GIS and **QGIS** Software: An Introduction

Training Guide
November 2020

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BACKGROUND

This tutorial was originally created by REACH. REACH is a joint initiative of two international non-governmental organizations – ACTED and IMPACT Initiatives = and the UN Operational Satellite Applications Programme (UNOSAT). REACH's mission is to strengthen evidence-based decision making by aid actors through efficient data collection, management and analysis before, during and after an emergency. For more information please visit www.reach-initiative.org.

The U.S. Department of State's MapGive initiative updated this tutorial for QGIS version 3 and made a few modifications. For more information on the MapGive initiative please visit www.mapgive.state.gov.

QGIS RESOURCES

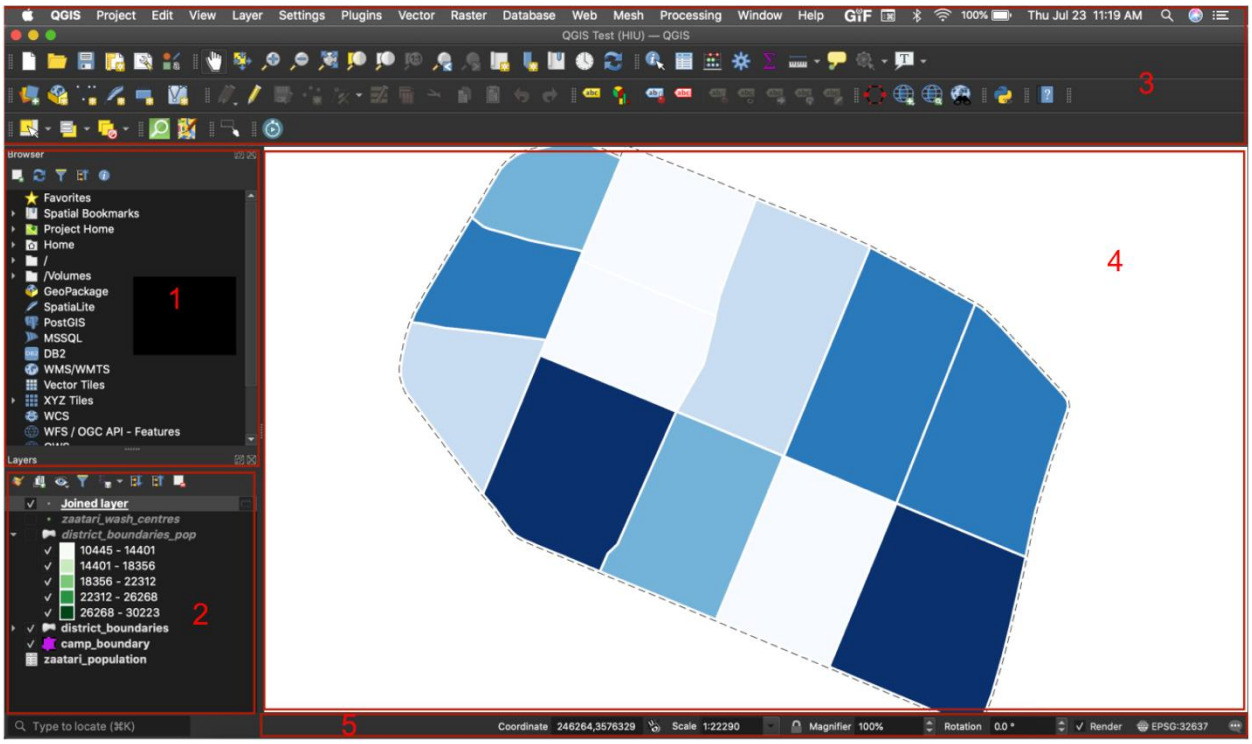
The following links are for useful online resources for QGIS, in addition to links that provide more detail on the subjects covered in this training.

- Software download: **https://www.qgis.org/en/site/forusers/download.html**
- Overall documentation of the software: **https://docs.qgis.org/3.16/en/docs/**
- Joins:
    - **Spatial:** **http://www.qgistutorials.com/en/docs/3/performing_spatial_joins.html**
    - **Attribute:** **http://www.qgistutorials.com/en/docs/3/performing_table_joins.html**

INTRODUCTION TO QGIS AND GIS DATA

Data necessary to complete this tutorial can be located here on Github: https://github.com/state-hiu/virtual-mapgive-course/tree/master/activity_5_QGIS_tutorial

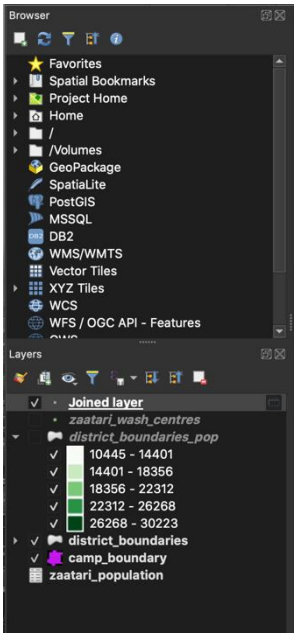
Understanding the QGIS software



The elements identified in the figure above are:

1. Layers List/ Browser Panel
2. Browse Panel
3. Tool Bar
4. Map Canvas
5. Status Bar

(Note that the “side toolbar” found in QGIS ver 2 is now contained within the tool bar, under “Open Data Source Manager button”)

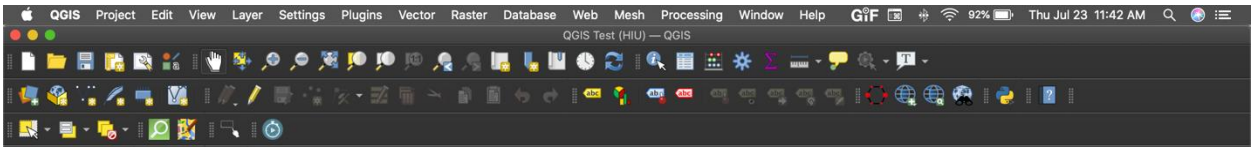


1/2: Layers panel, Browser panel

In this view you see the Browser panel on top of the Layers panel, although they can be rearranged. The Browser panel lets you easily view the files located on your computer, in this case navigate to the where your tutorial data is saved. Then you can easily drag and drop the files as needed to the Layers panel.

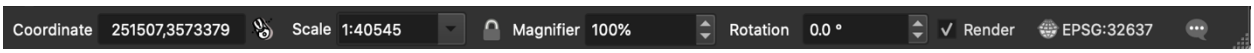
The Layers panel is very important to understand in order to view and edit the map. When you have many layers in the panel you will see them listed in the in the order they appear on the map. You can move them up and down and access the layer properties as well by right-clicking on them. Expanding collapsed items (by clicking the arrow or plus symbol beside them) will provide you with more information on the layer's current appearance.

3: The Toolbar



This is the primary toolbar in the software that will allow you to perform basic functions such as saving, opening files, panning and zooming around the map, editing and viewing layer properties, opening the attribute table, field calculator, and many others. You can easily customize the interface to see only the tools you use most often, adding or removing toolbars as necessary via the **View > Toolbars** menu.

5: Status Bar



This area, located on the bottom right of your workspace, details key features of the map you are currently working with. You see the coordinates, map scale, and the rotation of the map (e.g. 0.0 above means the map is pointing directly to the north).

About GIS Data

There are two primary forms of GIS data: vector and raster.

Vector data: vector data is a representation of the world using **points, lines, and polygons**. Vector data is useful for storing data that has discrete boundaries, such as country borders, land parcels, and streets.

- **Points:** vector data that is stored as a single point with a discrete GPS coordinate (example: a vector data set of cities is typically a point data set)
- **Lines:** vector data that is stored as lines (example: roads)
- **Polygons:** vector data that is stored as an area (example: the boundary and area of a country)

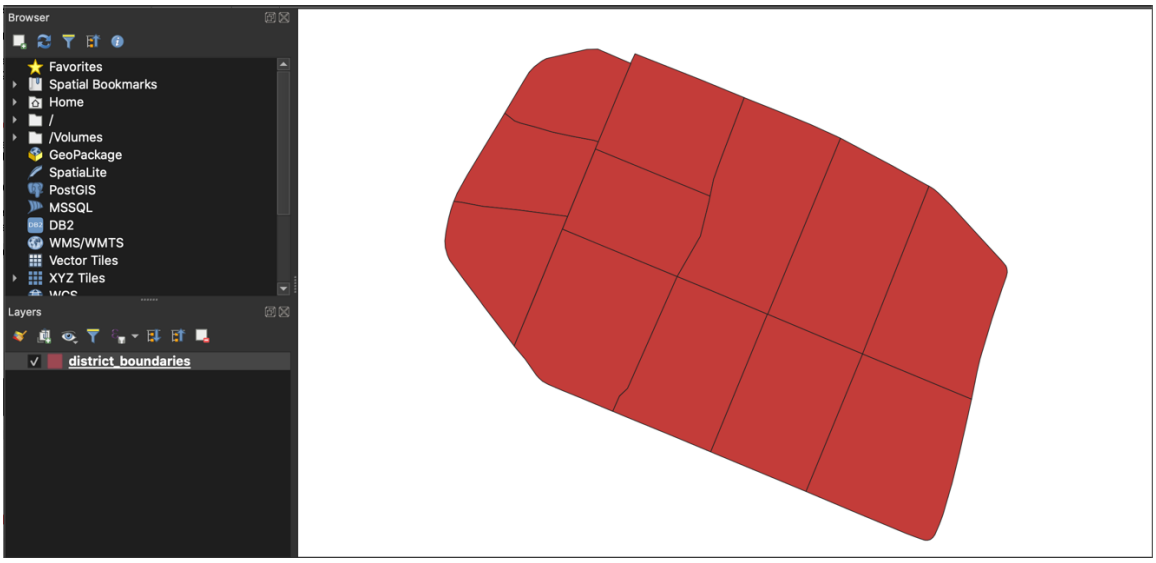
Raster data: raster data is a representation of the world as a surface divided into a regular grid of cells. Raster data is useful for storing data that varies continuously, as an aerial photograph, a satellite image, a surface of land types (urban, rural, forest, etc), or an elevation surface.

Adding GIS data to QGIS

Within the toolbar above the Browser and Layers panels, there are various buttons that allow you to add and manipulate features. The most important is “open data source” button, which allows you to **add vector** and **add raster** layers. These are the two primary types of data used in GIS.

Step 1: Select the **Open Data Source** button 
Step 2: Select **Add Vector**
Step 3: Select Browse, to the right of Vector Dataset(s)
Step 4: locate the files called district_boundaries.shp in your tutorial data folder. Make sure the encoding is set at “UTF-8” which allows for Arabic data as well. Click **Add** in the bottom right corner

You now have a basic map showing the data of Za’atari Refugee Camp’s 12 districts. See screenshot below.

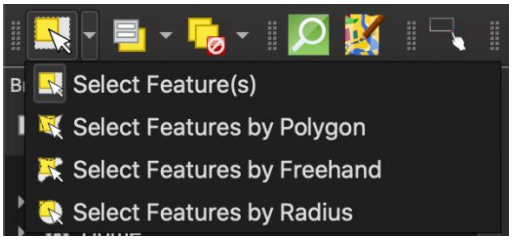


Panning, zooming, and selecting data

Now that you've added a data set to your map, you should become more familiar with some basic functions of the map canvas.

- Select the **Pan Map** button to move around the map canvas. **Note:** if you're using a mouse you can also click the wheel of the mouse and drag to pan on the map.
- There are various ways to zoom, the mouse wheel being the easiest method for zooming. However, you can also zoom to specific features or areas of the map.

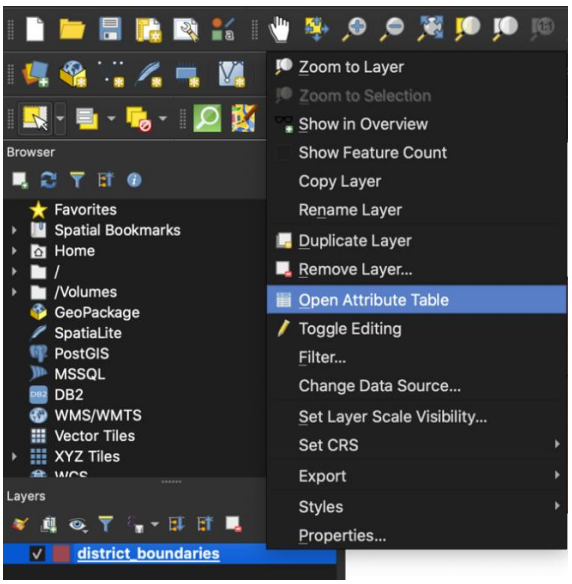
  The **Zoom to Layer** button is a very easy way to quickly zoom to an area of interest, right click the layer highlighted in the map canvas, zoom to layer will automatically zoom to this layer. The **Zoom to Selection** button will allow you to zoom to features that you've selected using the selection tool (see below).
- To select features for editing and analysis, you can use the **Select features** tool which allows for selecting items of interest on the map and exploring their attributes in the attribute table. You can select by clicking a feature, select features by drawing a polygon, or various other ways (see screenshot below).



Attributes of GIS

Explore the attributes (i.e. data table) of the GIS data file to understand the information it includes. The attribute table is very important to allow you to visualize the data in a certain way, perform basic analysis, and link the GIS data to external data sources like a table in Microsoft Excel or a CSV. At a basic level, the data you see is not only

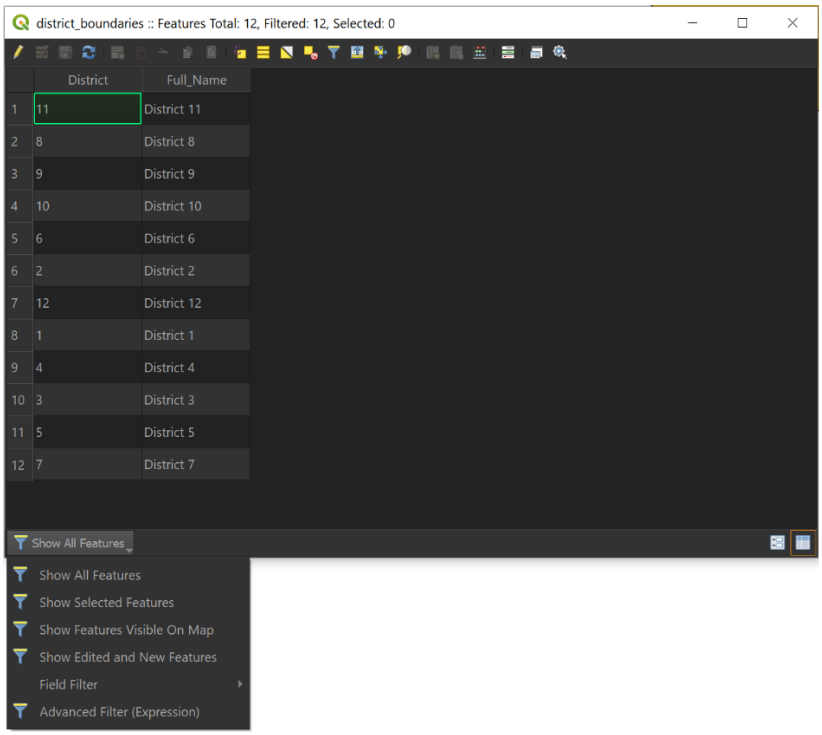
represented in terms of “where,” but also the “what.” You can see it on the map and also view the raw information behind what you see.



Step 1: In the layers panel on the right, right-click the district_boundaries layer and select “open attribute table”.

Another way to open the attribute table is to select the  button on the toolbar (this will open the table for the layer that is currently highlighted in your layers panel).

Step 2: Explore the attribute table (see screenshot below) as you can view the features in many ways. The highlighted buttons allow you to change between viewing the whole table and viewing the features one at a time to see all the characteristics. “Show all Features” is a dropdown button allowing you to view the various attributes in specific ways, like only the “selected” attributes.



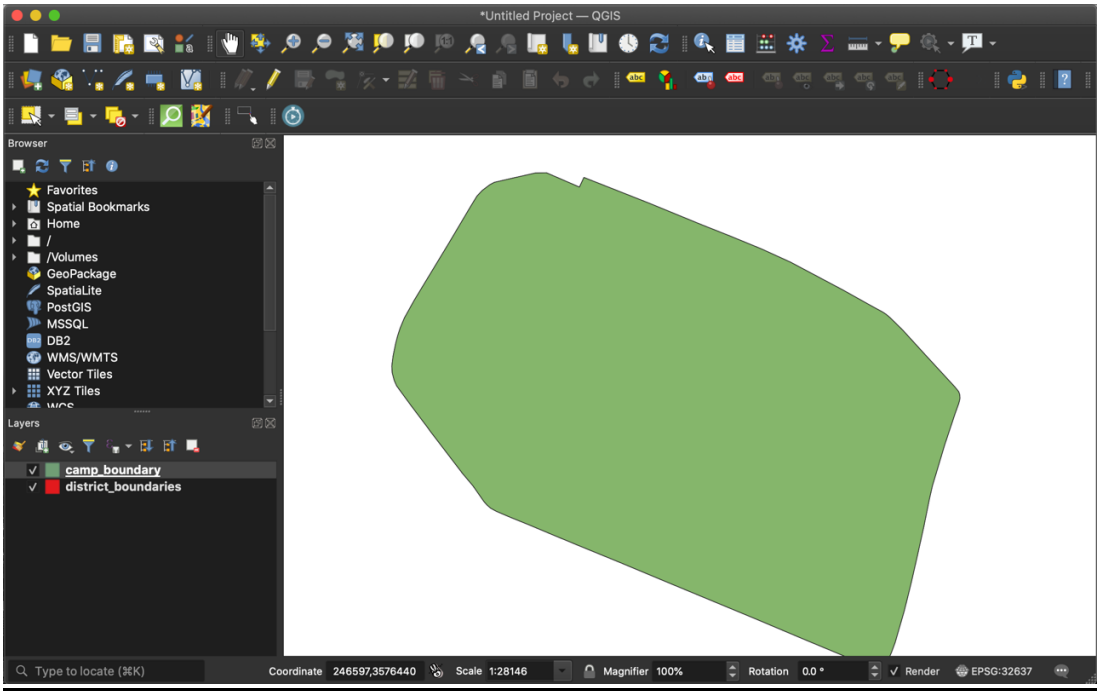
Step 3: Select one of the numbers on the left hand-side of the attribute table to select one of the items in the GIS data set, you will see it light up in yellow on the map.

VISUALIZING AND ANALYZING DATA

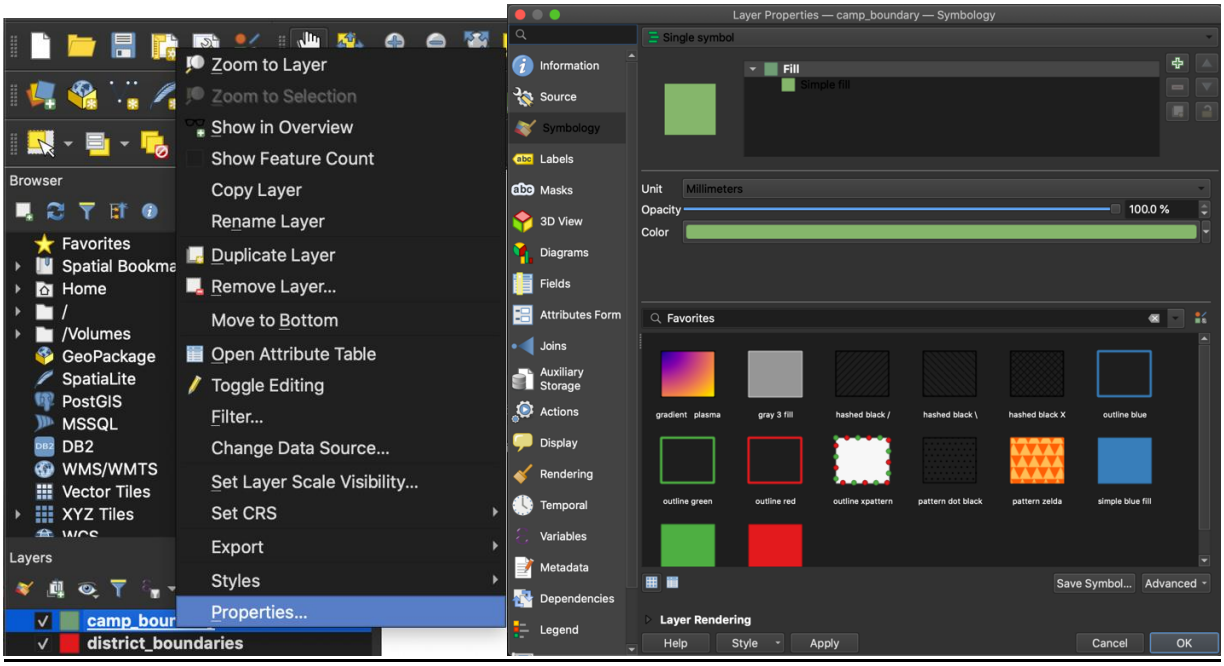
Layer symbology

All data in QGIS will have to be visualized in a certain way, this is referred to as **symbology**. The symbology of a layer is its visual appearance on the map. The basic strength of GIS over other ways of representing data with spatial aspects is that with GIS, you have a dynamic visual representation of the data you're working with.

Step 1: Navigate to the **Open Data Source** button and select Vector, browse and add the camp_boundary.shp file to the workspace. This layer will appear on top of the districts and you will no longer see the district boundaries.



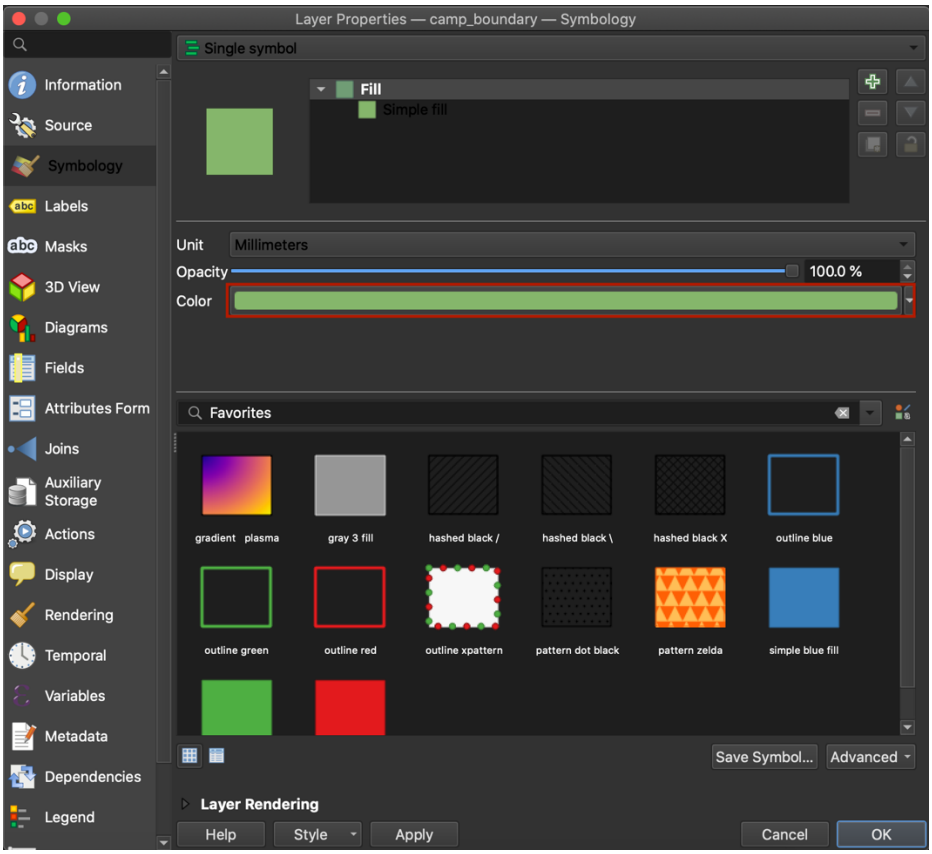
Step 2: Right click on the camp_boundary layer in the layers list and select the menu item Properties. Then select symbology. **Note:** You can also access the layer properties by double clicking the layer in the list.

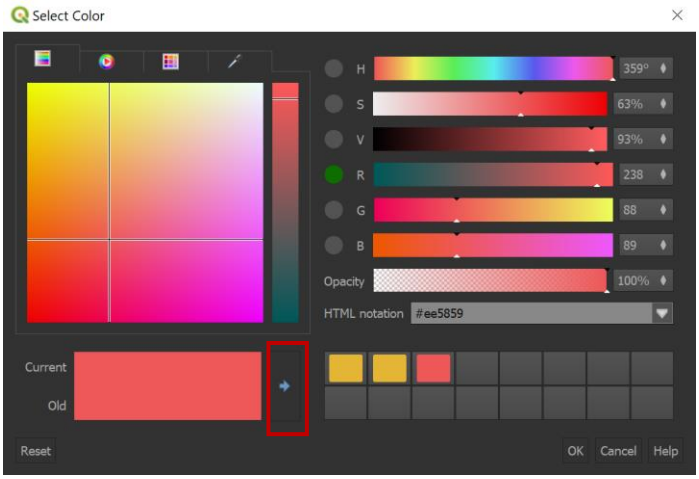


The layer properties dialog (screenshot above right) gives you many options for viewing and changing settings and information for the data layer. Under the **Style** tab you can change the colors and symbology for the layer.

Step 3: Click the color box (green) to view a color selector window to view the **Select Color** window which will allow you to change the fill of the polygon feature. You can move the black arrows below each color bar or enter numeric values (RGB) to make the color specific to a value you need (i.e. standard REACH red, UNHCR blue, etc.)

Note: you can also select the small black arrow in the style properties dialog which will allow you to select a recent color or standard colors.



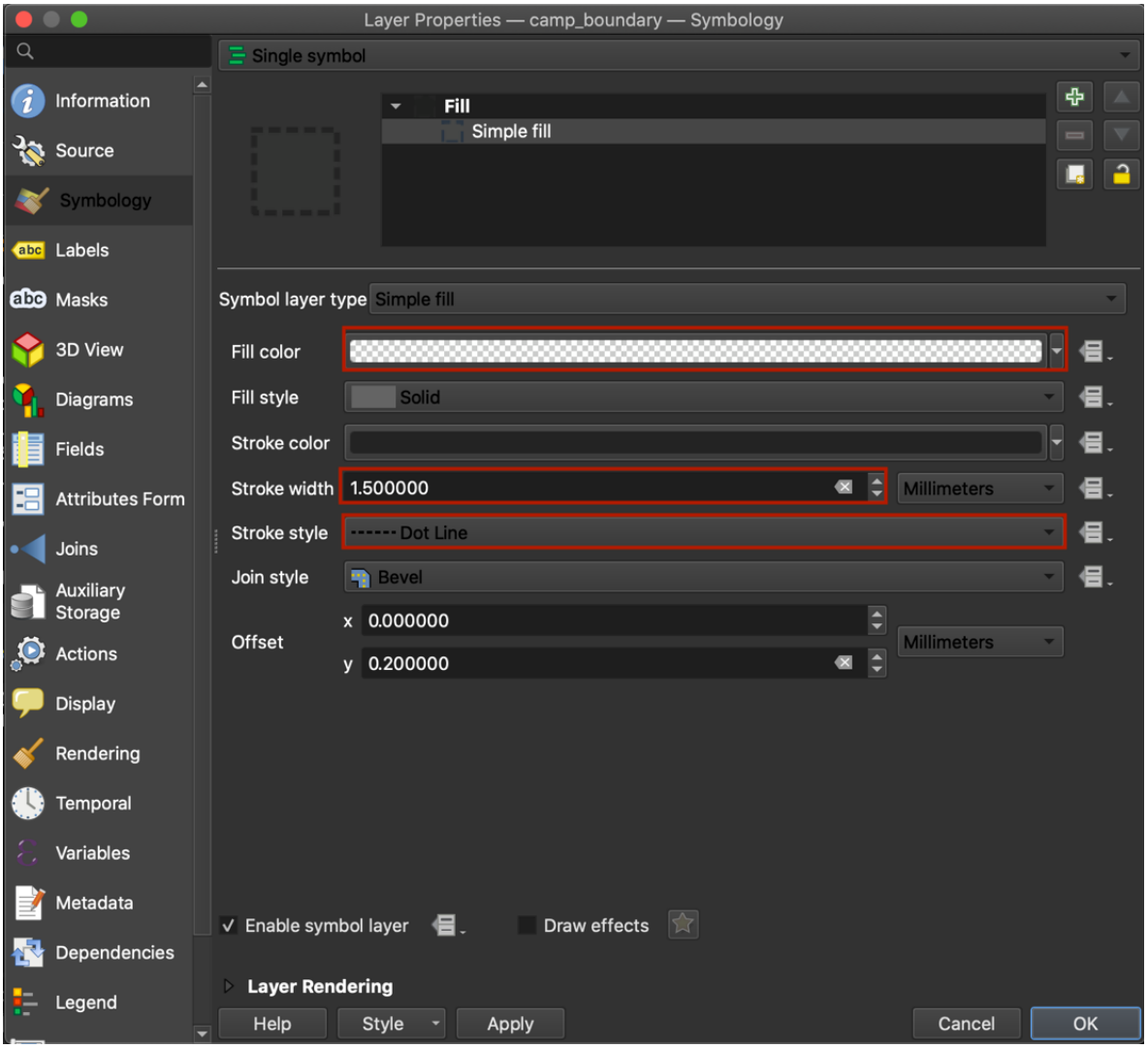


Step 4:

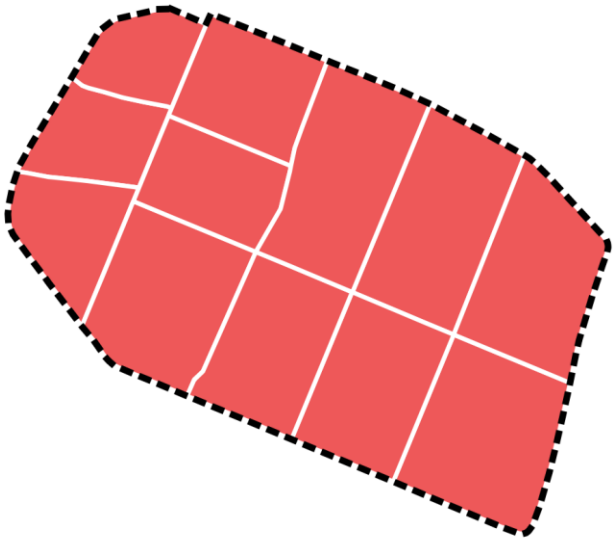
- In the Symbology window, select the **Simple fill** icon in the text space to the left and notice that the information changes. This will allow you to change the border of the area as well as the fill
- For the **Fill**, select the arrow to the right of the color box and select “transparent fill” to make the fill empty.
- For **Stroke**, select the arrow to the right and select black under standard colors.
- For **Stroke Style**, selected *Dot Line*

- Then, for **Stroke Width**, change this to 1.5.

You will then see the map change to have a black border for Za'atari, and you will then see the district boundaries again.



`Repeat this exercise for the district_boundaries ***layer, but make the polygons have a red fill (Red 238, Green 88, and Blue 89) and a white stroke with a stroke width of 1. Your result should look like the screenshot below.***



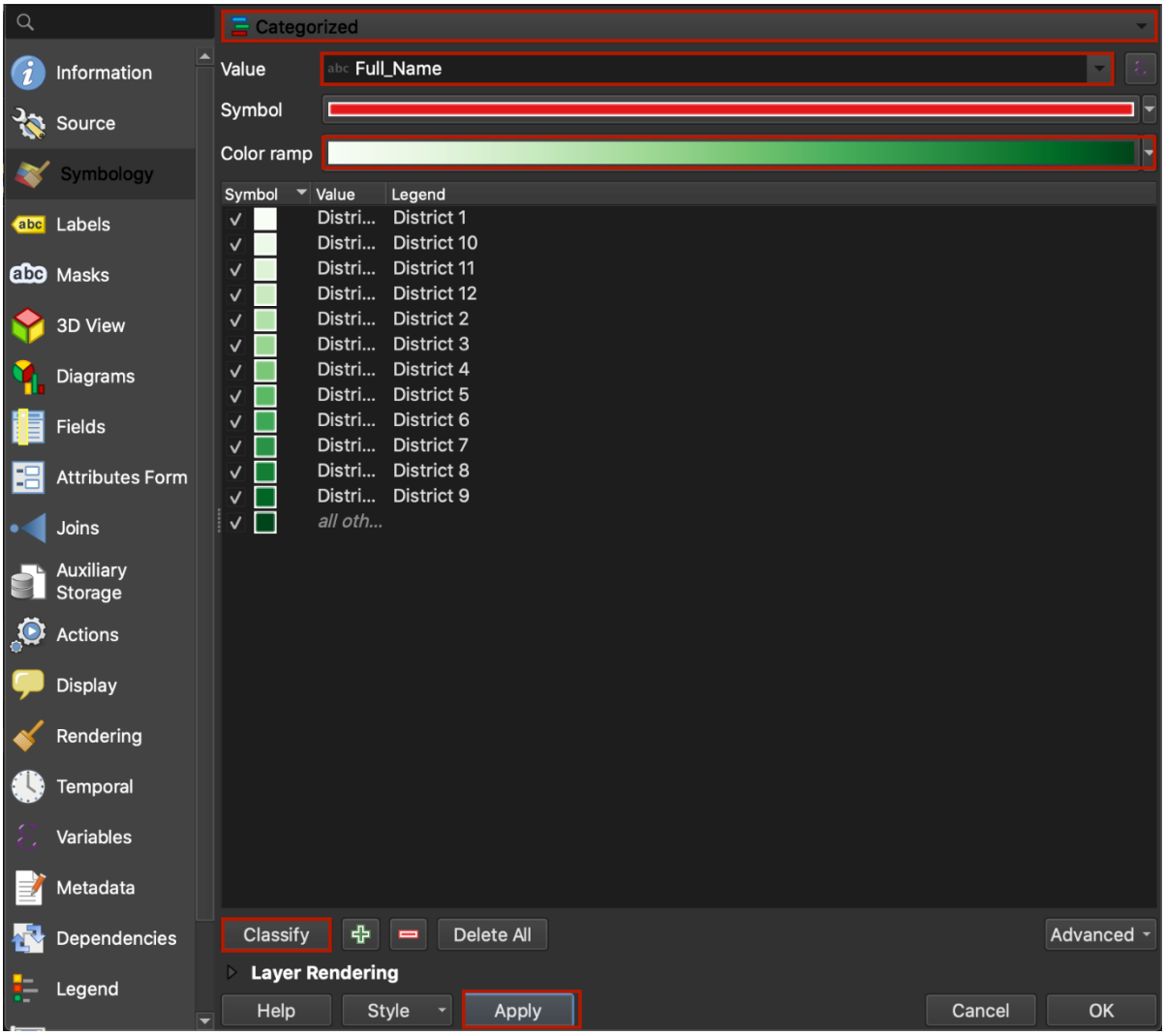
Now we'll edit the colors of the districts again to make them different along a specific color scale (i.e. light blue to dark blue, light green to dark green).

Step 1: Double click the district_boundaries layer in the list and go to the style tab again. In the top left, click the black arrow next to **Single Symbol** and select **Categorized**

Step 2: just below next to "Value," click the black arrow to the right and select "Full_name" as the column in the attribute table used to represent the colors.

Step 3: Select the arrow to the right next to "Color ramp" and find "Greens"

Step 4: Click the **Classify** button below the white area to then have all the districts (features) show up on the list along the color scale. Close the window by selecting **Apply** at the bottom right.


Information
Source
Symbology
Labels
Masks
3D View
Diagrams
Fields
Attributes Form
Joins
Auxiliary Storage
Actions
Display
Rendering
Temporal
Variables
Metadata
Dependencies
Legend
Categorized
Value
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Color ramp
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Distri... District 1
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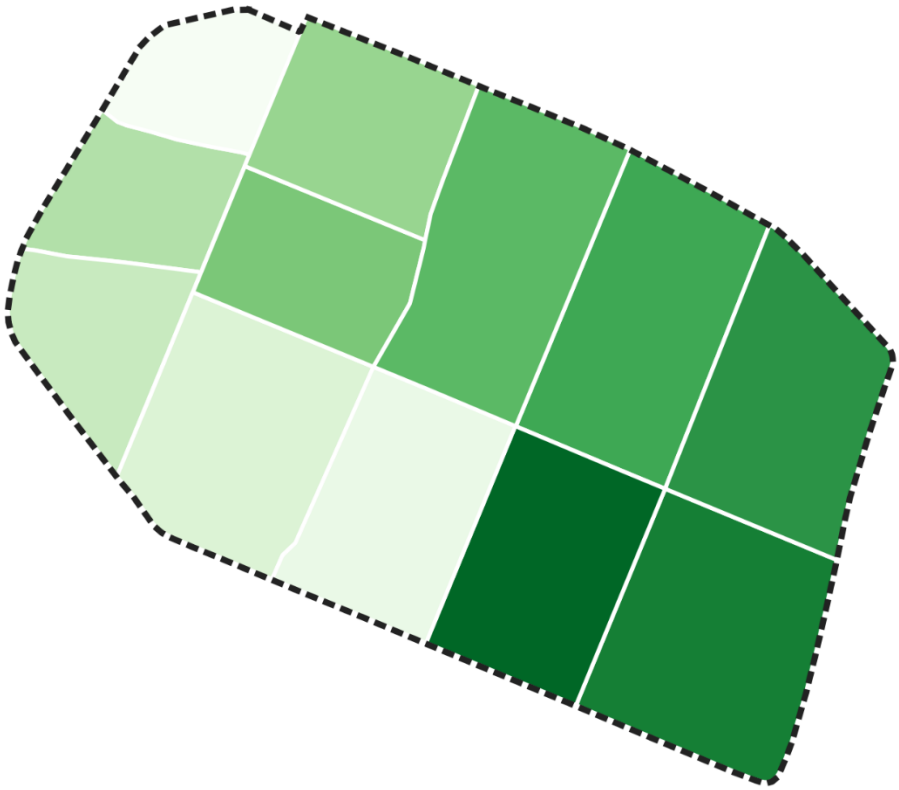
Distri... District 6
Distri... District 7
Distri... District 8
Distri... District 9
all oth...
Classify
Delete All
Advanced
Layer Rendering
Help
Style
Apply
Cancel
OK



Labelling

Step 1: Open the properties window to the layer again and select “Labels” on the left side

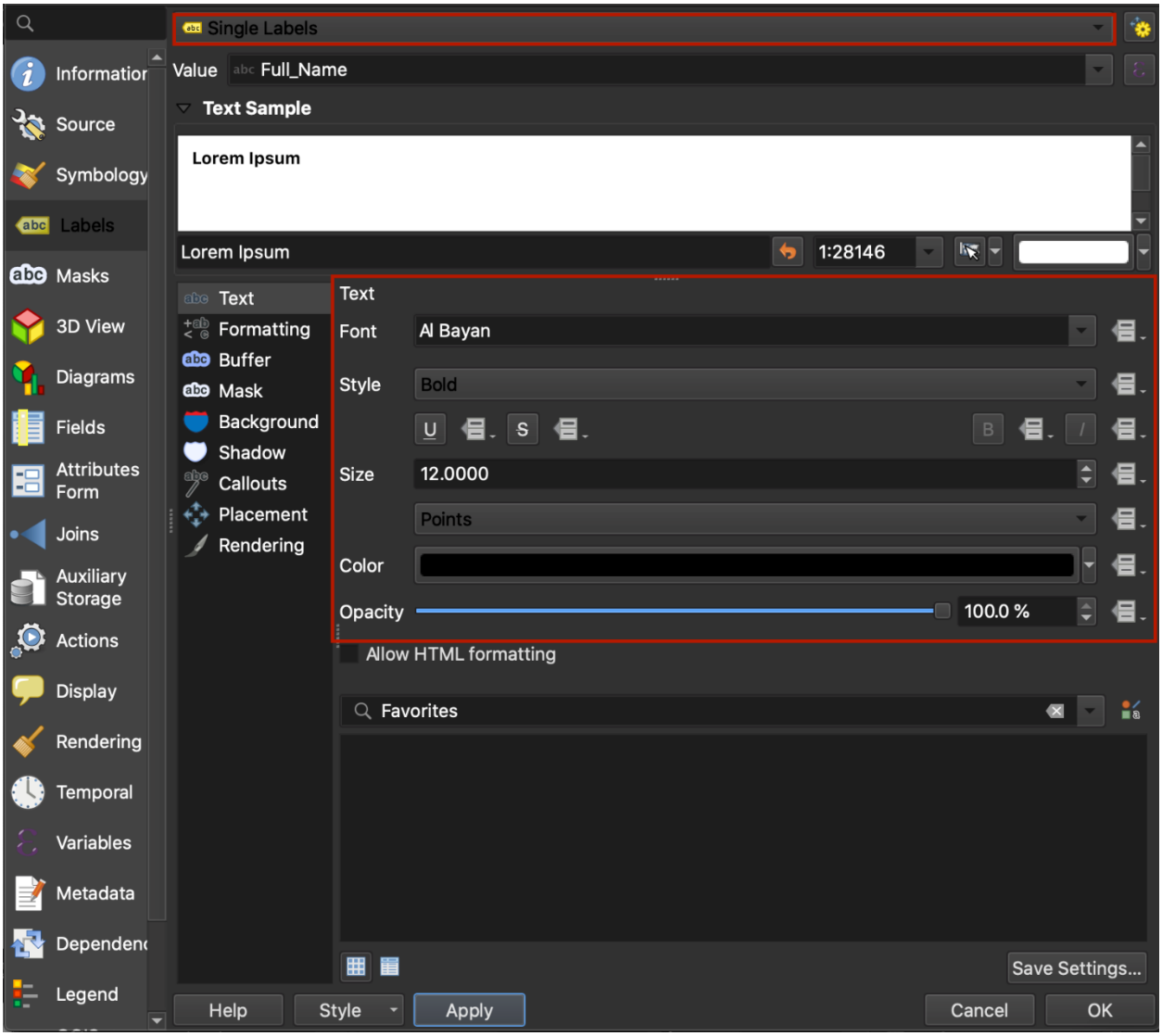
Step 2: At the top, click “No labels” and change to “Single Labels”

Step 3: Next to “Value” click the black arrow and select **Full_Name** as this is the field in the attribute table you will use to label each feature.

Step 4: Change the font type, size, and color to the below.

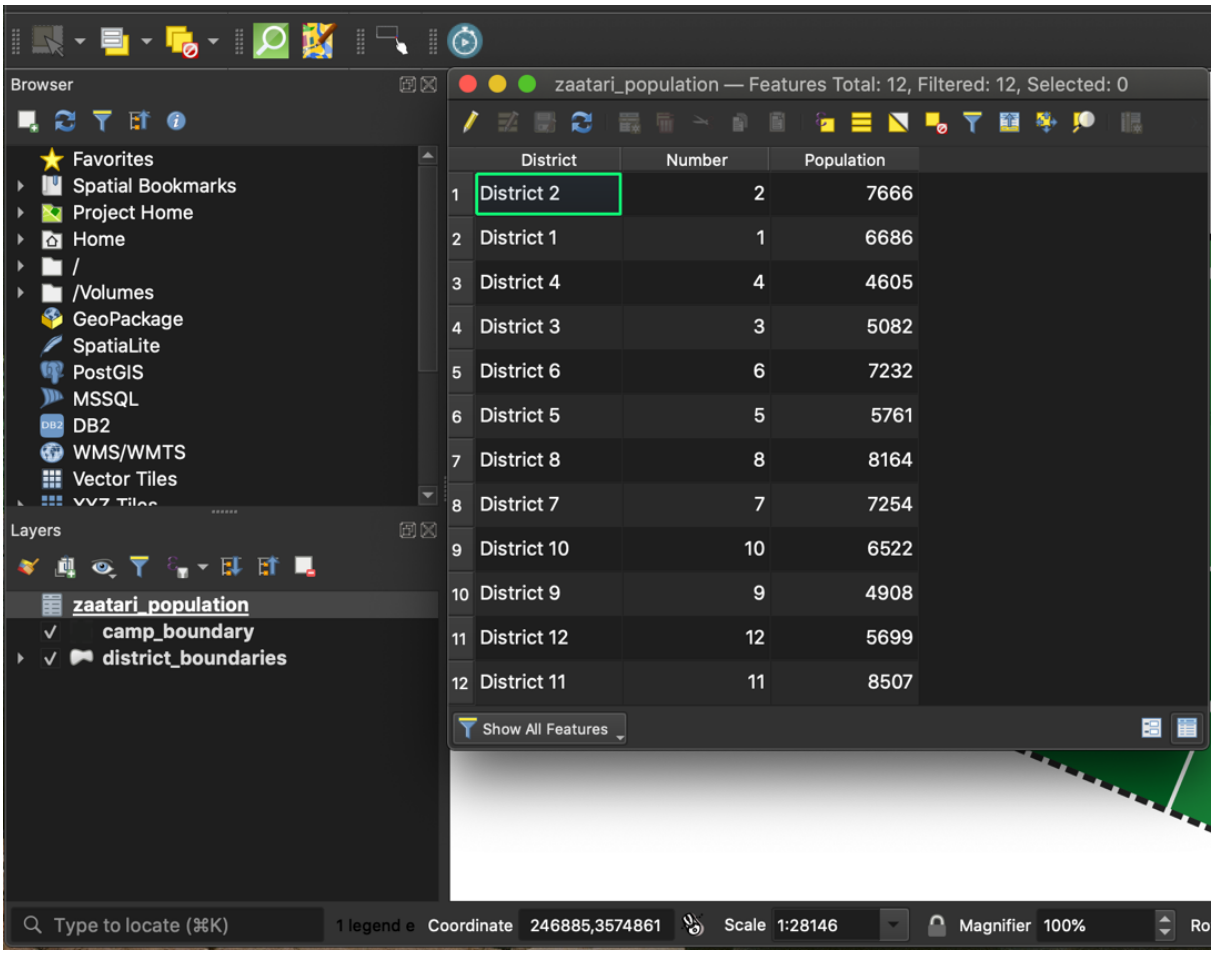
Step 5: Select “Buffer” to the left of the Text Style area, and add a white buffer to the text label to make it more clear

Select OK or Apply and you should see the district labels appear on the map.



Conducting an Attribute Join

At the moment the map is symbolized and labelled with simply one data set, the district boundaries and their names. Now we will add some additional data to the workspace and link this data to the district boundaries to then have more information associated with the districts. This process is called an *attribute join.*

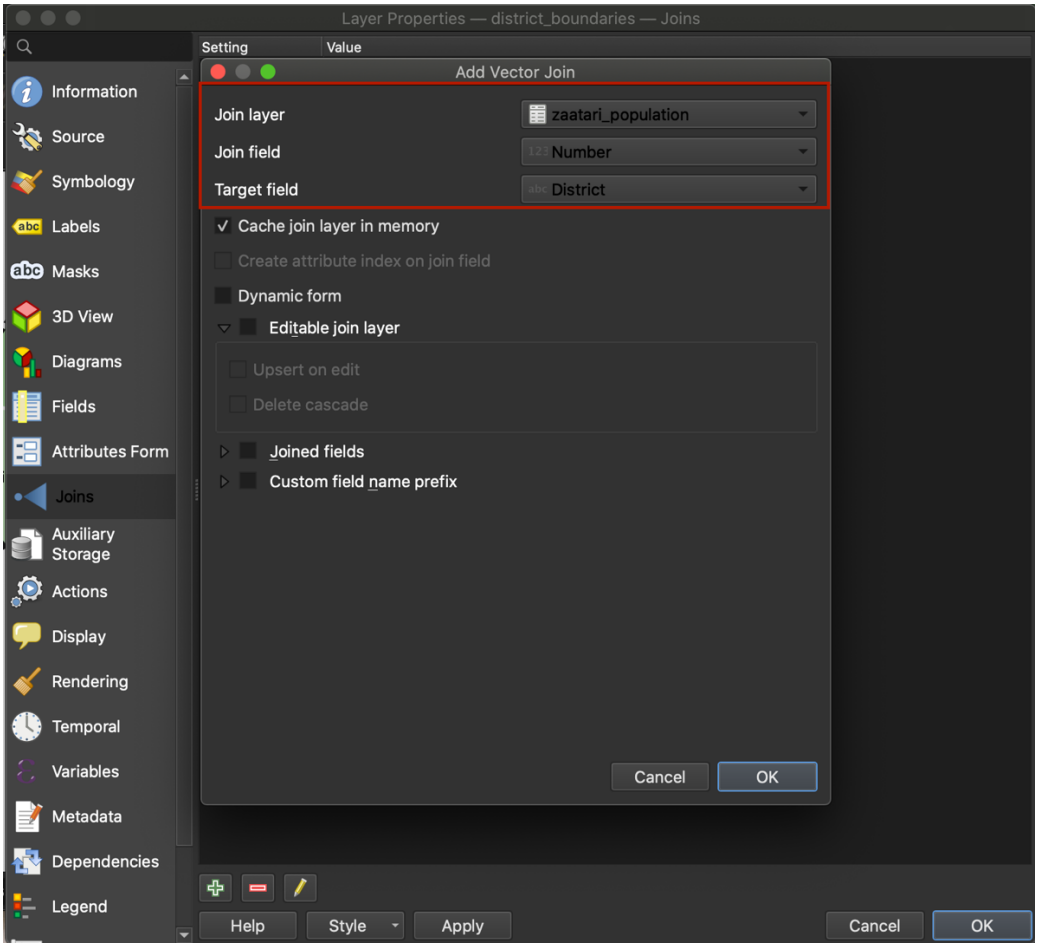


Step 1: In the browser panel, click and drag the XLS file named *zaatari_population.xlsx* from the folder for the data to the layers panel. **OR** select the “Data Source Manager” button again and “add vector” from the browse function

Step 2: Open the attribute table for *zaatari_population* and notice that it has a “population” field in the table with numeric values that represent the population of each district based on the **REACH population count from January 2015**.

Step 3: Open the properties box for the *district_boundaries* layer and select “Joins” on the left-hand side. Then select the green plus (+) symbol in the bottom left—this is the “add new join” function.

Step 4: In the “Add vector join” window, select *zaatari_population* as the “join layer”, **Number** as the “Join Field”, and **District** as the “Target Field”. The join layer is the layer / table you want to link to the current layer, the join field is the field from the join layer that you want to join with, and the target field is the matching field from the other layer.



Now you've joined the population data to the boundary data, now we're going to visualize the camp by population by district.

Creating Thematic Maps

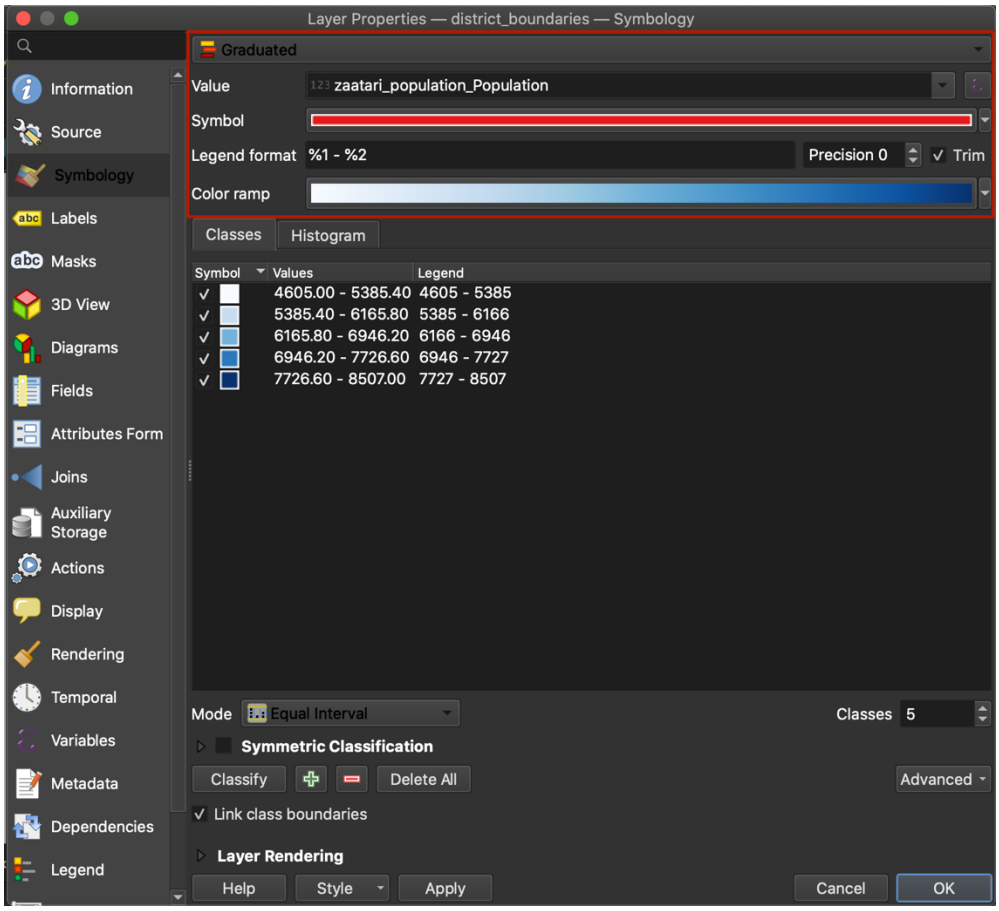
Step 1: Open the properties window to the district_boundaries layer. Again, under the Symbology tab, change the type of symbology to **Graduated** at the top of the window. Graduated means changing colors based on certain values, in this case it will be the population of each district.

Step 2: Select the Column to be *zaatari_population_Population* (this is the field in the attribute table that was joined to the boundaries layer. This means that you are using the population field as the value for each color.

Step 3: Change the Color ramp to **Blues**

Step 4: Keep the Mode at "Equal Interval" which means that the numerical space between each class is the same (e.g. a space of 10 between each). Keep the classes at 5 (number of categories) and click **Classify** to the right to have all the classes show up. Click classify again to make the decimals disappear for the legend labels.

Click OK / Apply, you now have Za'atari visualized by total population per district!



Using the Field Calculator

The field calculator is a very important tool that allows you to edit the attribute table of shapefiles. This is useful in many ways, such as conducting analysis directly within the GIS workspace, or creating and editing new fields based off of existing data.

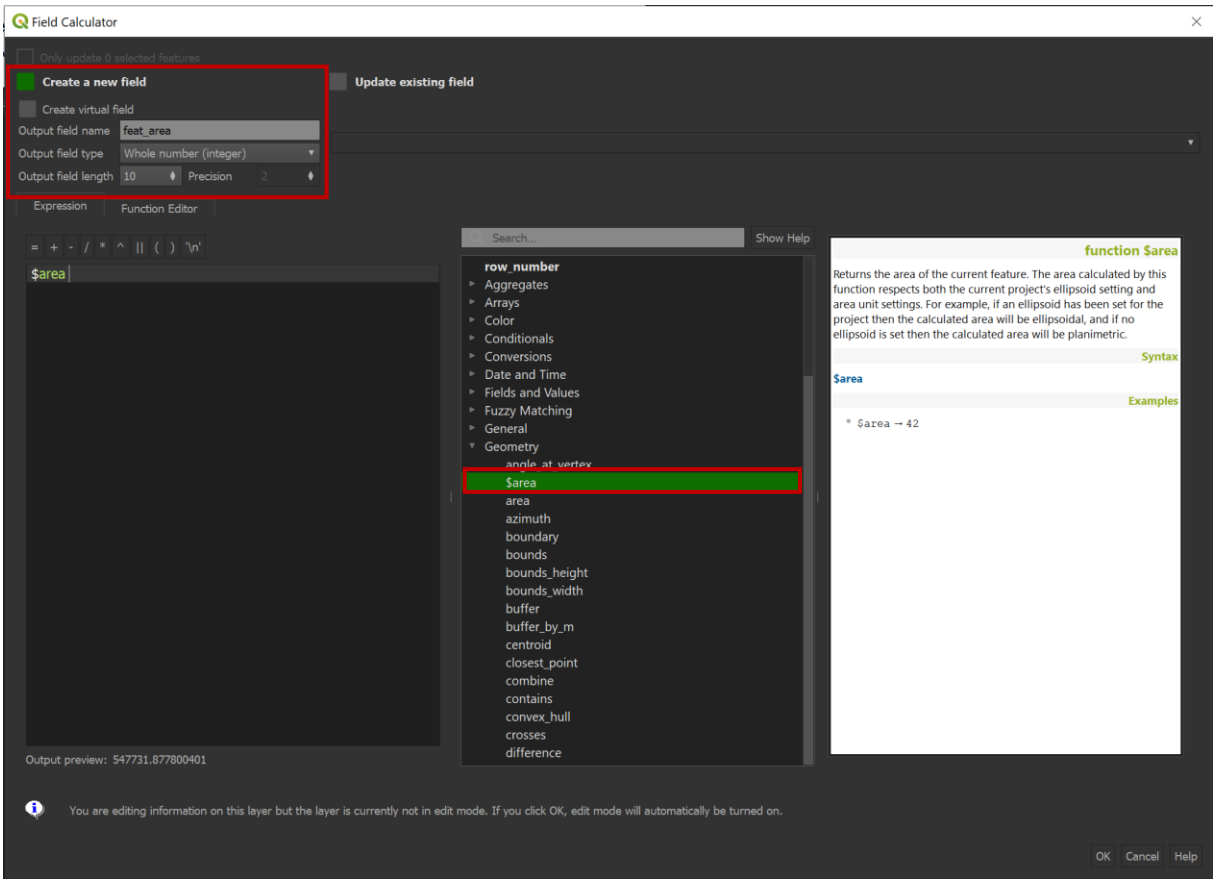
After the last step, you have a district_boundaries shapefile with the population per district. Now we're going to calculate the population density of each district through a few steps in the field calculator. The field calculator makes calculations in the units of your map projection. Verify that your district_boundaries file is in the WGS_1984_UTM_Zone_37N projection and has meters as units. The district_boundaries file has a .prj file that defines the projection, so the correct projection should automatically be set.

Step 1: Right click on the *district_boundaries layer* and open the attribute table;

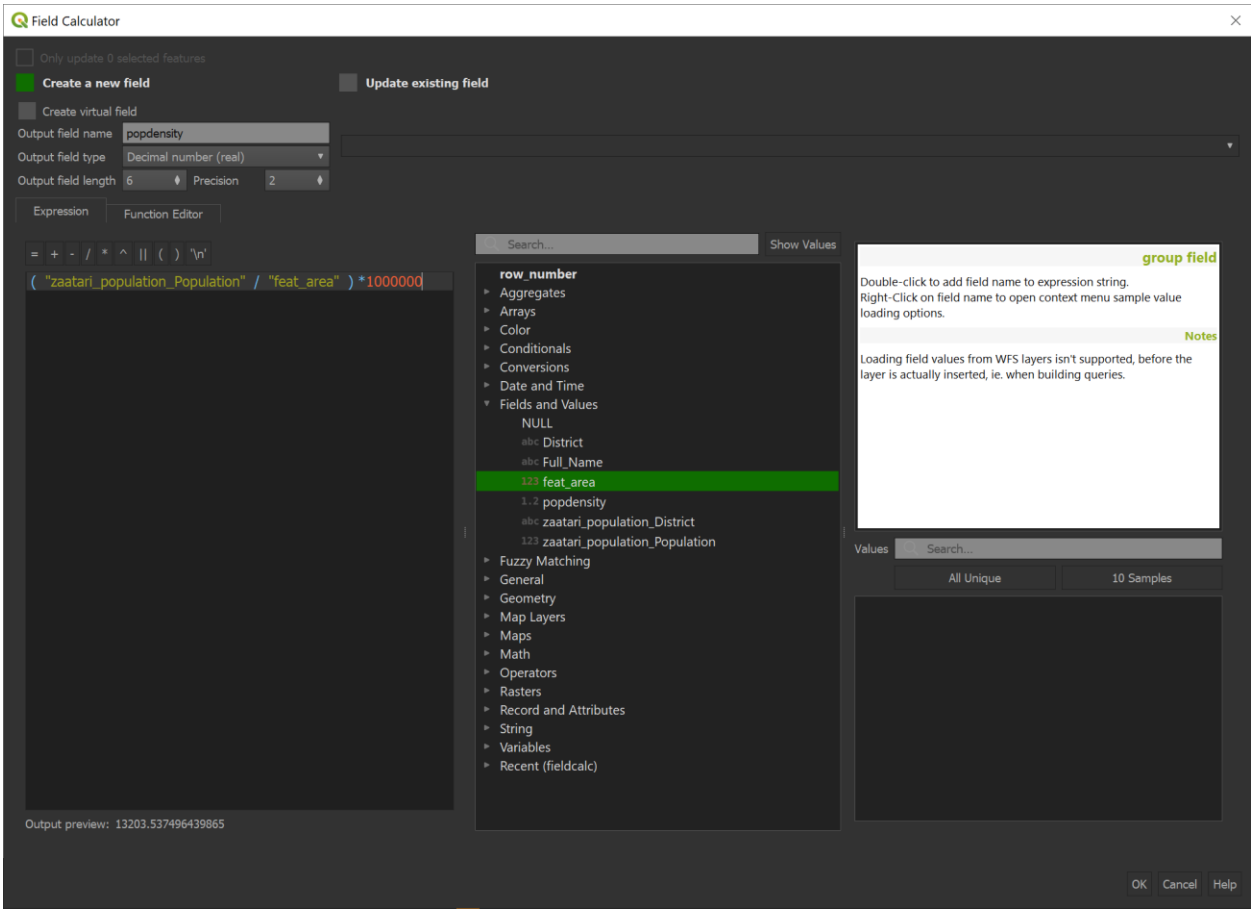
Step 2: Click on the "Open Field Calculator" button  to open the window in the below screenshot;

Step 3: Select the box to **Create a new field**, type “feat_area” under the **Output field name**, select “Decimal number (real)” for the **Field type**, and change the precision to 2 (to allow for decimal points);

Step 4: Then, in the list below the search bar, under the **Geometry** section, double click **$area** to make it appear in the expressions window, then select OK.



Now that you have a field for the district size (in square meters), use the field calculator again to create a new field named “popdensity”, with the decimal field type, precision 2. Create a new field of population density (# of people per square kilometer). Hint: you can do this by selecting the field for population and under “Fields and Values” in the field calculator. You need to put brackets () around the formula before multiplying by 1,000,000 to make the result people per square kilometer instead of square meters. Ex. (population / $area) * 1,000,000



Step 5: Export the current *district_boundaries* file to a new, standalone shapefile (right click > “Save as”). Save the layer as an **ESRI shapefile** with the projection system WGS 84 / UTM Zone 37N, and name it *district_boundaries_pop*.

Step 6: Repeat steps 1-4 under “Create thematic maps” for this new layer file to visualize population density in the camp in comparison with the population layer. Make sure to change the symbology to white borders with outline thickness = 1. You can then view this layer over the population layer and see the difference.

Important and visualizing an external table with GPS data

Sometimes you have a spreadsheet with GPS coordinates of important features. Using QGIS it is simple to create a GIS file for a map using the spreadsheet. It is important to note that you need to have the spreadsheet in CSV format to easily incorporate to QGIS.

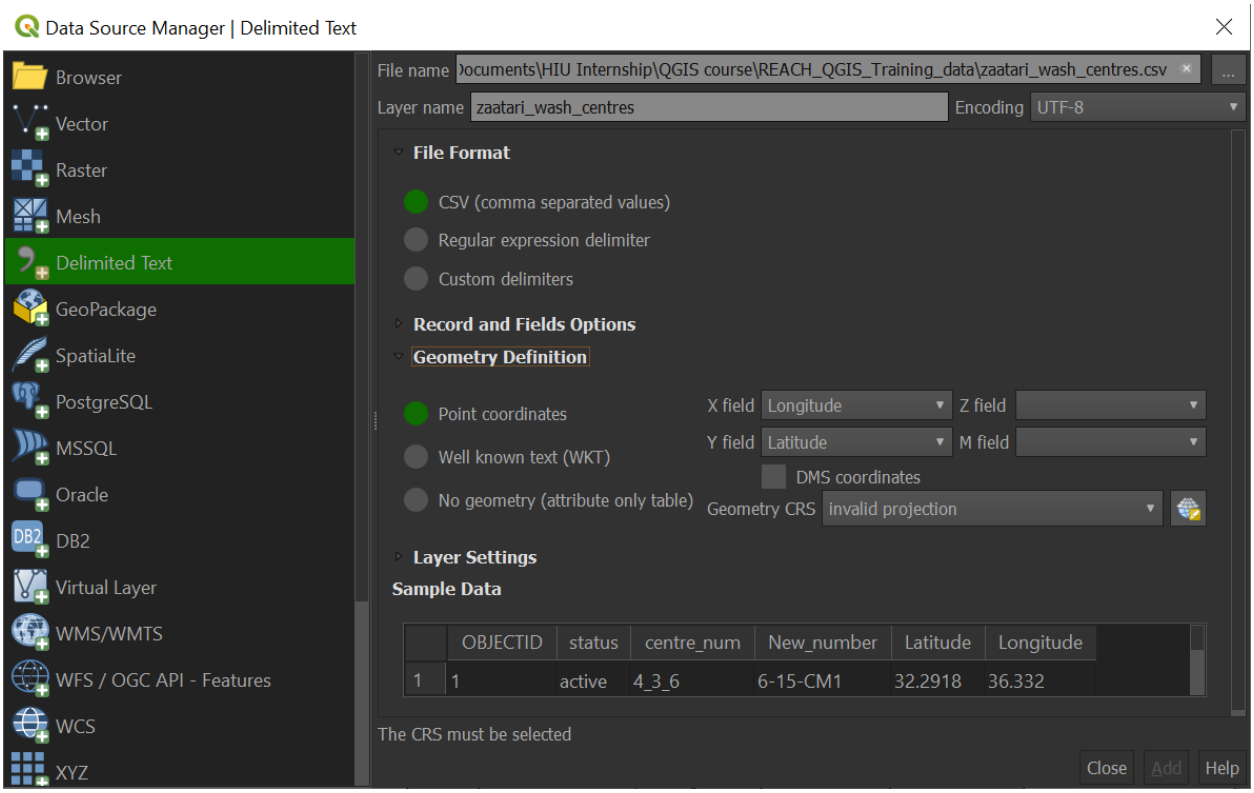
Step 1: Navigate to the **Open Data Source** button and select “Add Delimited Text Layer” from the left-hand pane.

Step 2: Refer to the screenshot below, in the window to create a layer from a delimited text file. For the File name select the file *zaatari_wash_centres.csv* from the training data folder.

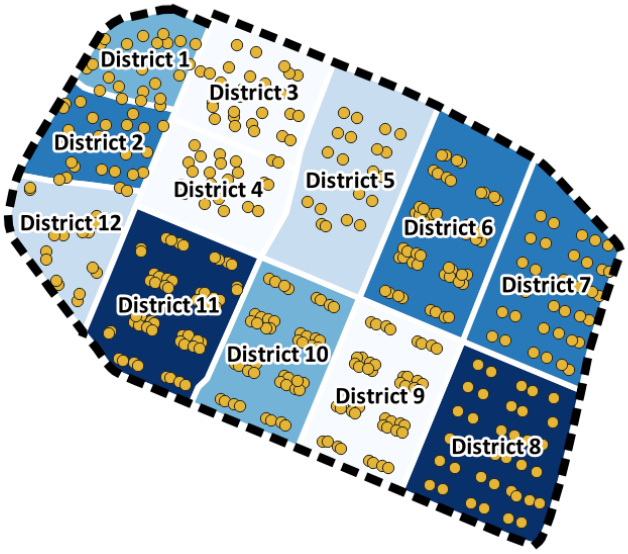
Step 3: Select **CSV (comma separated values)** under "File format" since this is a CSV file it will separate all of the fields by the commas in the file.

Step 4: For "Geometry definition" select **Point coordinates**, then for "X field" select **Longitude,** for "Y field" select **Latitude** (this may already be filled in automatically), and for "Geometry CRS" select **WGS 84** (very important).

Note: For this step, *you must select **WGS 84*** instead of the projected coordinate systems of **WGS 84 / UTM zone 37N.** When importing a spreadsheet you cannot "project" the data but instead only reference it to a geographic coordinate system. **WGS 84** forms the basis of different geographic projections, which are representations of the earth using different mathematical algorithms.



The output should look something like this below.



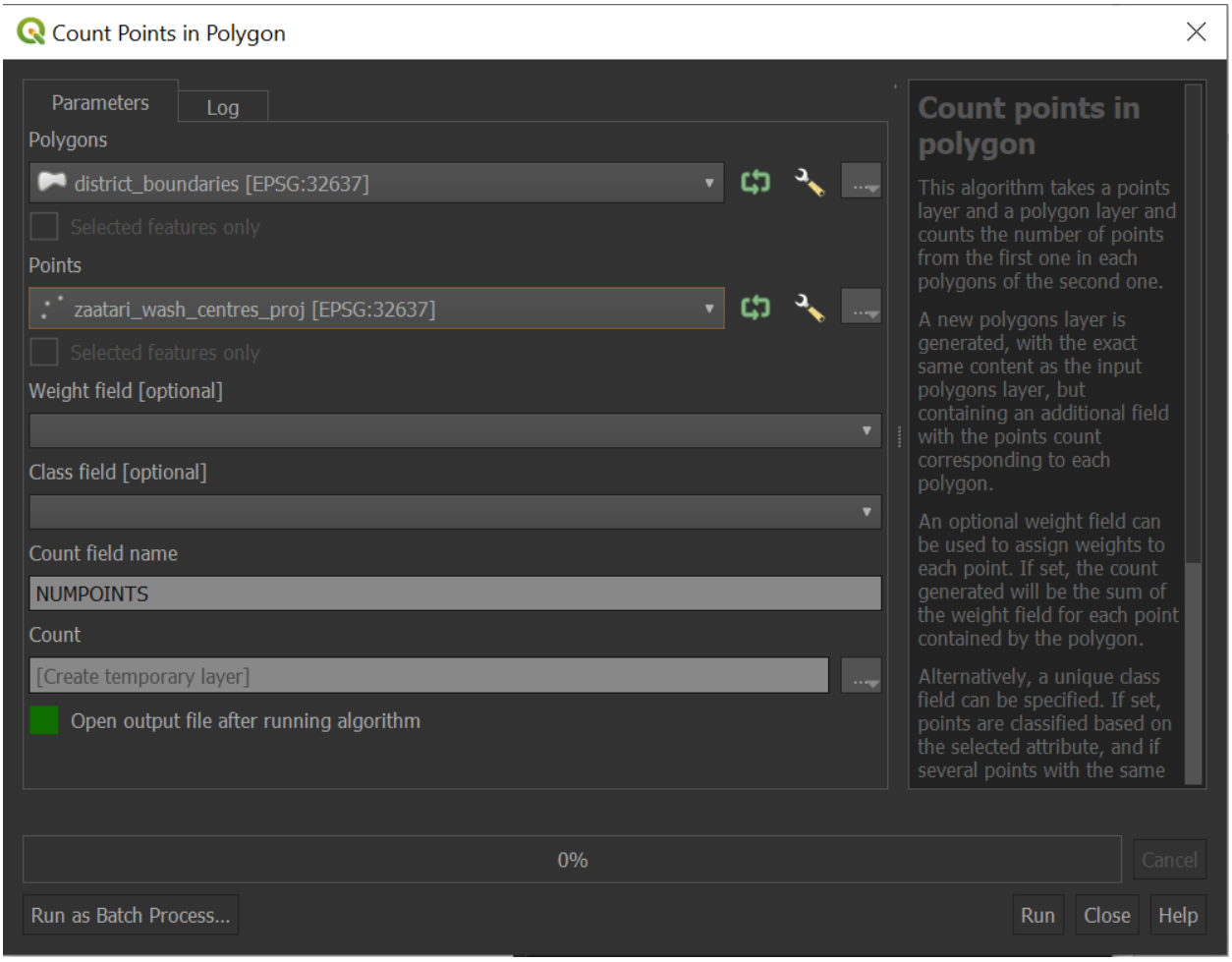
Step 6: Right click the *zaatari_wash_centres* layer in the panel and select “Save as.” In the window, select “ESRI Shapefile” as the file format and save the file in the data folder with the name *zaatari_wash_centres_proj*. Select **WGS 84 / UTM Zone 37N** as the CRS (Coordinate Reference System) and select OK. You now have a GIS shapefile for WASH centres (before it was simply the CSV visualized using GPS coordinates). Delete the layer *zaatari_wash_centres* from the layers panel.

Conducting basic spatial analysis

Using geographic data you can perform steps that summarize counts of features and their attributes based on their spatial location. In this step we will take the WASH centre data, and the number of them within the district boundaries to calculate the number of WASH centres per district.

Step 1: On the menu at the top, select *Vector >Vector Analysis > Count points in polygon*

Step 2: Under the new window, select *district_boundaries* as the “Polygons”, *zaatari_wash_centres_proj* as the “Points.” Make sure the “Count field name” is set to “NUMPOINTS” (which is the field that will be used for generating the new polygons layer).



Step 3: After selecting RUN, open the attributes table for the new “Count” layer. The number of WASH centres per district is now displayed under the column “NUMPOINTS.”

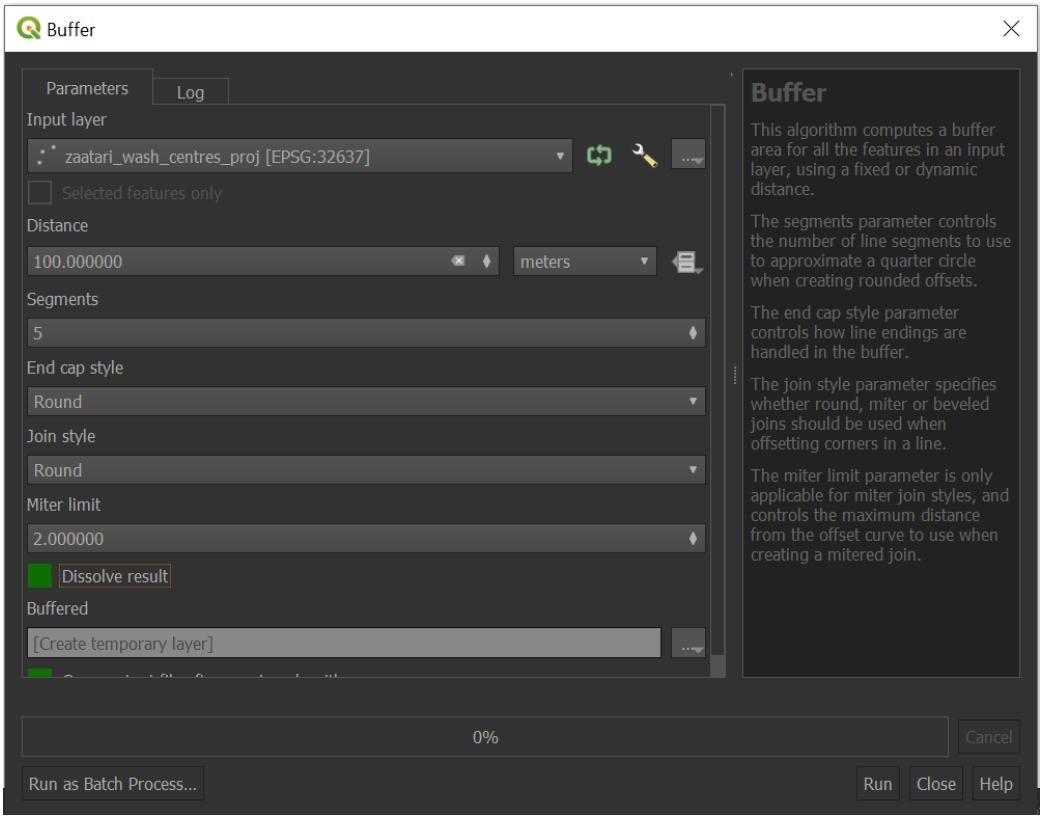
Note: A previous version of this tutorial for QGIS 2 used the tool, “join attribute by location.” With major functionality changes between versions, it appears that the functional elements related to summarizing intersecting features were moved to other tools, such as the “Count points in polygon” tool.

Creating a buffer

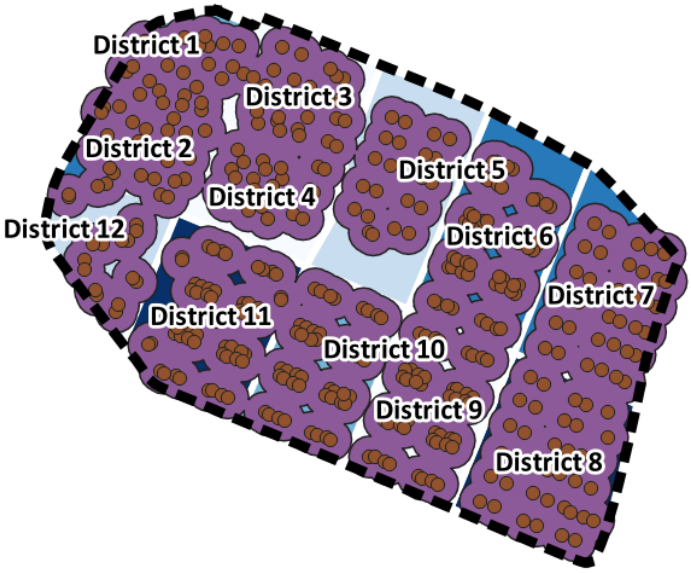
Creating a buffer is a basic yet fundamental aspect of GIS and is a very easy way to conduct geographic analysis. Many times, a buffer can be used to be the basis of a spatial join to give you better information (e.g. how many households fall within 100m of a WASH centre).

Step 1: On the menu at the top, select *Vector >Geoprocessing Tools > Buffer*

Step 2: In the buffer window, select *zaatari_wash_centres_proj* as the input layer. Put 100 as the buffer distance (this is meters since the UTM projection is based upon meters). Check the box for “Dissolve results” (this will merge any buffer features that overlap with each other). Name the output file *wash_centres_buffer*.



You're result should look something like this:

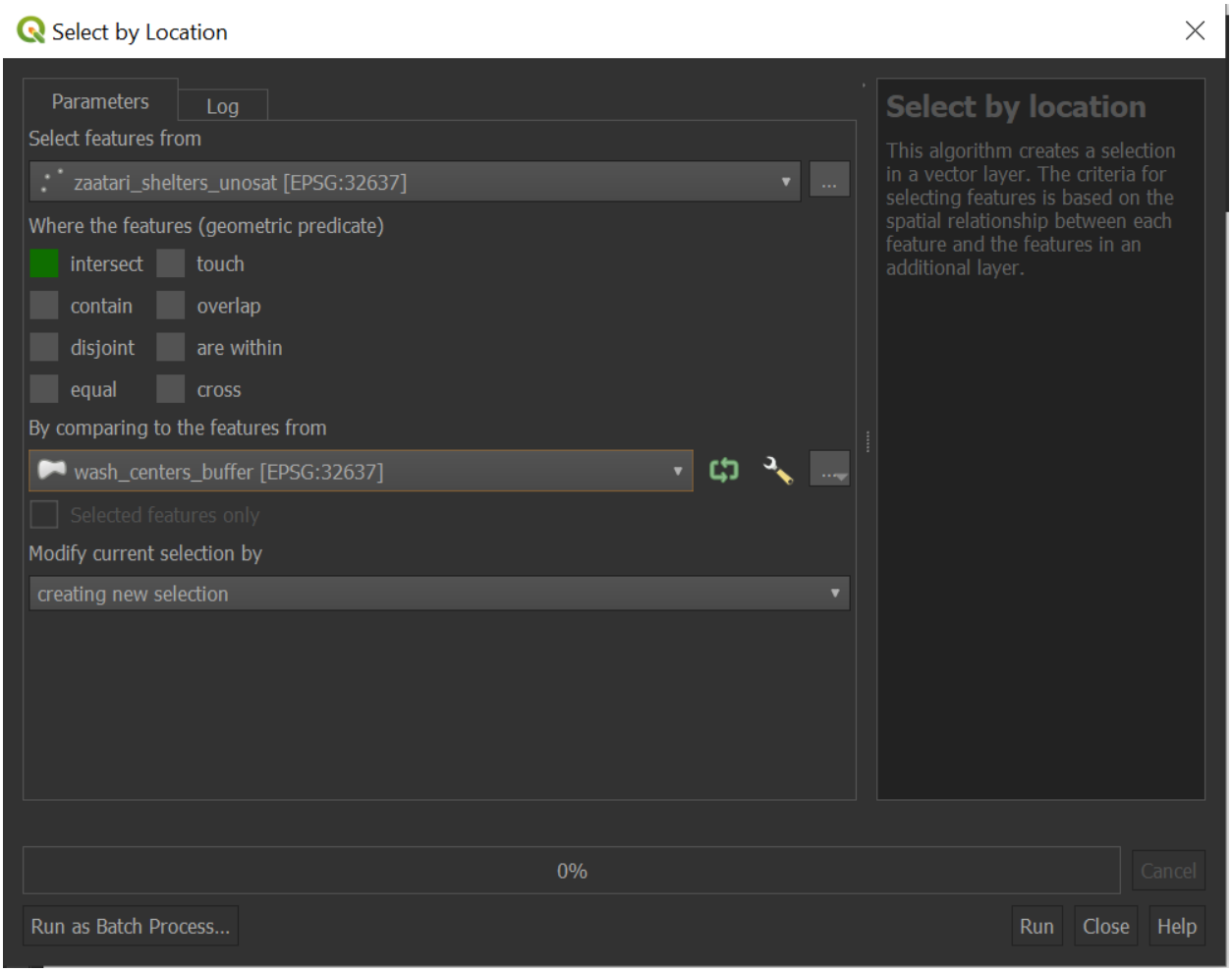


Spatial Analysis — an introduction

One of the unique powers of GIS is the ability to perform calculations that overlay various layers, and allow you to identify key patters in your data sets that would not be possible by using other types of analytical methodologies. As you've seen with counting points in polygons, you can combine various layers to aggregate and generalize data compared to other data sets. In this section we'll go a step further and perform some useful analysis using spatial queries and intersect functions.

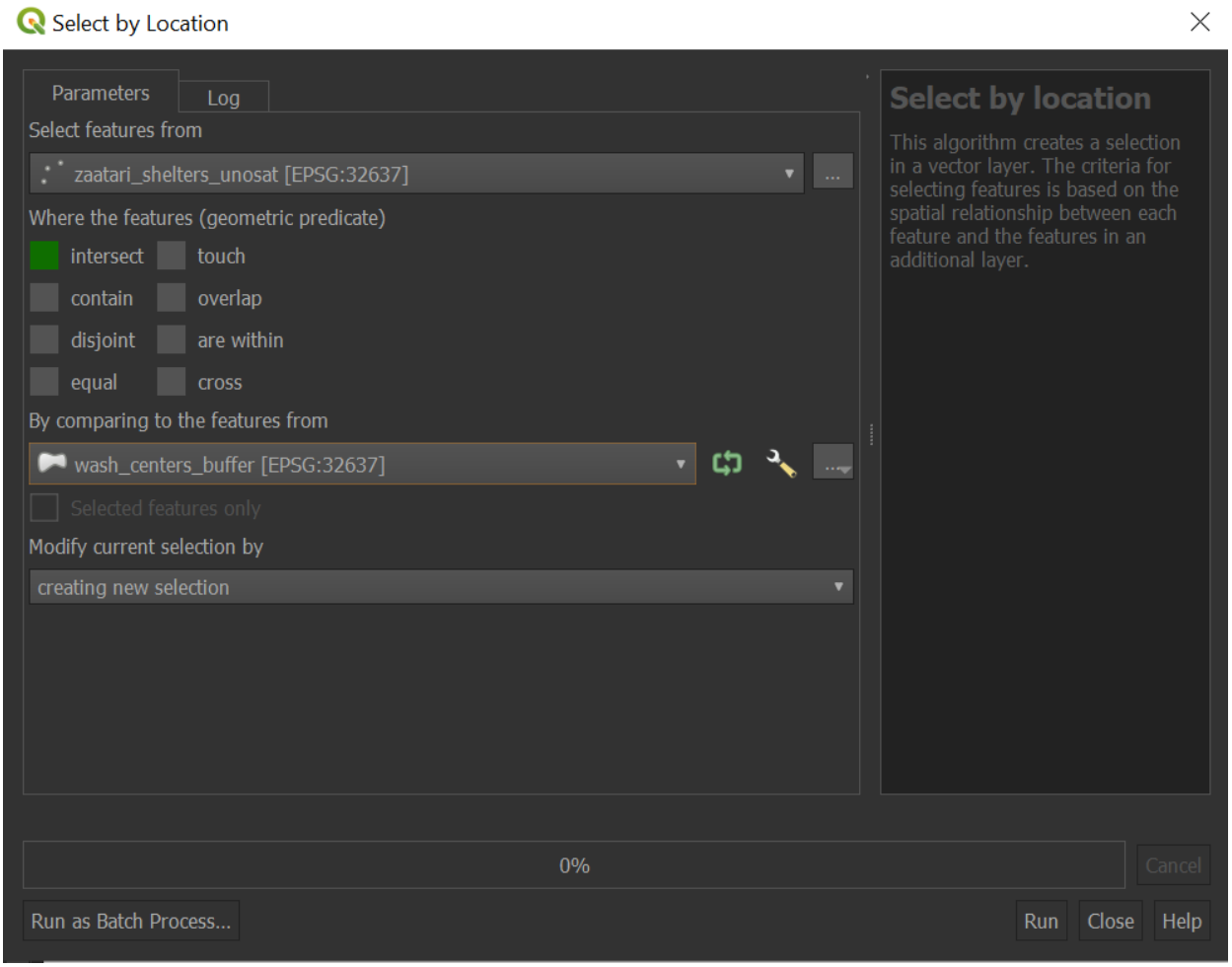
Step 1: Add the shapefile *zaatari_shelters_unosat* to the layers panel.

Step 2: Select all of the shelter points that fall within the *wash_centres_buffer* layer. In the menu, select *Vector>Research Tools>Select by Location.* In the screenshot below you see that we are selecting features from *zaatari_shelters_unosat* that intersect features from *wash_centres_buffer*. The options below allow for various operations, and in this case we'll just select those that "intersect" rather than "touch", "overlap", etc. After selecting OK, it will take some time to process but you should see all of the shelter points within the buffer selected and highlighted in yellow.



Step 3: Open the attribute table of the *zaatari_shelters_unosat* layer and you will see that 77,323 features are selected out of 85,209 (91%). Now, select the Toggle Editing Mode button in the top left of the attribute table toolbar and add a new column to the table called “wash_dist” (to add a field select the New Field button). The type should be text (string), with a length of 20.

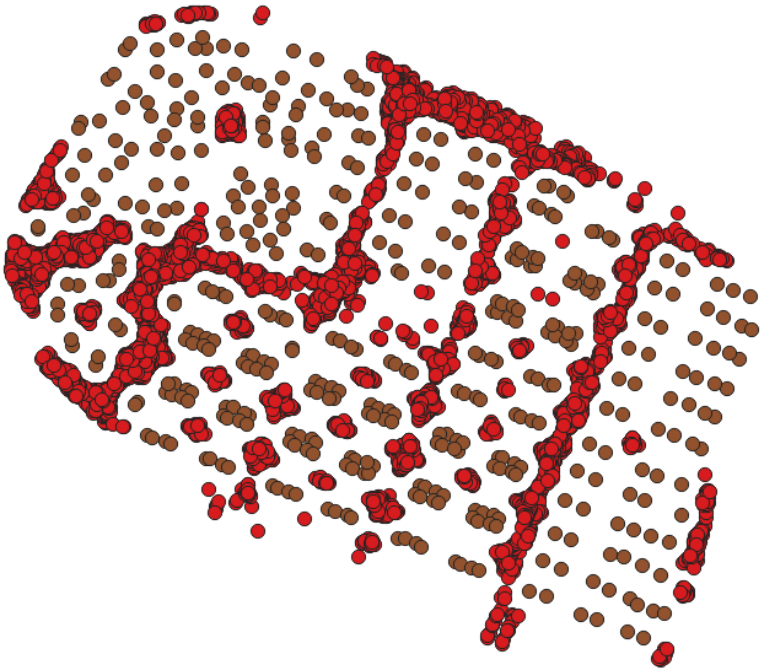
Step 4: Open the Field Calculator and change the values of the selected features in the “wash_dist” column to “within”. Make sure that you check the box for “Only update 77,323 selected features” and “Update Existing Field”. Select the “wash_dist” field on the right side and in the expression window type ‘within’ (note the single quotation marks around ‘within’).



Step 5: Now you have added a value of "within" to every point that falls within the WASH centres buffer layer that we create. To edit the remaining features (those outside of the buffer), reverse the selection in the attribute table to select all the features that weren't selected in the initial task. Select the Invert Selection button on the attribute table toolbar, and this will switch your selection.

Step 6: Repeat Step 4 where you added the text 'within' to each feature, but instead this time make sure you only update the newly selected features (7,886 in total) and add the text 'outside' in the expression window. Select OK then in the attribute table select the Toggle Editor Mode button again and save your edits. It will take some time to save since it's such a large file.

Step 7: Now let's visualize all of the shelters by their distance to WASH centres, with the categories we just created. Open the properties of the *zaatari_shelters_unosat* layer and under the Symbols tab, select categorized as your symbology type, "wash_dist" as the column for symbology and classify the symbols based on the two categories: within & outside. Change the colors appropriately (e.g. red for outside, green for within). Alternatively, you can also visualize solely the features outside of the buffer by only adding that category to your symbology list. See screenshot below.



Rotating the map

If you weren't already aware, the map by default uses north facing up. As a result Za'atari camp is at an angle since it does not face true north. In QGIS it is very easy to change the orientation of the map based on a "degree" that you specify.

At the bottom right of the map is the **status bar**. There is a field called "Rotation" and you should input the value **-21**, hit enter on your keyboard and the map will orient itself to have the camp shown straight.

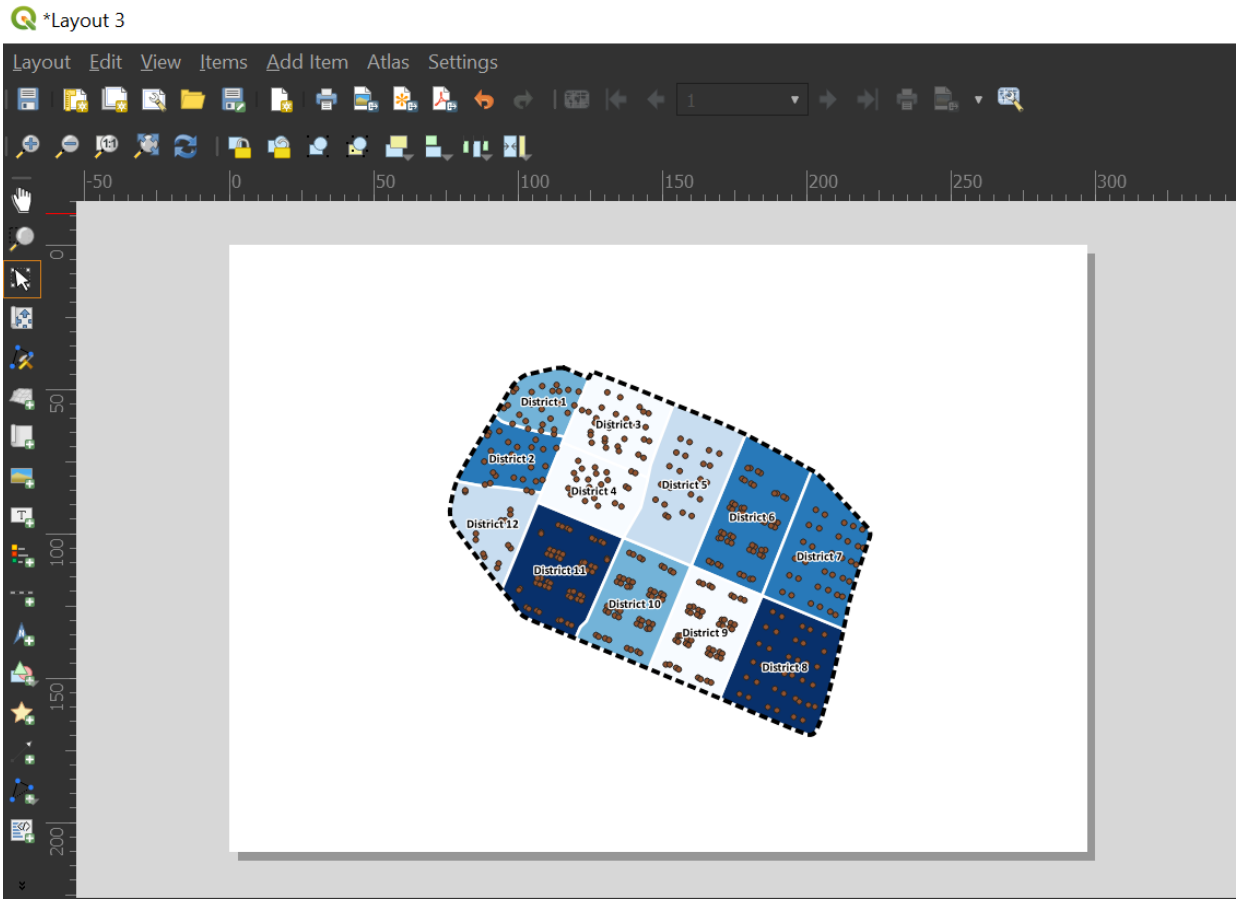
Formatting and exporting as a map

Now that you've done so much to create the data and make a map, it's time to actually export this as a map that you can send to colleagues.

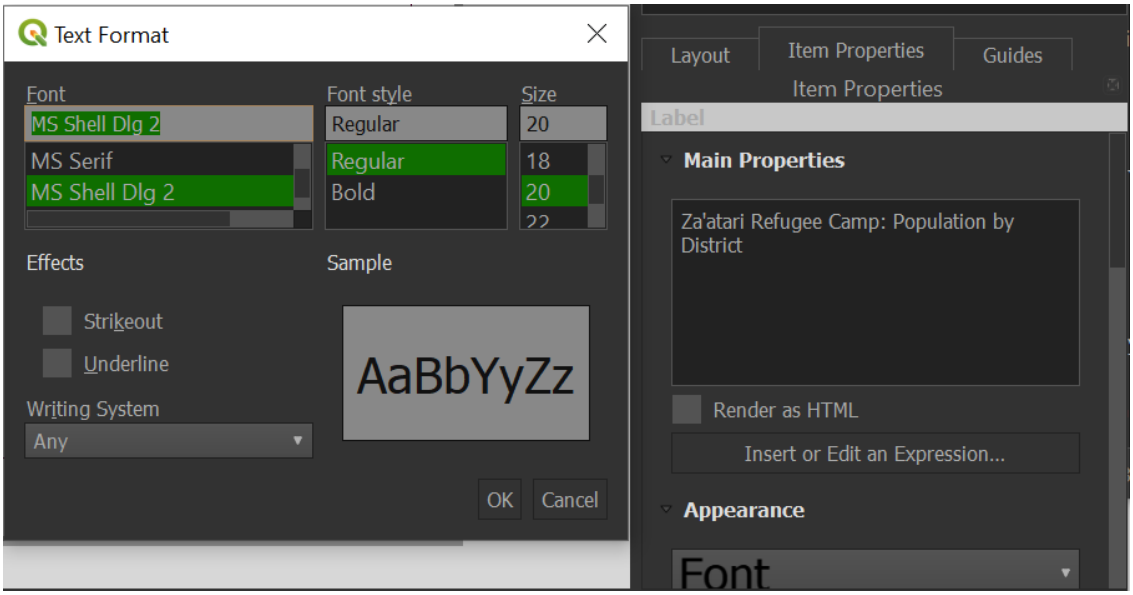
Step 1: Click the **New Print Layout** button in the toolbar at the top left. 

Step 2: Add a title for this print layout (you can also leave this box blank, should you so choose, and a new layout title will be automatically generated). Press OK to continue.

Step 3: Select the **Add map** tool then click / drag a box on the white space to show the map you have in the QGIS workspace.



Step 4: Add a title to the map with the **Add new label** tool . You can re-size the box of the text to make sure it's large enough to fit for your title. Note that on the right hand side you can highlight the text in the Items panel, and then under item properties you can change the text and then the font type and size.



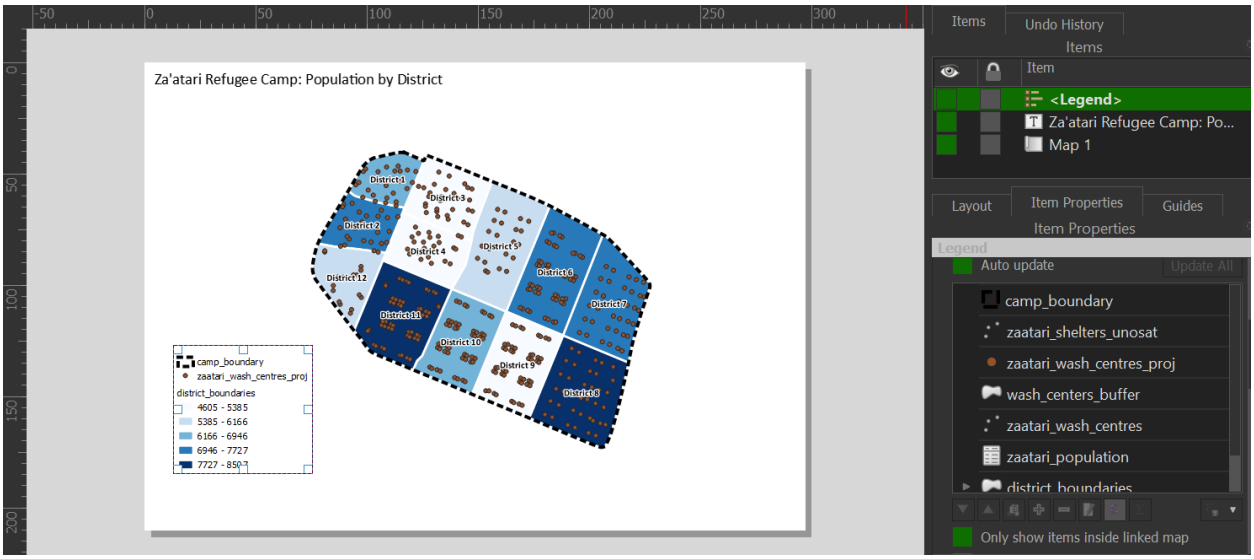
Step 5: Add a legend to the map using the **Add new legend** tool  . Then, click on the map and the legend will appear based on the layers that you have visible on the map. Similar to the title, you can go to the properties on the right and change the properties for the layer, such as what is labeled and included on the map.

Legend tips:

-Under **Legend Items** uncheck “Auto update” and you can then choose the items you want to include in the legend. For example, uncheck the camp boundary layer as we do not want it visible in the legend.

- **Only show items included on the map:** To easily eliminate superfluous information, check “Only show items inside linked map” in “Item Properties.”

- You can go back to the QGIS main workspace and change the name of the layer (right click and select “Rename”) and this will change in the legend after you select “Update all” (if you have “Auto update” deselected).



Step 6: Select the **Composition** tab on the right-hand side to give the map document the properties you want, such as size A4, dpi 300, etc.

Step 7: At the top-left select “Composer” and select either **Export as Image / Export as PDF** and save the files with an appropriate name. You now have a map!