixel value_NDVI <= threshold value THEN pixel value_vegetation = 0
IF pixel value_NDVI > threshold value THEN pixel value_vegetation = 1

Produce the vegetation map

In *Raster Calculator,* the operation you will perform can simply be represented by the following expression (use a period as a decimal separator for the threshold value):

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if ("Atlanta_ndvi@1" <= threshold value,0,1)
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Pixels in the image that have a value below the chosen threshold are assigned a value of 0, and other pixels a value of 1.

To give a name to the new output layer, first click on [...] and go to the ***Atlanta*** folder, then type ***Atlanta_vegetation*** as the file name and confirm with OK.

Once the result has been added to the layers panel, double-click on the layer, select the Symbology tab on the left, and then select the *Style* tab. Click on *Load style*... and, in the style folder, open the ***Atlanta_style_vegetation*** file in the Atlanta folder. Confirm with OK.

Note: While the NDVI that corresponds to the minimum value in the histogram may be considered a good first guess for the threshold value, it is not necessarily the most optimal choice. Indeed, some trial and error might be required to properly discriminate vegetation from non-vegetation. Compare the vegetation map which you obtained with the true and/or false color image. If you zoom in on both layers and you notice that there is much more or much less vegetation present in your vegetation map than you expect based on the true and/or false color image, then you have not chosen a proper threshold value for the NDVI. If this is the case, recreate the vegetation map with a new threshold value. If you recreate the vegetation map, you can simply overwrite the previously obtained map.

EXERCISE 4.2

Briefly discuss the spatial distribution of greenery within the city. Do you see specific patterns? Where in the city do we find a lot of urban green? Where is green less present? Do you recognize a particular park or forest?

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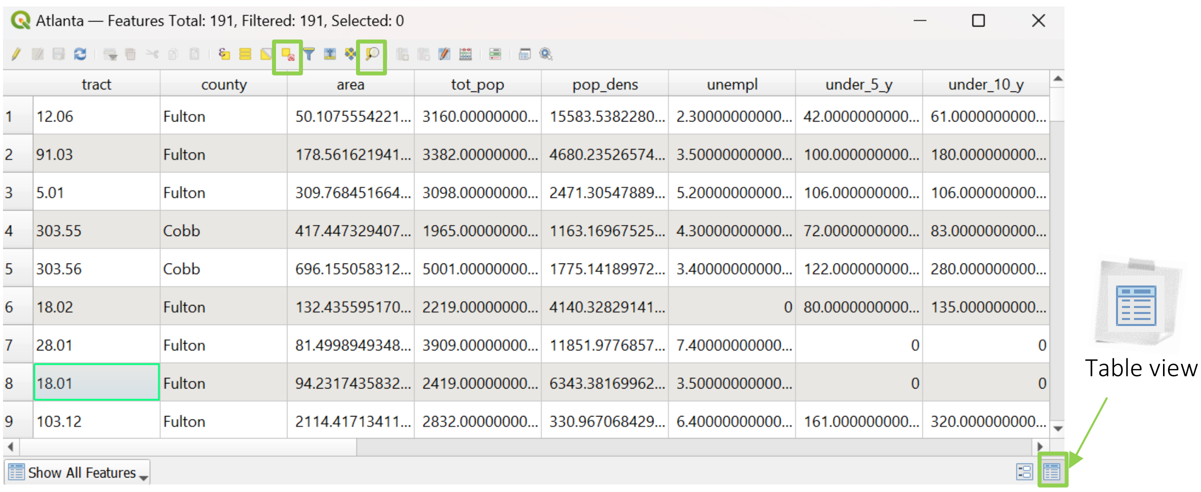
PART 2 – Compare green cover with temperature

EXERCISE 5.1

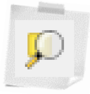
In this part of the workshop, we will study the relationship between urban green cover and temperature. For this, we will work at the level of census tracts. First, have a look at the ***Atlanta*** layer in QGIS. You can do this by checking this layer and by disabling the other layers or dragging them down in the layers panel. In doing so, the ***Atlanta*** layer will be displayed on top of the other layers, and you will no longer see the layers beneath it in the map canvas. Note that, unlike previous layers, the ***Atlanta*** layer is not a raster layer but a vector layer consisting of polygons. In GIS, polygons represent what we call "area" in everyday speech. Each polygon in the *Atlanta* layer corresponds to a census tract. The image below shows the tracts of the City of Atlanta.

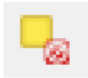
Right-click the ***Atlanta*** layer in the layers panel, then left-click "*Open Attribute Table"* to get more information about each polygon that is visible on the map. You can use the button in the lower-right corner to open the attribute table in table view.



	tract	county	area	tot_pop	pop_dens	unempl	under_5_y	under_10_y
1	12.06	Fulton	50.1075554221...	3160.00000000...	15583.5382280...	2.30000000000...	42.0000000000...	61.0000000000...
2	91.03	Fulton	178.561621941...	3382.00000000...	4680.23526574...	3.50000000000...	100.000000000...	180.000000000...
3	5.01	Fulton	309.768451664...	3098.00000000...	2471.30547889...	5.20000000000...	106.000000000...	106.000000000...
4	303.55	Cobb	417.447329407...	1965.00000000...	1163.16967525...	4.30000000000...	72.0000000000...	83.0000000000...
5	303.56	Cobb	696.155058312...	5001.00000000...	1775.14189972...	3.40000000000...	122.000000000...	280.000000000...
6	18.02	Fulton	132.435595170...	2219.00000000...	4140.32829141...	0	80.0000000000...	135.000000000...
7	28.01	Fulton	81.4998949348...	3909.00000000...	11851.9776857...	7.40000000000...	0	0
8	18.01	Fulton	94.2317435832...	2419.00000000...	6343.38169962...	3.50000000000...	0	0
9	103.12	Fulton	2114.41713411...	2832.00000000...	330.967068429...	6.40000000000...	161.000000000...	320.000000000...

Each row of the attribute table corresponds to a polygon in the map layer. Each column represents a characteristic (or attribute) of the polygons. In this exercise for Atlanta, the eighth row in the table describes the census tract identified as 18.01, which has an area of 94.23 acres. Left-click any row in this column (click the row number) to select a census tract. Buttons at the top of the attribute table allow you to zoom in or deselect the selected tract on the map. Close the attribute table for now (top right cross).



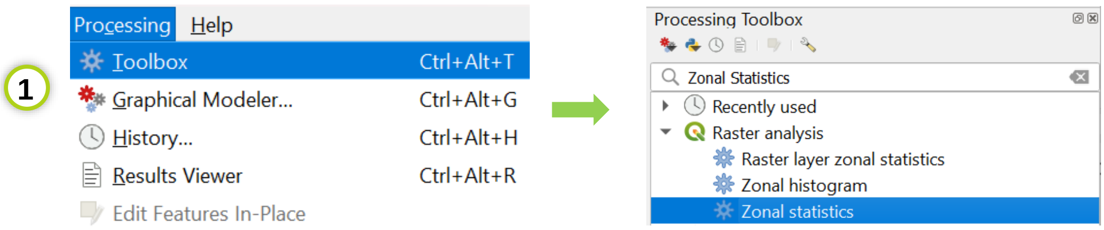


Now calculate the proportion of green (number of green pixels/total number of pixels; a value between 0 and 1) within each census tract using the *Zonal Statistics* tool. Use the ***Atlanta_vegetation*** raster layer and the ***Atlanta*** polygon layer for this.

With this exercise, a new column will be added to the attribute table of the Atlanta polygon layer. The new column will contain statistics (mean) of pixel values from the ***Atlanta_vegetation*** raster layer that fall within each polygon of the polygon layer. Carry out the steps below. You can also see the steps in the figure on the next page.

The 'Zonal Statistics' Tool

1. Open the **Zonal Statistics** tool in the toolbox (*Processing* > *Toolbox* > *Raster Analysis* > *Zonal Statistics*). You can access this tool via the search bar in the Processing panel.



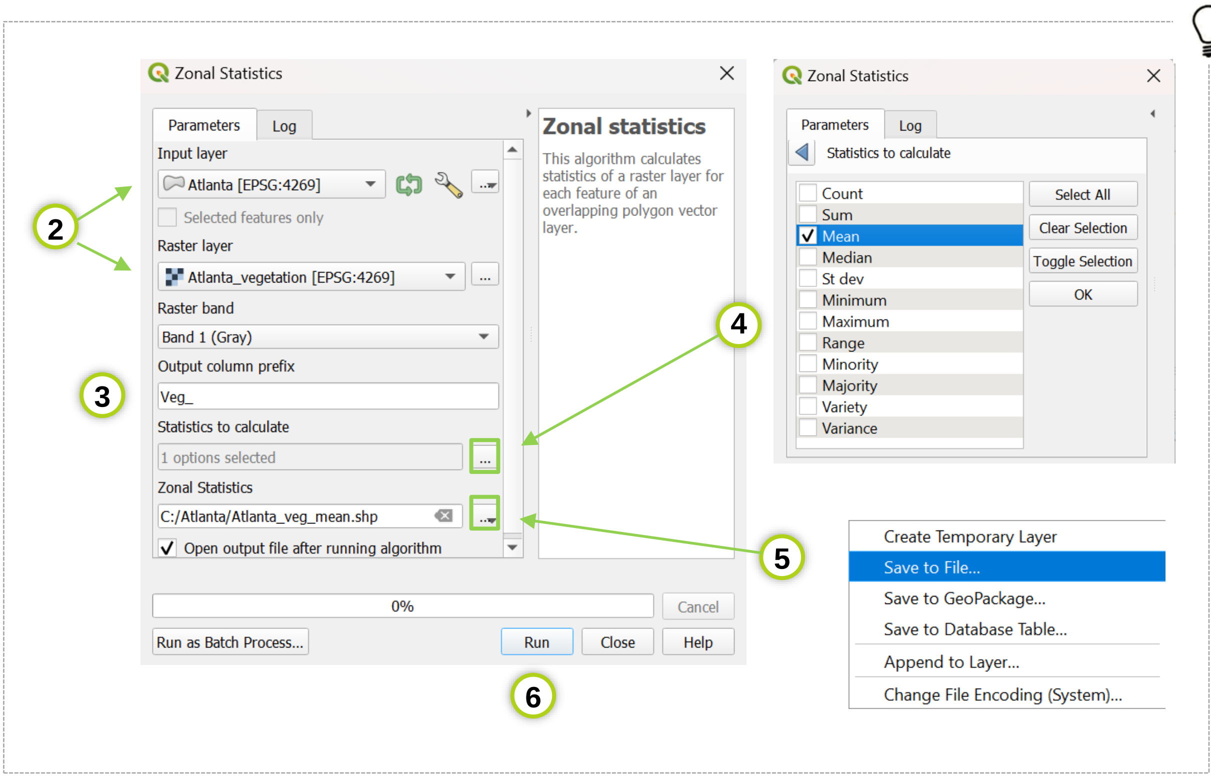
2. In the Zonal Statistics window, select the ***Atlanta*** polygon layer as the "*Input Layer*" and the ***Atlanta_vegetation*** raster layer as the "*Raster layer.*"

3. The "*Output column prefix*" is a prefix for naming the new column. Type in the prefix "**veg_**".

4. In the "*Statistics to calculate*" field, you will indicate which statistics will be calculated. Select only "*Mean*" as the metric to calculate. This will calculate the proportion of the area (in pixels) within the tract that is green. The new attribute is automatically named "**veg_mean"** and is added as a new column to the ***Atlanta*** attribute table.

5. Before running the tool, make sure to save the result of this operation as a new layer. In the "*Zonal Statistics*" section, select "*Save to File.*" Name the new layer "***Atlanta_veg_mean***" and save it in the ***Atlanta*** folder.

6. Run the tool. The newly created "***Atlanta_veg_mean***" layer will be added to the layer panel. You can open its attribute table and see the new field named "*veg_mean"* at the right end of the table.



EXERCISE 5.2

Open the ***Atlanta_veg_mean*** layer's attribute table and answer the questions below.

- Which census tract has the lowest proportion of green? Also, note the proportion as a percentage (%).

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- Which census tract has the highest proportion of green? Also, note the proportion as a percentage (%).

  ………

Tip: You can sort the rows in the table from the lowest to the highest value or vice versa according to the attribute values by clicking on the attribute name in the table header.

EXERCISE 5.3

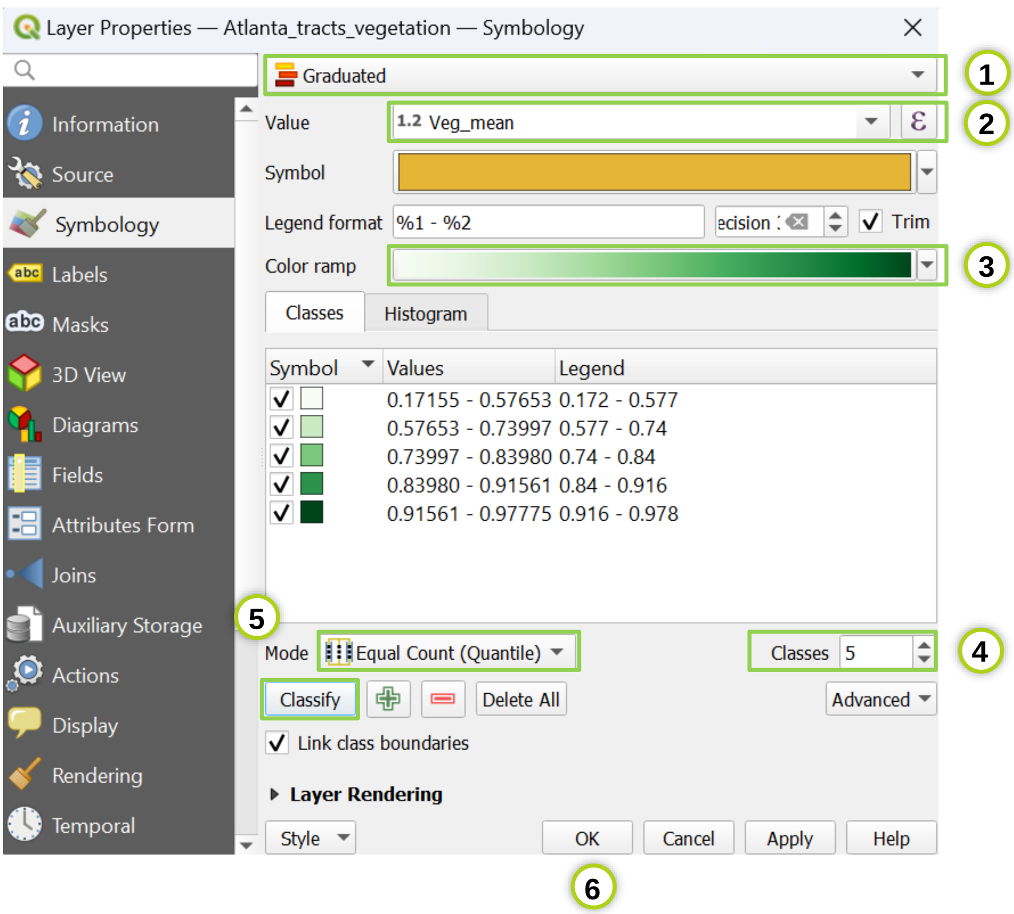
Now that you have calculated the proportion of green for each census tract, you can also map it out. We will first create a new map layer, starting from the ***Atlanta_veg_mean*** layer. In the layers panel, right-click the ***Atlanta_veg_mean*** layer and select *Duplicate Layer*. This will create a new map layer with the name ***Atlanta_veg_mean_copy***. Right-click the newly created ***Atlanta_veg_mean_copy*** map layer and select *Rename Layer*. Change the name to ***Atlanta_tracts_vegetation***.

We will now color each tract based on the proportion of green in this new map layer. Choose a color scheme that goes from light green to dark green and divides the tracts into 5 classes, from tracts with little green to tracts with a lot of green. When defining the classes, you should use the quantile method, which means that there will be an equal number of tracts in each class. This creates a map in which spatial patterns can easily be observed.

Color tracts based on the proportion of green

Double-click on ***Atlanta_tracts_vegetation*** and select the *Symbology* tab on the left. Then make the adjustments shown below:

1) At the top of the window, change the symbology to "graduated."
2) Select the attribute you want to display in the *Value* section, in this case ***veg_mean***.
3) Change the *Color ramp* to green (*Greens*).
4) Classify 5 classes.
5) In the Mode field, select "*Equal Count" (Quantile)*. If you click the "Classify" button, you can see the classes in the space above.
6) Apply the generated color scheme to your map.



EXERCISE 5.4

In this exercise, we will calculate the average temperature for each census tract. Take a look at the ***Atlanta_temperature*** layer. The pixel values in this layer show temperatures in degrees Celsius (°C).

First, use the *Raster Calculator* tool to convert the values from Celsius to Fahrenheit (°F). Save the new raster layer in the ***Atlanta*** folder and name it ***Atlanta_temp_fahrenheit***. You can use the following formula to convert °C to °F:

$$°F = (°C * 1.8) + 32$$

In the *Raster Calculator* expression window, use this formula: ("Atlanta_temperature@1" * 1.8) + 32.

Repeat Exercise 5.1 to calculate the average temperature by census tract. This time, use the ***Atlanta_veg_mean*** vector layer as the polygon layer in the *Zonal Statistics* tool. Use the newly created ***Atlanta_temp_fahrenheit*** layer as a raster layer. Again, under *Statistics to calculate*, select only *Mean* as the metric. Use the prefix "**temp_**". Name the new polygon layer ***Atlanta_veg_temp_mean*** and save it in the ***Atlanta*** folder.

Atlanta_temp_fahrenheit captures the afternoon temperature in the city on July 28, 2021. The unit used in this raster layer is °F. Note that the temperature in some places is very high, up to 105 °F. This is because the satellite sensor measures surface temperature, not air temperature.

EXERCISE 5.5

Open the ***Atlanta_veg_temp_mean*** layer's attribute table and answer the questions below. Remember that you can sort the rows in the table according to the values of an attribute.

- Which tract has the lowest average temperature? Note the average temperature in °F and the proportion of vegetation as a percentage (%).

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- Which tract has the highest average temperature? Note the average temperature in °F and the proportion of vegetation as a percentage (%).

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EXERCISE 5.6

Create a new map layer, starting from the ***Atlanta_veg_temp_mean*** polygon layer. In the layers panel, right-click the ***Atlanta_veg_temp_mean*** map layer and select *Duplicate Layer*. Right-click the newly created ***Atlanta_veg_temp_mean_copy*** map layer and select *Rename Layer*. Change the name to ***Atlanta_tracts_temperature***. Starting from this new layer, create a temperature map showing the temperature for each tract using a color scale. This time use the *red* color scheme, which goes from light red (low temperature) to dark red (high temperature). Again, select five classes and the quantile classification method.

EXERCISE 5.7

Compare the maps of the average proportion of green and average temperature per tract by alternately checking and unchecking them. What do you notice? Can you briefly describe the spatial relationship you see between temperature and green cover?

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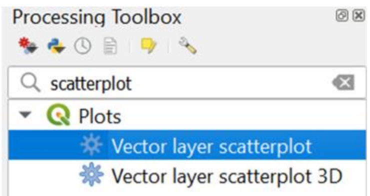
EXERCISE 5.8

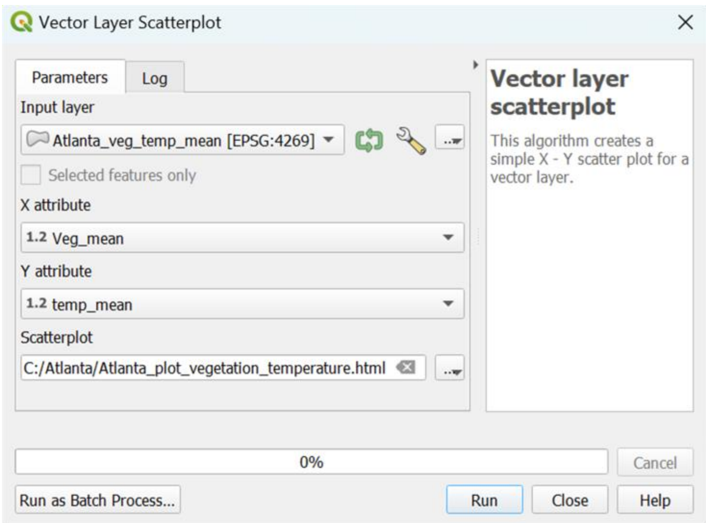
By now, you have probably noticed a relationship between temperature and green cover. To show the connection between these two variables even more clearly, we will use a method that is very often used to compare two types of data called a scatter plot.

The "Vector Layer Scatterplot" tool

A scatter plot is a graph where data points are plotted in an x, y coordinate system. The x and y coordinates of each data point correspond to the values of the two types of data being compared. In our case, there is a data point for each census tract, and the variables "**veg_mean**" and "***temp_mean***" (these are the proportion of vegetation and the average temperature per tract) will be compared.

Open the *Vector Layer Scatterplot* tool (*Processing > Toolbox > Plots > Vector Layer Scatterplot*). In the window, use the ***Atlanta_veg_temp_mean*** polygon layer as the input layer. Select "***veg_mean***" as the *X attribute* and "***temp_mean***" as the *Y attribute*. To save the plot, click on ... , select *Save to file...*, go to your project folder (***Atlanta***), and save the plot as ***Atlanta_plot_vegetation_temperature***.





In the *Toolbox* window on the right, you will find the plot you created under *View results*. Double-click on the plot to see the result in your browser. What can you conclude from the plot?

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EXERCISE 5.9

In the introduction section of the workshop, you were asked to estimate the percentage of the total area of Atlanta that is covered by green.

Now, answer the same question, but this time use QGIS to determine the exact percentage of urban green in Atlanta. After calculating the percentage, discuss how accurate your original estimate was compared to the figure you calculated.

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<u>Tip</u>: In Exercise 5.1, you calculated the percentage of green in each of the 191 census tracts in the Atlanta polygon layer. To make the same calculation for the entire city you need a single polygon layer showing the boundaries of the city.

In the Zonal Statistics window, use the ***Atlanta_boundary*** layer as the input layer and the ***Atlanta_vegetation*** layer as the raster layer. Again, under *Statistics to calculate*, select only *Mean*. Use the prefix "**veg_**". This time, keep the new layer as a temporary layer and click "*Run*". You can view the result in the attribute table of the newly created temporary layer in the layers panel named ***Zonal Statistics***.

Remember that unless you save this layer to disk, the temporary layer will be lost permanently when you exit QGIS. You can click on to save the temporary layer in your ***Atlanta*** folder.

PART 3 – Investigate the relationship between urban green, temperature, and socio-economic data

The goal of this last part of the workshop is to use the knowledge you now have to conduct your own research and to compare vegetation and temperature per tract with other data. For this, you can start from the calculated zonal statistics about vegetation and temperature, which you have saved in the polygon layer ***Atlanta_veg_temp_mean***. You will notice that a whole range of socio-economic data are also available in the layer. These data tell you more about the characteristics of the population living in the tracts (density, age distribution, income, level of education, etc.) and about the type of dwellings found in each tract.

The table below gives an overview of the available data in the attribute table of the ***Atlanta_veg_temp_mean*** layer. The data provided in the table comes from the 2020 Census, except for the last two variables (veg_mean and temp_mean), which you have added yourself.

tract	Identifier of the census tract
county	County in which the census tract is located
area	Area of the census tract (acre)
tot_pop	The population of the census tract
pop_dens	Population density of the census tract
unempl	The ratio of the population of the census tract that is unemployed (%)
under_5_y	The ratio of the population of the census tract that is less than 5 years old (%)
under_10_y	The ratio of the population of the census tract that is less than 10 years old (%)
under_15_y	The ratio of the population of the census tract that is less than 15 years old (%)
over_65_y	The ratio of the population of the census tract that is more than 65 years old (%)
over_70_y	The ratio of the population of the census tract that is more than 70 years old (%)
over_80_y	The ratio of the population of the census tract that is more than 80 years old (%)
alone	The ratio of the population of the census tract that lives alone (%)
no_dipl	The ratio of the population of the census tract that has no high school diploma (%)
high_sch	The ratio of the population of the census tract that only has a high school diploma (%)
degree	The ratio of the population of the census tract that has more than a high school diploma (%)
renter	The ratio of the population of the census tract that rents a house or apartment (%)
pre_1960	The ratio of the dwellings in the census tract that are built before 1960 (%)
pre_1980	The ratio of the dwellings in the census tract that are built before 1980 (%)
after_2014	The ratio of the dwellings in the census tract that are built after 2014 (%)
apartments	The ratio of the dwellings in the census tract that are an apartment (%)
attached	The ratio of the dwellings in the census tract that are an attached house (%)
detached	The ratio of the dwellings in the census tract that are a (semi-) detached house (%)
med_income	The median income of the population of the census tract ($)
veg_mean	The ratio of the vegetation in the census tract as a fraction of the total area
temp_mean	The mean temperature in the census tract in °F

<u>Note:</u> Sometimes you will find a NULL value in the attribute table. This means that no value for the attribute is available for that particular tract. This is because not all data is available for all tracts. Some tracts are so small that few or no people live there. In this case, no data is available.

In Part 2 you learned how to map the spatial distribution of a variable for each tract. You also learned how to make a scatter plot to compare two different variables. Use these skills now and get started with the available data.

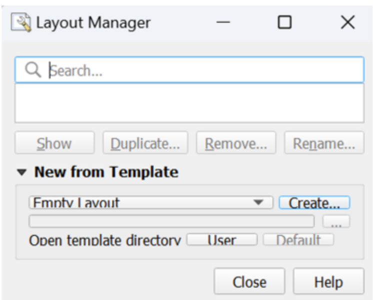
Ask yourself which data would be interesting to compare with the city's vegetation or temperature distribution, create new maps, explore the relationship between different variables, and describe what you observe. For each new map you want to make, make sure you duplicate the polygon layer you are working with, rename it, and then create the map. Give each new map layer a clear name, such as ***Atlanta_tracts_xxxx*** (replace *xxxx* with the name of the data you are mapping). Once you have created a map, you can export it as a high-quality image, so that you can use it in another program (for example, for making a poster in PowerPoint).

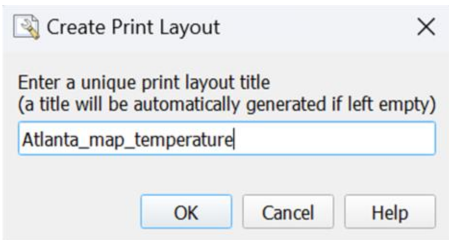
Designing and exporting a map

In QGIS, you can quickly and easily create a map and export it as an image. You can define your own layout by adding important elements to your map, such as a legend, scale, north arrow, etc. Below are the most important steps to create a polished map.

STEP 1

Select your map in the layers panel. Under Project, choose *Layout Manager* > *Create*... You will then see the window below. Give your layout a name (for example, ***Atlanta_map_temperature*** if you want to give a nice finish to the temperature map in the *Atlanta_tracts_temperature* layer) and then click OK.





STEP 2

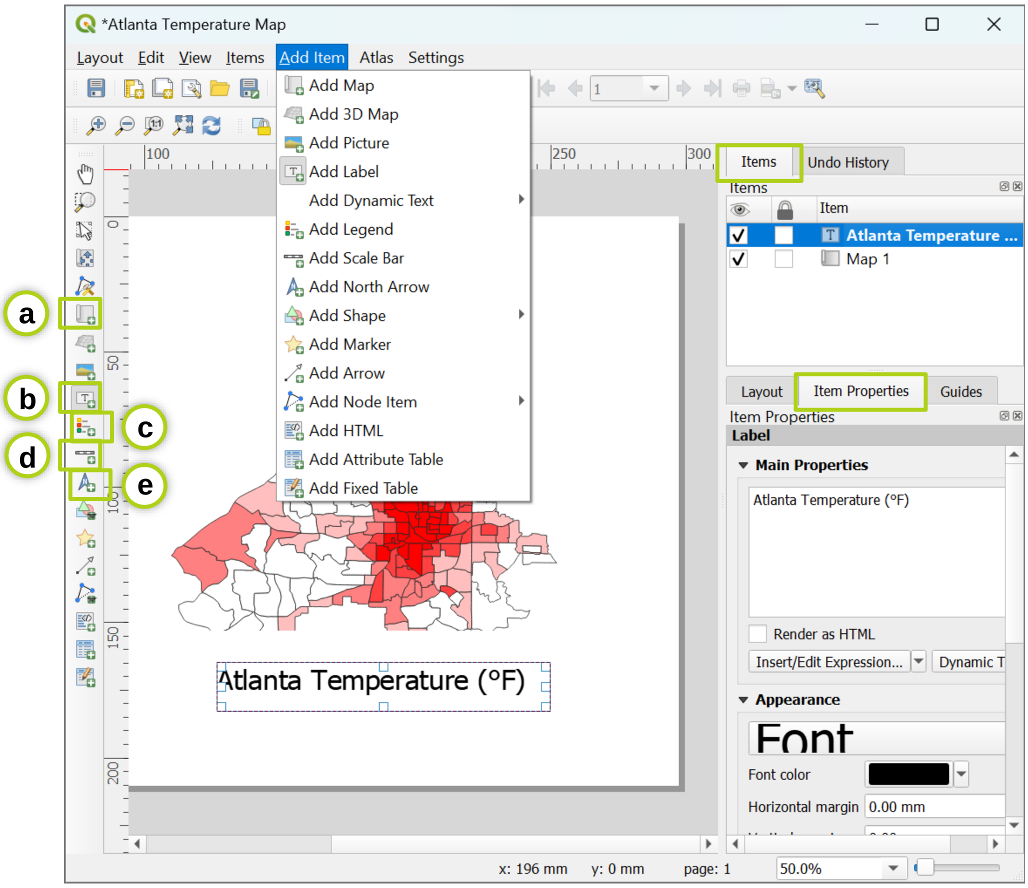
Now you can create a layout by adding elements. You can add elements to the layout either through the "Add Item" menu or by clicking the icons on the left side of the layout window. After clicking on the desired icon, place each map element by drawing a rectangular window in your layout with your cursor (left-click and drag).

You can easily move the rectangles you define for each map element to change your layout, and you can resize them by pulling the bottom right corner of the window. If you want to avoid changing the shape of the rectangles, hold the "*Shift*" key while you expand the window.

Each time you add a new element to the layout, it is listed in the "*Items*" window in the upper right of the layout screen. In the "*Item Properties"* tab below, you can edit different properties of the selected element such as the font, size, color, and names.

Different elements can be added to the layout, some of which are indicated below (see also the image below):

a. Add ***map***. What is shown in your QGIS map window will be placed in your layout window. You can change the map's scale, rotation, and frame in the "Item Properties" window.
b. Add a ***title*** (*label*). This could be *Atlanta Temperature (°F)*, for example. You can change the name under the "*Main Properties*" section and increase the font size under the "*Appearance*" section in the "*Item Properties*" window.
c. Add a ***legend***. The legend will always match the legend in your layers panel in QGIS. When you create the legend, click on the new map layer in the "*Item"* window on the right while its rectangle is selected on the layout. Then, go to the "*Item Properties*" tab for the legend and check "*Only show items that are within the linked map*" at the bottom. This way, only the legend of your chosen map is shown. You can also customize the legend's title and appearance by searching for your legend in "*Items for the legend*", double-clicking the title or any other legend items, and typing the desired text.
d. Add a ***scale***. You can change the style, scalebar unit, and label of the scale in its "*Item Properties*" window.
e. Add a ***north arrow***. You can change the shape, color, and size of the arrow.



STEP 3

Export your map as an image via *Layout > Export as image*. Select your project folder and click Save. You can export the map in different formats. Select .png.

You can also export the attribute table information attached to a map so that you can work with the table in programs such as Excel. You can then do all kinds of operations on your data or create additional graphs.

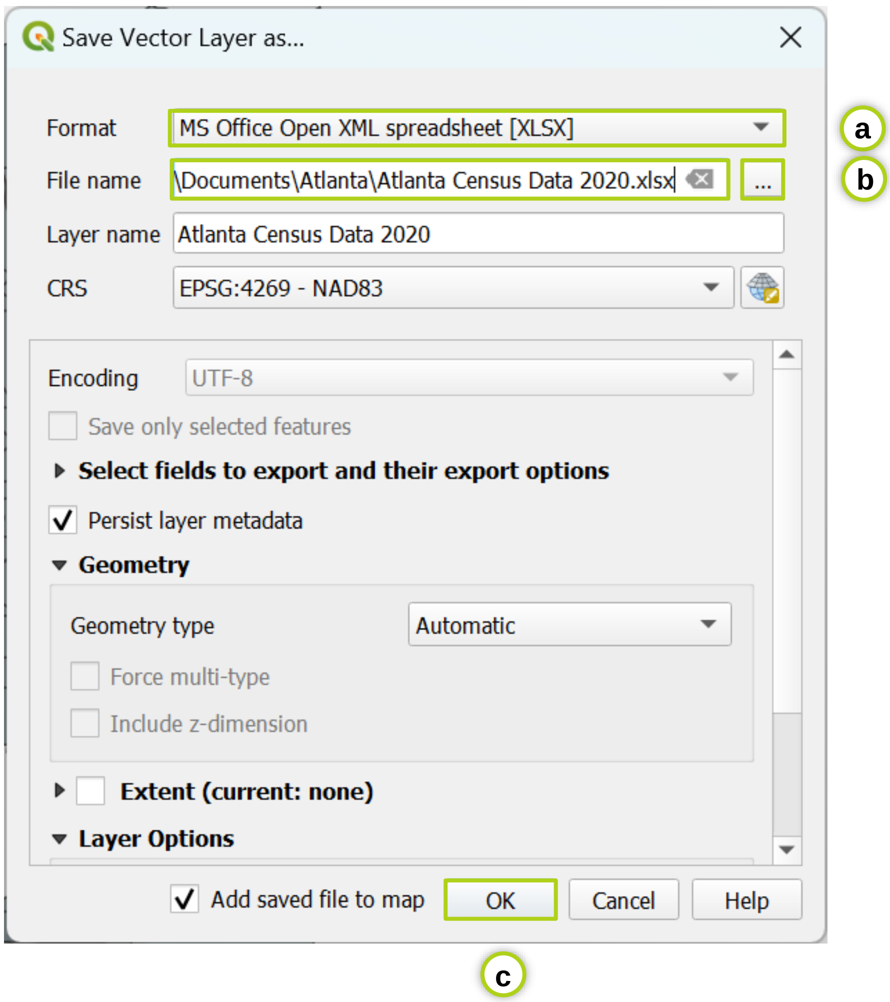
Unleash your creativity as a researcher and try it out.

Export an attribute table to Excel

You can export the attribute table of your map to Excel. This way, you can make all kinds of graphs from the data you have produced. This is done as follows (see also the figure on the following page):

- Right-click your map layer in the layers panel.
- Select Export > *Save Features as…*
    a) Select as format "MS Office Open XML spreadsheet [XLSX]"
    b) Select your project folder (***Atlanta***) and choose a name for the file in which you will save your exported table. For example, to export the attribute table of the ***Atlanta*** vector layer, choose a file name like "***Atlanta Census Data 2020***".
    c) Click "OK".

If you're new to making charts in Excel, look for YouTube tutorials that demonstrate how to use Excel to make visually appealing charts. For example, search YouTube for "create graphs in Excel" and you will find numerous videos to help you create all kinds of graphs. You will be able to find a tutorial for any type of graph you want to make. Go explore for yourself.


Save Vector Layer as...
Format
MS Office Open XML spreadsheet [XLSX]
File name
\Documents\Atlanta\Atlanta Census Data 2020.xlsx
...
Layer name
Atlanta Census Data 2020
CRS
EPSG:4269 - NAD83
Encoding
UTF-8
Save only selected features
Select fields to export and their export options
Persist layer metadata
Geometry
Geometry type
Automatic
Force multi-type
Include z-dimension
Extent (current: none)
Layer Options
Add saved file to map
OK
Cancel
Help
a
b
c