Research jointly supported by the ESRC and DFID

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Practical guidance on mapping and visualisation of crime and social data in QGIS

Complete Manual (2018): Lessons 1-5

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Preparation: installing & setting up of QGIS

Introduction

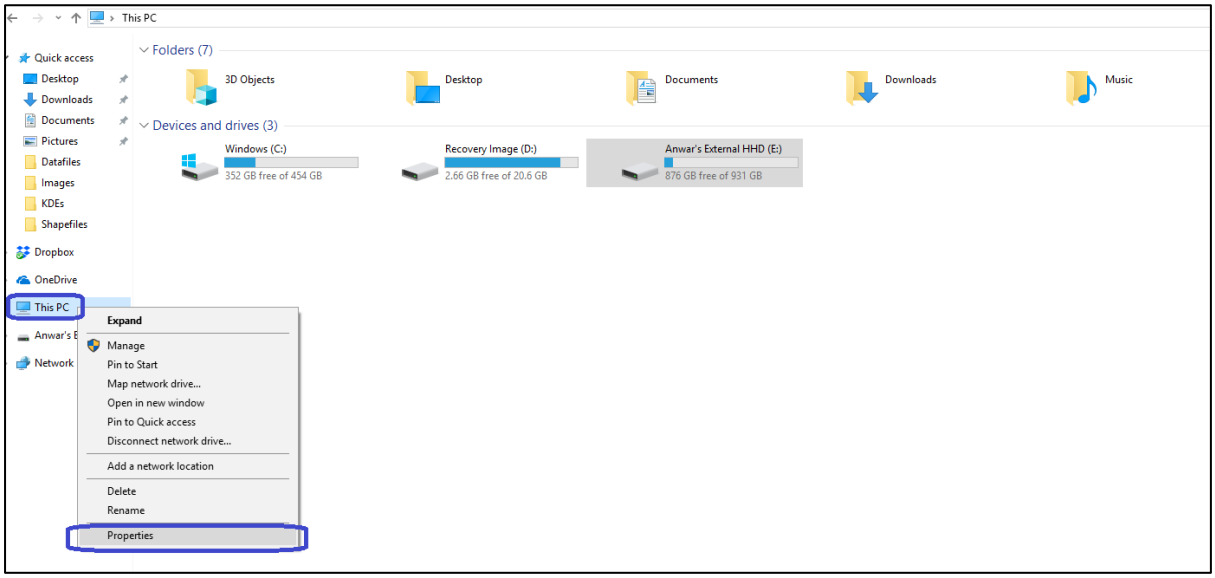
Quantum GIS (QGIS) is a friendly open source geographical information system (GIS) software which is compatible with many operating systems such as Android, LINUX, Windows and Macs. It supports numerous spatial data formats that come as vectors or raster data. It has a wide range of plugins which can be remotely installed to provide additional functionalities for handling spatial data and perform complex spatial analyses. More information about QGIS can be accessed on https://qgis.org/en/site/.

Installing the QGIS Desktop version 3.2.0 (Bonn)

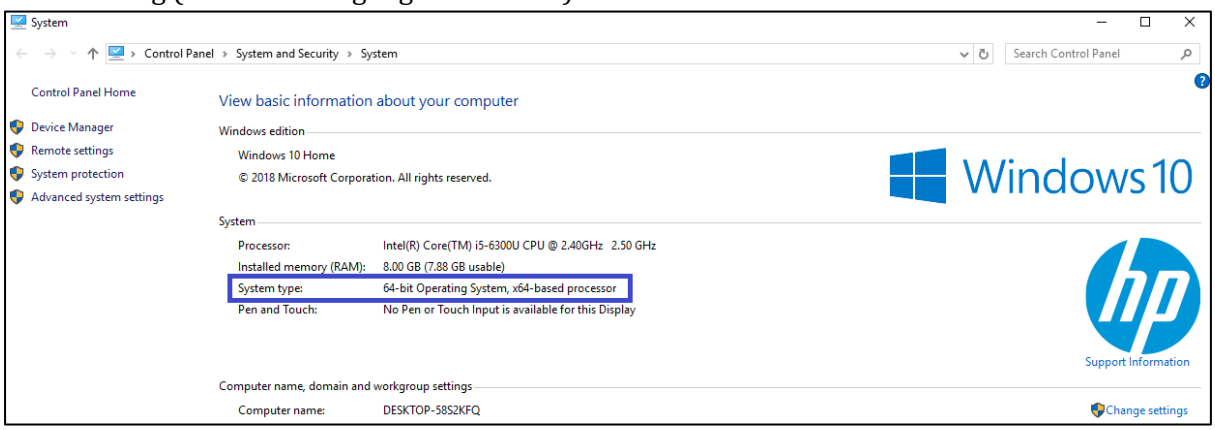
The latest version of QGIS is version 3.2.0 which can be downloaded from the web link on https://qgis.org/en/site/forusers/download.html.

Download for Windows: QGIS is available for PCs with system types that are 32- or 64-bit. You can check your computer's system type by:

- Opening the *This PC* folder
- Right-clicking on *This PC* icon and click on *Properties*

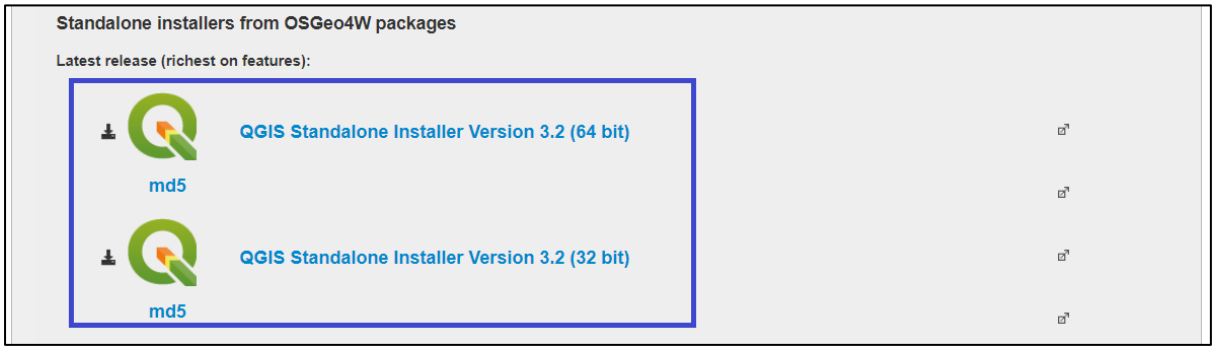


- Clicking on *Properties* will bring up a window called *System*. This shows details of the computer's specification. You can access information about the type of system you are using (see section highlighted in blue)



Make sure to download the correct application that corresponds with your computer's operating system:

- Users with a **64-bit Windows OS** should download the latest version of QGIS by choosing the application **QGIS Standalone Installer Version 3.2 (64 bit)**.
- Users should select the latter **QGIS Standalone Installer Version 3.2 (32 bit)** if the machine system is a **32-bit Windows OS**



Download for Apple/Mac OSX: for Apple/Mac Users: expand the section **Download for Mac OSX** and select **QGIS macOS Installer Version 3.2** to download the latest application of QGIS on your Apple/Mac computer

Download the application of QGIS, and install the software onto your computer. Before installing the software ensure to have at least **1.9 GB** free storage space on your console. Installation of QGIS will result in seven different being application being installed which is fine. These are listed accordingly:

- OSGeo4W Shell
- QGIS Browser with GRASS
- QGIS Browser
- QGIS Desktop with GRASS
- **QGIS Desktop**
- Qt Designer with QGIS custom widgets
- SAGA GIS

We will only be interested in **QGIS Desktop** (only) as it will provide us with tools to do the practical lessons.

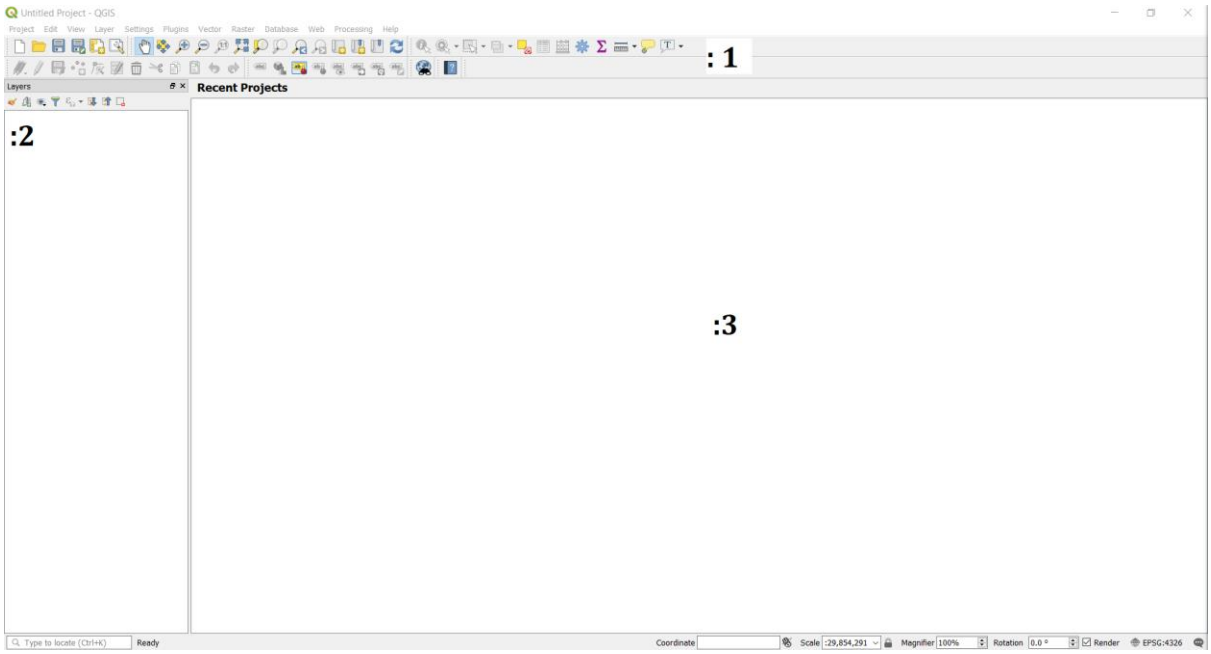
Important note for Apple/Mac OSX users: the images presented throughout the course were generated from a Window OS 64-bit console. Nevertheless, the images and instructions presented in these lessons should not differ. An Apple/Mac user should able to follow the tutorials as well.

Setting up, and being familiar with QGIS

When the installation of QGIS is complete, the icons for opening the software will be hidden in the *Start windows* section where all applications are listed. Do the following to open QGIS Desktop:

- Click on the *Start windows* button  and browse through the applications that have been listed in alphabetical order. Browse down to the letter *Q* where you should see *QGIS 3.2* folder annotated as *new*
- Expand this folder by clicking on it. There will be 7 other applications. The one we want to open is *QGIS Desktop 3.2.0* (only)
- Click on the icon  to open *QGIS Desktop 3.2.0*

When opening QGIS for the first time, you are greeted with a brand new window which looks like the example below:



This is QGIS main interface. The interface has three components for which the user must be familiar with:

The section labelled **1** is home to the ***menu and toolbars***. This tool allows the user to access various menu tabs such as the ***Project***, ***Edit***, ***View***, ***Layer*** and ***Plugins***. The menu tabs are position on top of the toolbars. The toolbars correspond to the various icons which allows the user immediate access to some functions.

The section annotated as **2** is the ***Table of Contents*** or ***Layer Panel***. It enables the user to see which list of spatial and non-spatial data are loaded into QGIS.

The section labelled as **3** is the ***Display window***. It shows which spatial data are active in our ***Layer Panel***. Here, we can visualise our spatial data and see constructions of our maps.

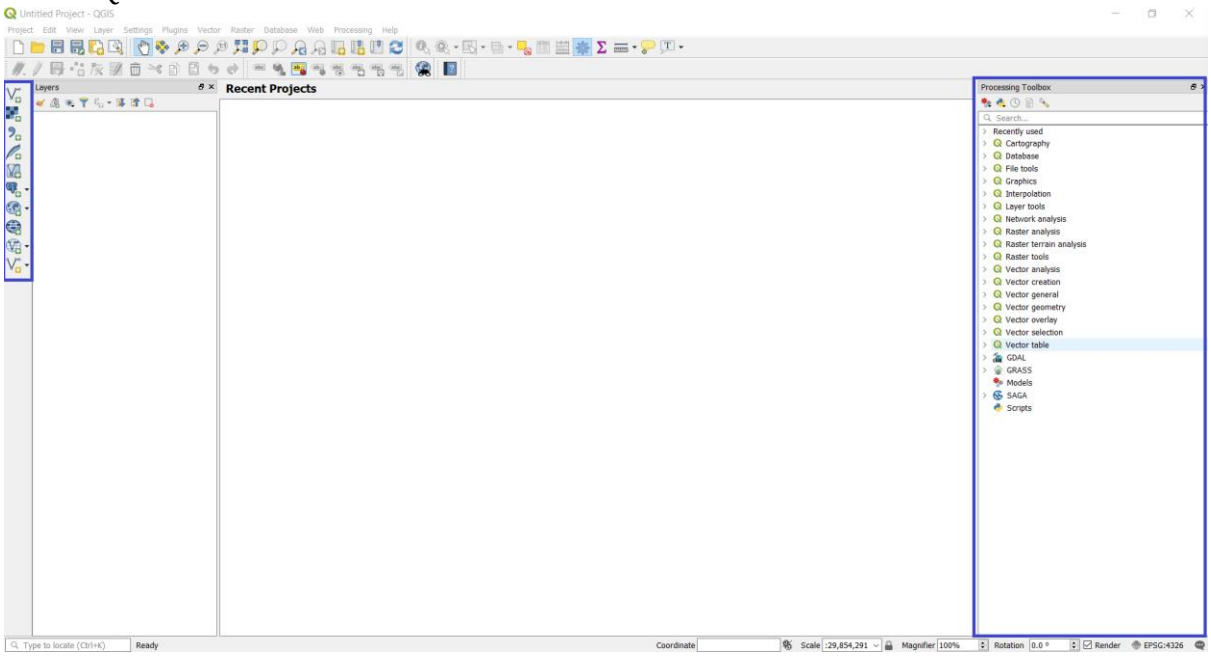
There are some additional toolbars that we will need for the tutorials – we need to activate the ***Manage Layers Toolbar***, and ***Geoprocessing Toolbox***.

To activate the *Manage Layers Toolbar*:

- Go to the menu tabs and click on the following: *View* > *Toolbars* > *Manage Layers Toolbar*.
- This toolbar should appear of the left-side of *Layers Panel*. This is an important toolbar as icons will allow the user to quickly add spatial and non-spatial into QGIS

To activate the *Geoprocessing Toolbox*:

- Go to the menu tabs and click on the following: *Processing* > *Toolbox*
- The toolbox should appear of the right-hand side panel of the *Display window*. This is another important tool as it contains various function for conducting spatial analysis in QGIS



There are some basic functions in the toolbar will use often during the tutorial series. Here are some of the functions in the Menu's and Layer's toolbars:

Some useful toolbars icons

Icons	Descriptions
	To open a new QGIS project
	To open an existing QGIS project from a folder
	Save
	Save as
	Create a new print composer
	To manage existing print composers
	To pan active layer

To zoom into active layer

To zoom out of active layer

To zoom to full extent of active layer

Some layer toolbar icons

Add vector data to layer panel

Add raster data to layer panel

Add attribute (or comma separated value) data to layer panel

Lesson 1: Adding spatial vector data in QGIS

Introduction

We will learn ways to add various types of vector spatial data into QGIS. It should be noted that are two distinct formats in which geographical information can be displayed – these are known as Vectors or Raster.

Vector data: Is a representation of the world, or any spatial outcome that's represented by points, lines or polygons. A vector is typically useful for storing data that has discrete boundaries, for example, country boundaries, streets and individual point locations of places (i.e. a town or city).

Raster data: Is a representation of the world, or any spatial outcome, as a surface that's divided into grid cells. A raster very useful for storing data that varies continuously on a surface. A typical example includes surface elevation, concentrations of ambient particulate matter, population density or satellite images.

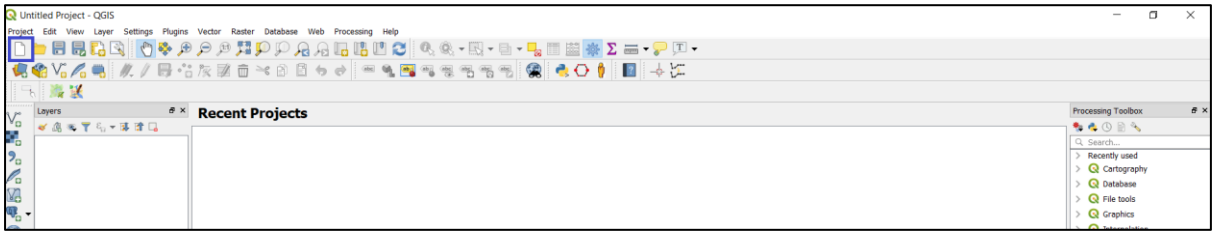
For now, we will be focusing of **vector data** (later, we will learn more about raster data). We will learn how to add vector spatial data into QGIS and construct a basic atlas of Africa showing its major cities and how their roads are connected.

If you have not already, please make sure to download the corresponding dataset for lesson 1 by going to our website on http://development-frontiers.com/tutorials/

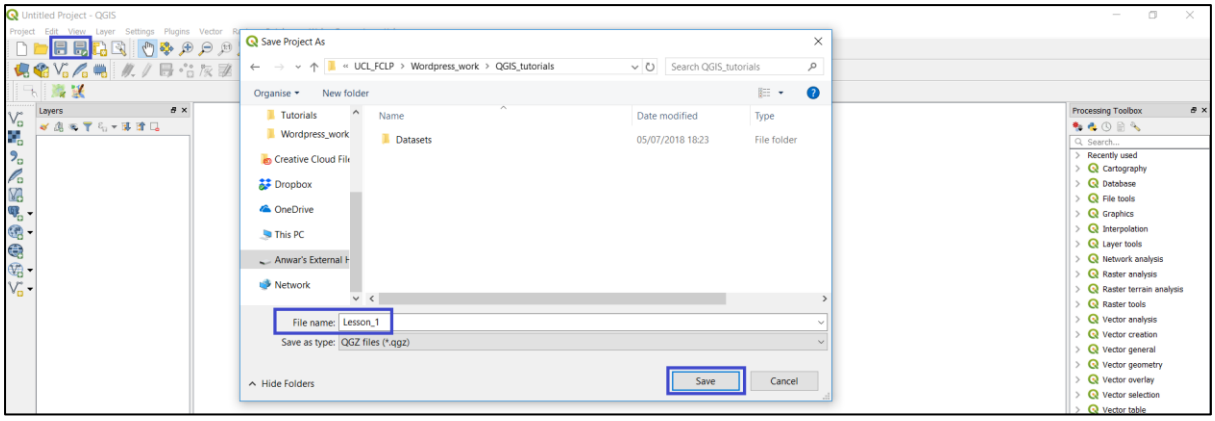
Opening and saving a new project in QGIS

Open *QGIS Desktop 3.2.0* by clicking on the icon  and you will be greeted with a blank window which reads *Recent Projects*. We are going to open a *New Project* for this practical session and save this project as "*Lesson_1.qgs*":

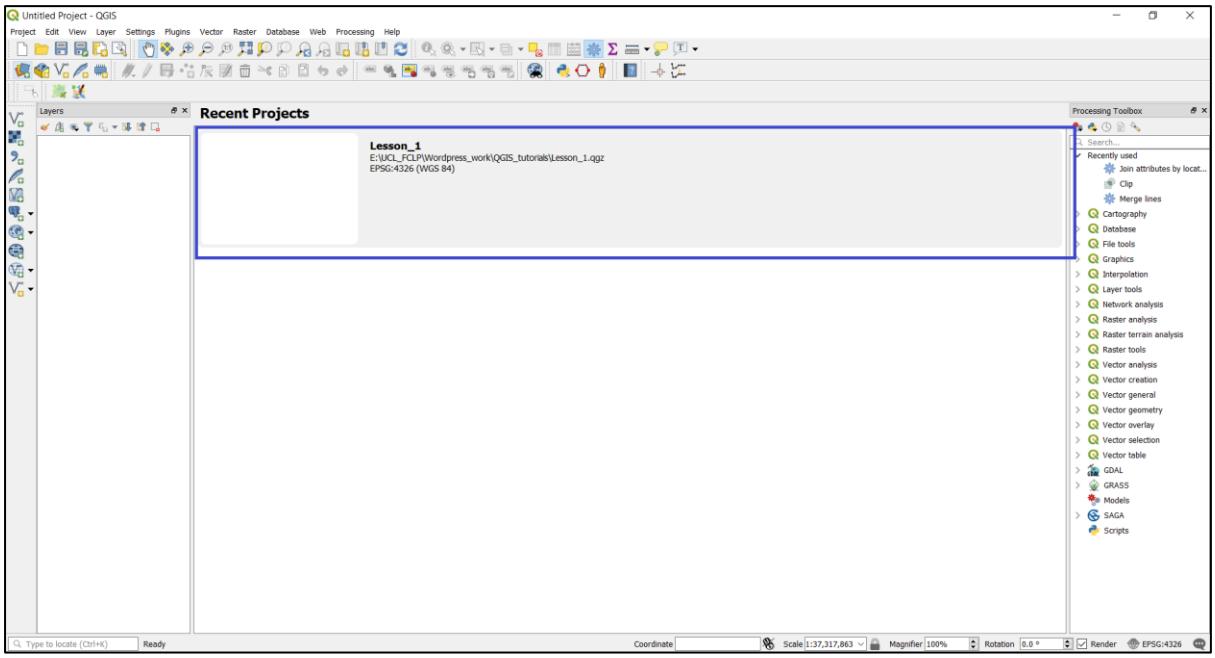
- Click on the icon  located in the toolbar to open a *New Project*



- Clicking on the *New Project* icon should refresh QGIS to the *Display Window*. You can save projects by using the save icons – *Save as*  to save a project for the first time; and *Save*  for overwriting or updating exist projects.
- Click on *Save as* icon  and a *Save As Project* window will appear. Name this project by typing "*Lesson_1*" in the *File Name:* bar and click on the *save* button to save it.



When working in QGIS it is always good practice to save your project frequently. This feature saves you progress, and so if you were to close QGIS and re-open the application, your project will be listed in the *Recent Projects* menu. The user can select project to continue where s/he had left off.



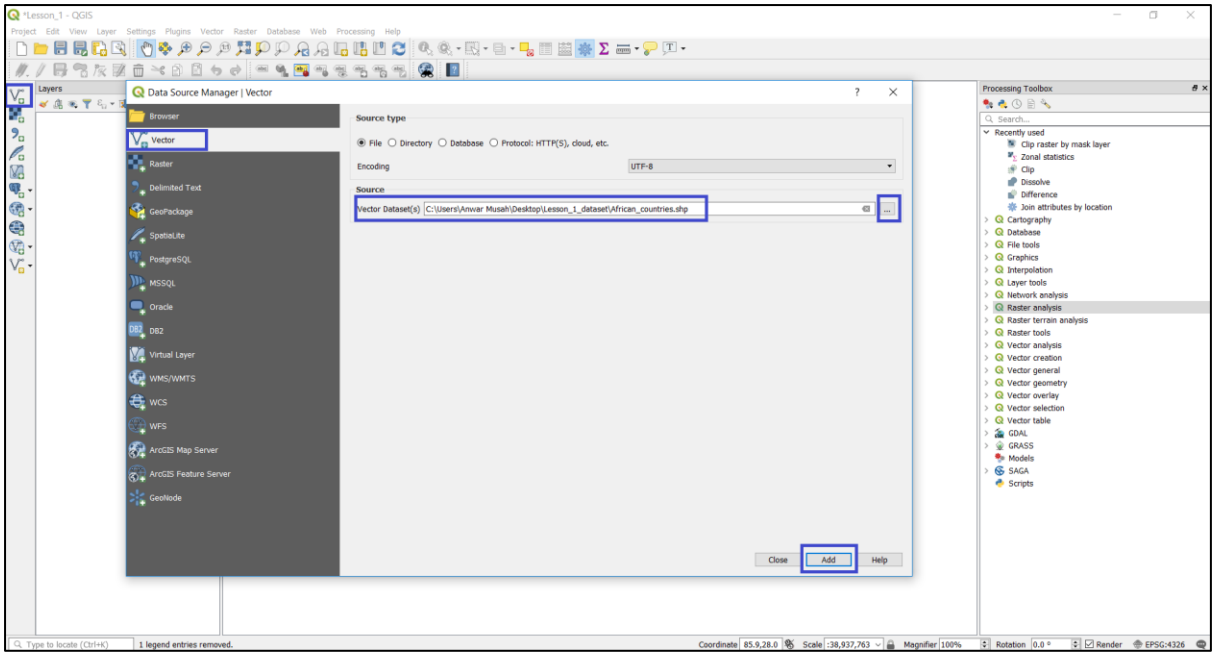
Displaying vector data in QGIS

Let's start to view some spatial data in the *Display window*. We are going to construct a basic atlas of Africa which shows the location of major cities and road networks. We have the following vector data (or shape files (*.shp*)) for the whole of Africa, the 349 major cities and over 200,000 roads.

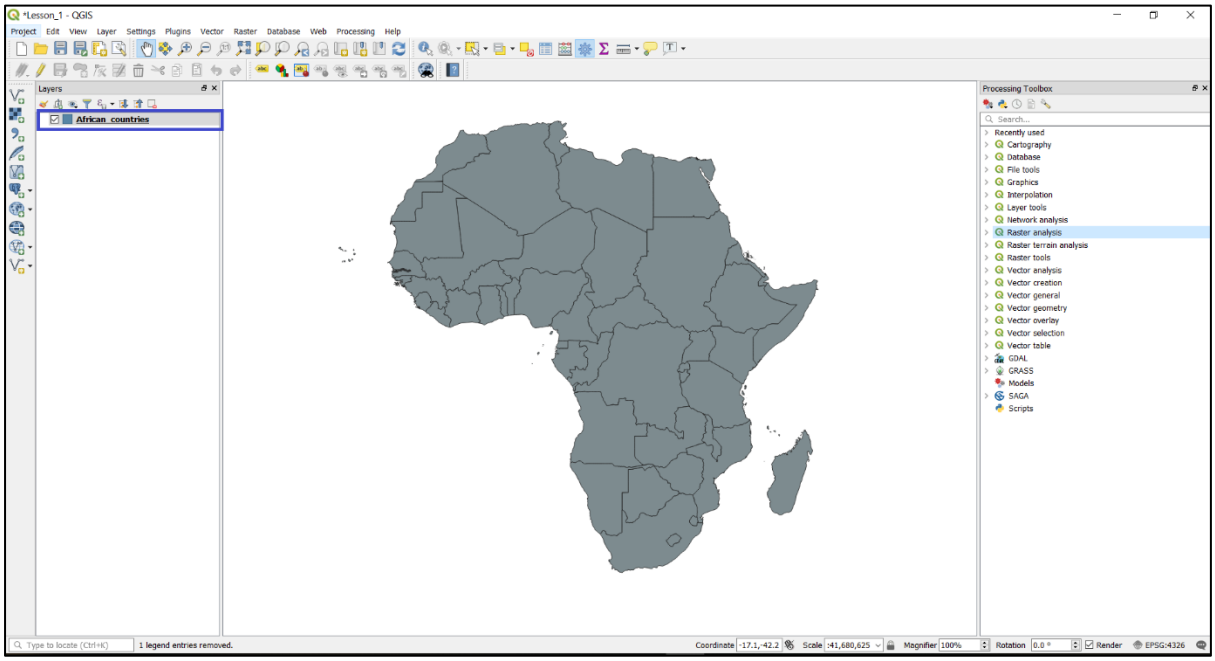
- *Africa_countries.shp*
- *Major_cities.shp*
- *Major_roads.shp*

Let's load these shape files starting with *Africa* as the base layer to our *Display window*:

- Click on the *Add Vector Layer* icon  in the *Layer Toolbar*. This will bring up a small menu called the *Data Source Manager*

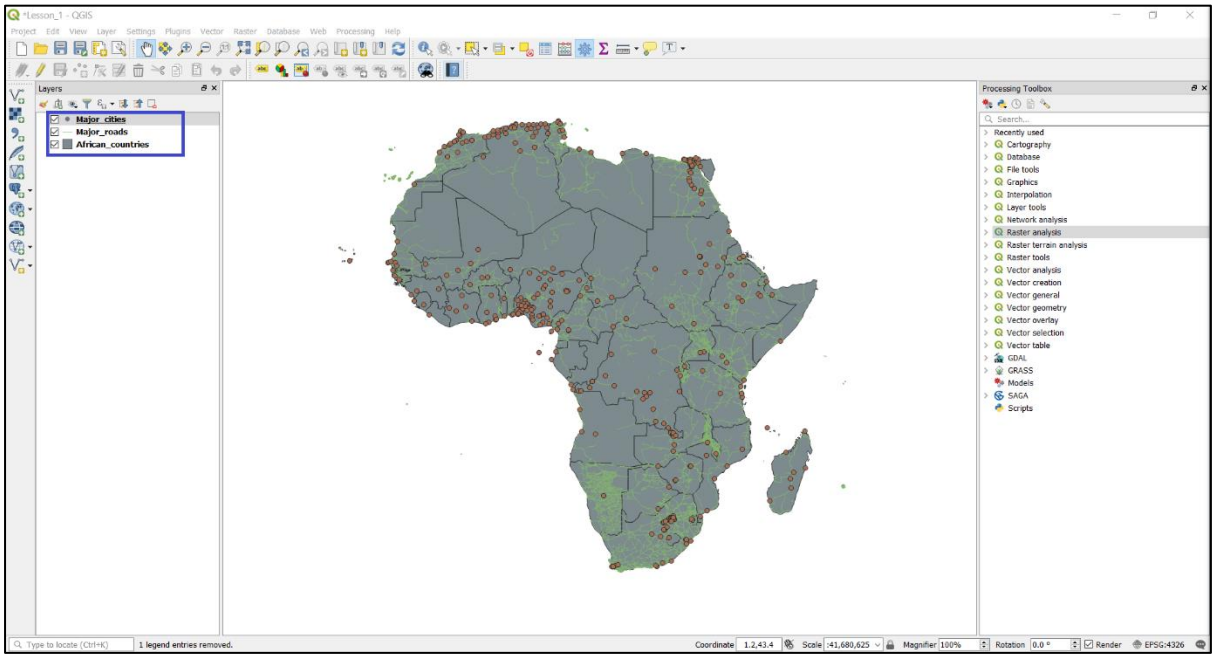


- Data Source Manager allows the user to navigate the directory to select their data. Click on the Browse button  and go to the location of your downloaded data and select the shape file *African_countries.shp*
- The selection and the path to the shape file's location will be shown in the *Vector Dataset(s)* panel
- Click on the *Add* button to add shape file into the *Display window*
- Click *Close* to close the *Data Source Manager* menu



The shape file for Africa has been added as a layer – you can see this in *Layers Panel*. The contains the boundaries of All African countries. This vector data is a typical example of a **polygon**. Now

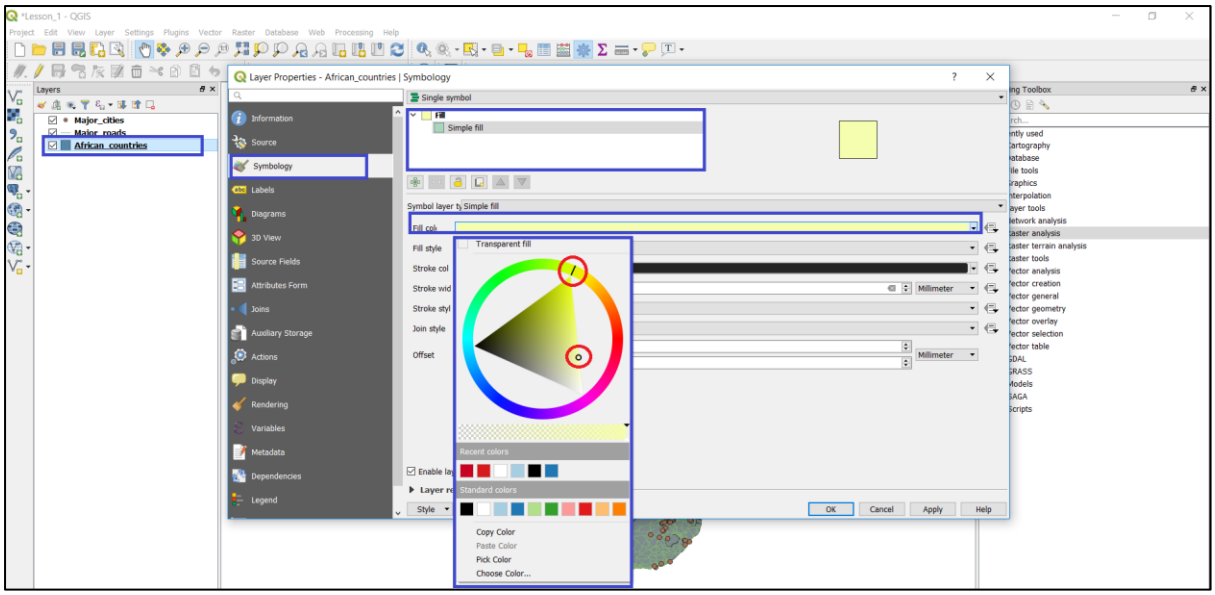
let's include road networks in Africa and the cities to the atlas – repeat the above steps by adding the data in the following order: *Major_roads.shp* and *Major_cities.shp*.



As you can see, the shape files for the roads and cities have been added as layers in the *Layer Panel*. The brown dots correspond to the point location of cities, and the roads are represented by the green lines. The vector data for the cities are classed as **points,** whereas those for the roads are termed as **lines.**

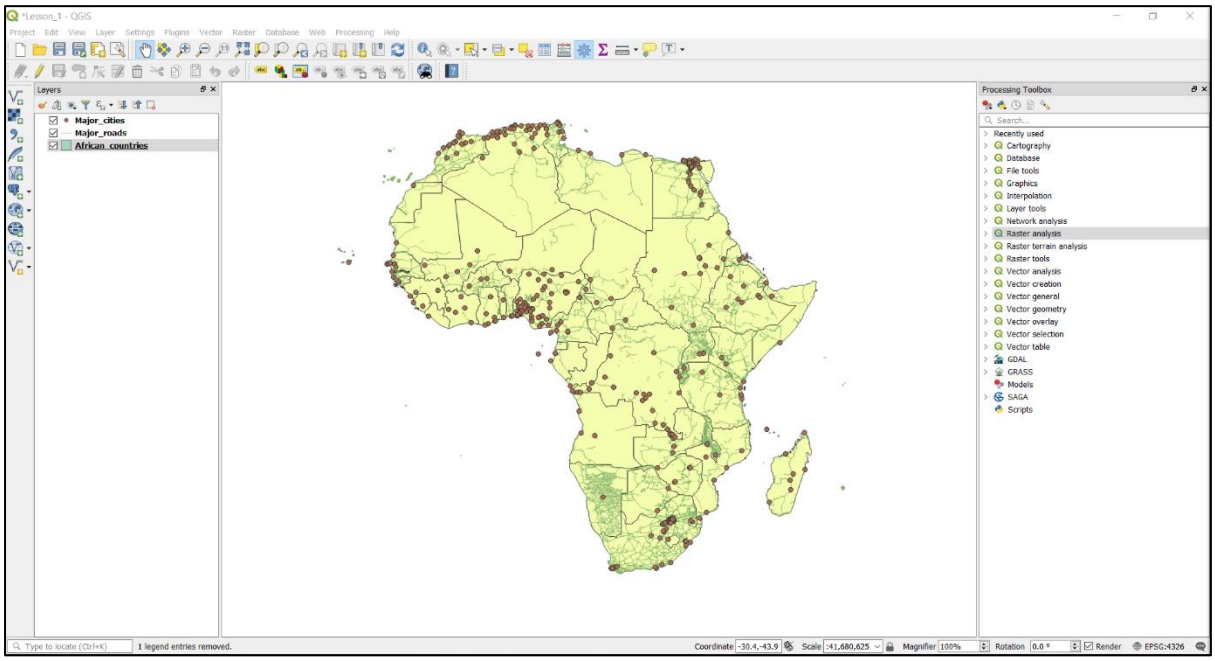
Changing the visual and colour properties of vector data

At the moment – the image in the *Display window* does not qualify as a decent atlas. We are going to modify the colours and symbology for Africa, the roads and the cities; and show the sea surrounding the continent. Let's give Africa a land colour of bone yellow:



- Right-click on the layer *African_countries* in the *Layers Panel* and select *Properties*
- The *Layer Properties* menu for *African_countries* will appear – on the left-hand side of the menu, select *Symbology*.

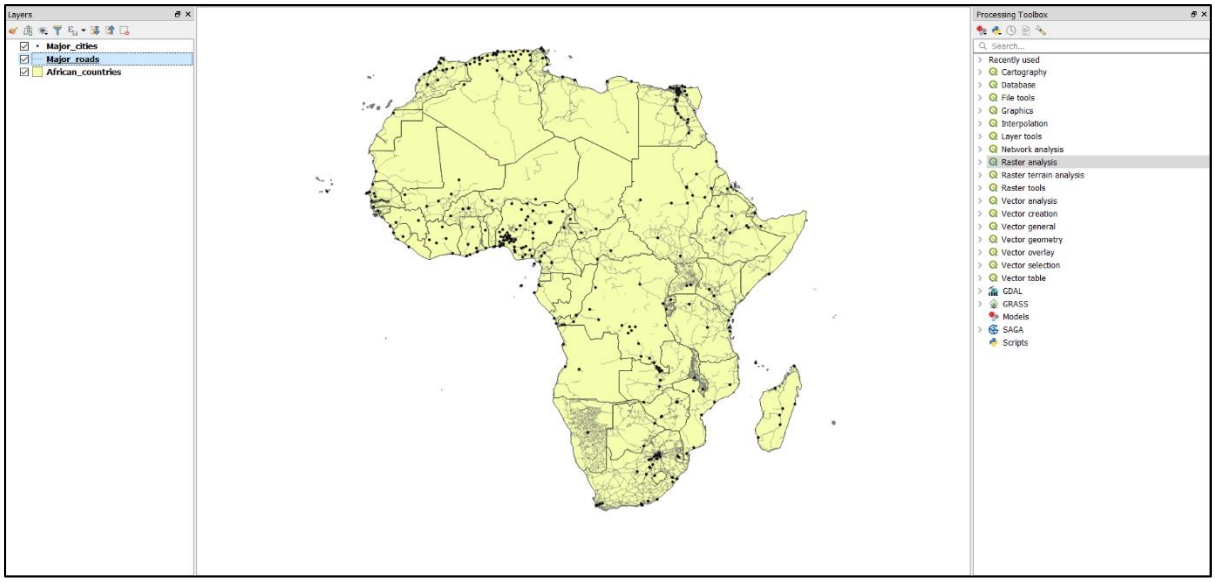
- Select *Simple fill* to change the fill colours of the polygons. This is located on the top of the right-hand side panel of the *Layer Properties* menu
- Click on the selection bar of *Fill colour* to select the desired colour. Here, should reveal a colour-wheel.
- You can rotate the *Triangle* by dragging the vertical bar around the colour-wheel to select a colour – this is referred to as Hue region. Lightness of the colour is controlled by dragging the circular held within the *Triangle*. You can play around with the colour parameters and try to select one that represents a bone yellow colour
- Click on *Apply* and *OK*



You repeat the above steps for changing the colours for the roads and cities by going into their properties. When you access the *Symbology* menu for the lines and point data – ensure to select *Simple Lines* and *Simple marker*, respectively, in the right-hand side panel of the *Layer Properties* to change their appearance.

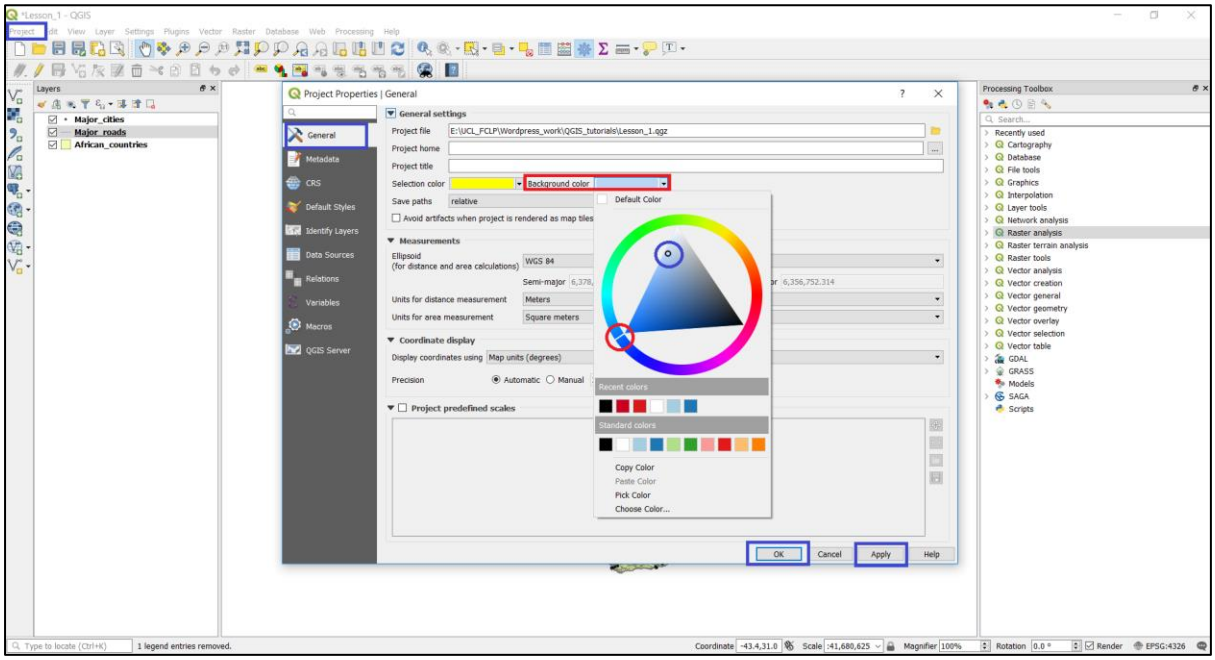
You can play around to make the following changes:

- *Major roads* – choose *Dark Grey* colour and *Stroke width* (line thickness) 0.15mm
- *Major cities* – choose *Black colour* and *Size* (diameter of point) as 1.0mm

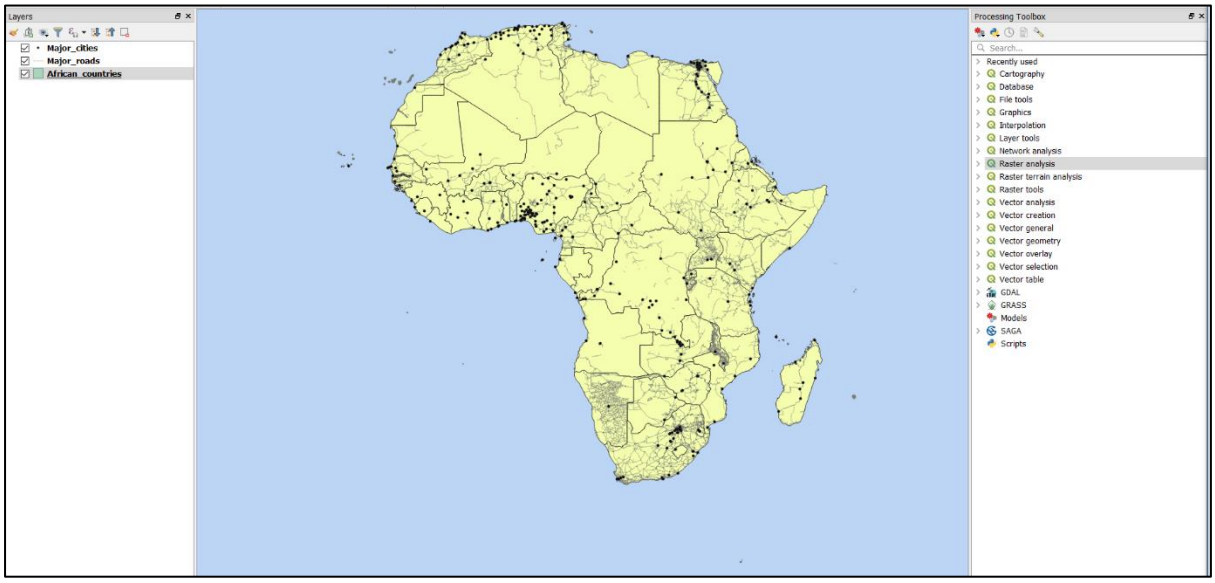


We can change the background colour of the *Display window* to represent the sea surrounding Africa. This can be done by:

- Click on the tab *Project* located on the top *Menu toolbar*, and then click on *Properties*
- The *Project Properties* menu will appear – click on the arrow for the *Background colour* section and select *Sea Blues* from the colour-wheel
- Click *Apply* and *OK*



The resulting atlas appear as follows in the Display window:



Now that we are done constructing our Atlas, we can end this project by saving it – click on the save icon  to save and overwrite "*Lesson_1.qgs*".

Summary

We constructed a basic Atlas showing the locations of big cities and roads in Africa, and familiarised ourselves with adding shape files in QGIS, and knowing what constitutes a **point**, **line** and **polygon** data. Finally, we learnt how to modify the appearance of these vector data by accessing their properties.

In the next tutorials, we will focus on the data science of managing spatial layers – the optimal way of arranging vector layers in the *Layer Panel* and modifying their properties for optimal visualisation. We also learn how to import spreadsheet data containing attribute information and perform spatial joins. Ultimately, these techniques will be used visualise the distribution of poverty in Nigeria.

Appendix: Lesson 1

Data source(s)

Datafile	Format	Source
African_countries	Shape file	https://gadm.org/download_world.html
Major_cities	Shape file	https://gadm.org/download_country_v3.html
Major_roads	Shape file	http://www.diva-gis.org/Data

Citation(s)

1 Global Administrative Areas (2012). GADM database of Global Administrative Areas, version 2.0. [online] URL: www.gadm.org

Lesson 2: Layer management and properties in QGIS

Introduction

In the previous tutorial - we learnt how to add vector to QGIS; however, we did not discuss about layer management. When adding spatial data QGIS will arrange them in such manner whereby the layers are superimposed on top of each other. It is important to note that a layer like those of **polygons**, when its superimposed on **point** or **line** data – can completely mask information of **points** and **lines**. Similarly, for **polygons** as well – for example, the extents of a district can be masked out completely by a higher administrative boundary (e.g. state- or country-level).

In this tutorial, we will strictly be dealing with vector **polygon** data. Here, we will focus on effective ways of layer management and further ways for modifying the properties of the layers. Further layer management includes spatial joins to harmonise spatial and non-spatial data. Ultimately, these techniques will lead us to construct an Atlas for Nigeria showing the burden of poverty across all districts.

If you have not already, please make sure to download the corresponding dataset for lesson 2 by going to our website on http://development-frontiers.com/tutorials/

Layer management

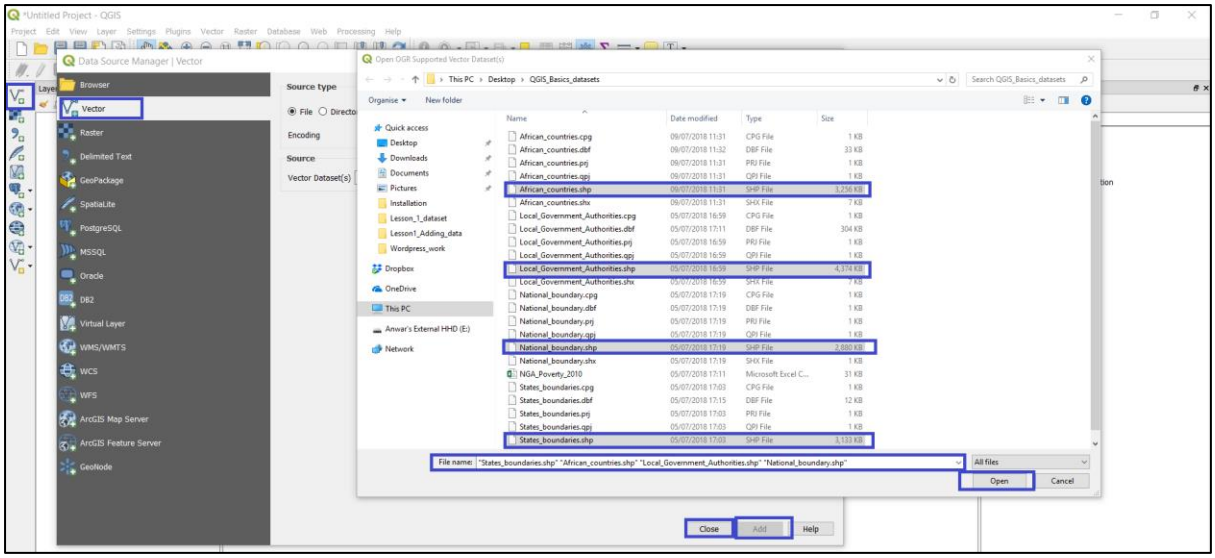
Open *QGIS Desktop 3.2.0* by clicking on the icon  and then open a *New Project* for this practical session and save it as "*Lesson_2.qgs"*

Let's begin by adding all at once the following vector layers into the *Display window*:

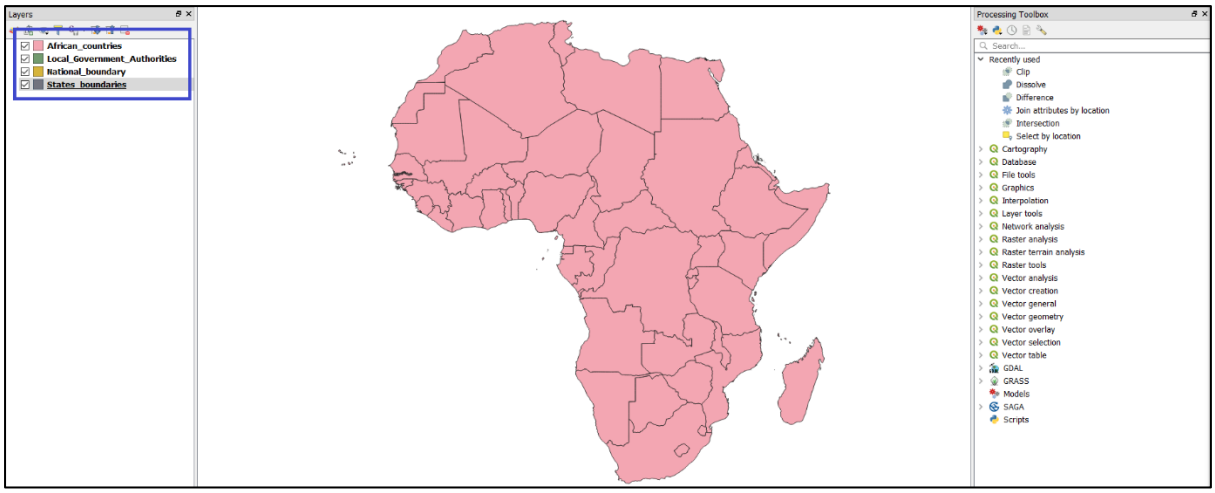
- *African_countries.shp* (shape file for all countries in Africa)
- *National_boundary.shp* (shape file for Nigeria's national borders)
- *State_boundaries.shp* (shape file for Nigeria's state borders)
- *Local_Government_Authorities.shp* (shape file for Nigeria's districts)

You can load everything in to the Display window by selecting the files with extension (*.shp*) by holding the CTRL button each time you click on a shape file:

- Click on the *Add Vector Layer* icon  in the *Layer Toolbar*. This will bring up a small menu called the *Data Source Manager*
- Data Source Manager allows the user to navigate the directory to select their data. Click on the Browse button  and go to the location of your downloaded data and select the listed shape files by holding the CTRL button and clicking on them. Make sure to select only files with extensions ending with (*.shp*)
- The list of selected files will appear *File name*. Click on *Open*
- Click on the *Add* button to add the shape files into the *Display window*
- Click *Close* to close the *Data Source Manager* menu



The shape files for Africa, and corresponding national and administrative borders for Nigeria have been added as a layer – you can see this in *Layers Panel*.

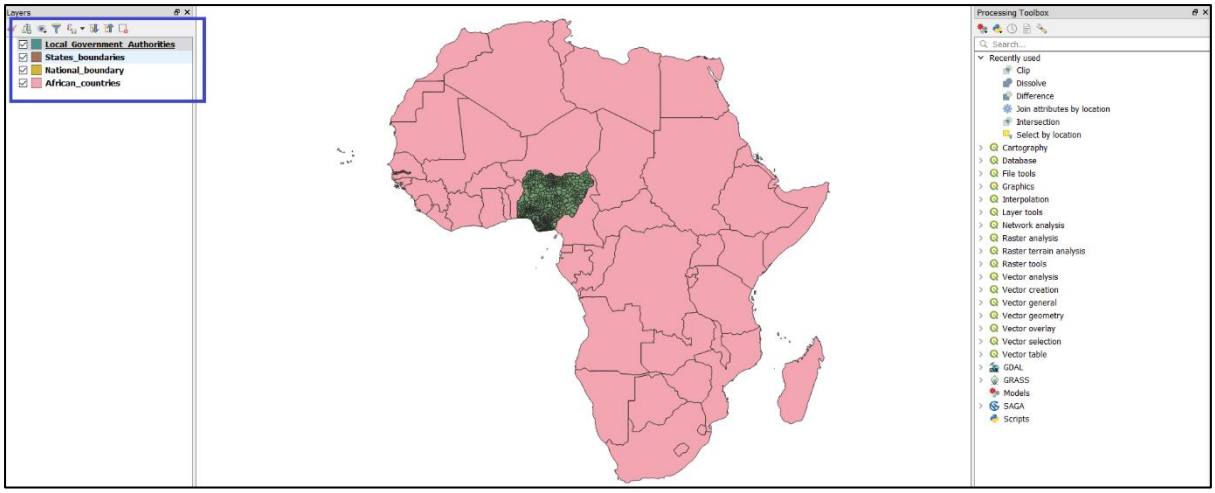


Notice, the layers are arranged in orderly manner. You can inspect the order of the layers by unchecking their tick boxes ☑ to deactivate them. By checking them you will see that the layer showing the African countries covering details about the administrative boundaries for Nigeria.

The *ideal* arrangement of these layers are:

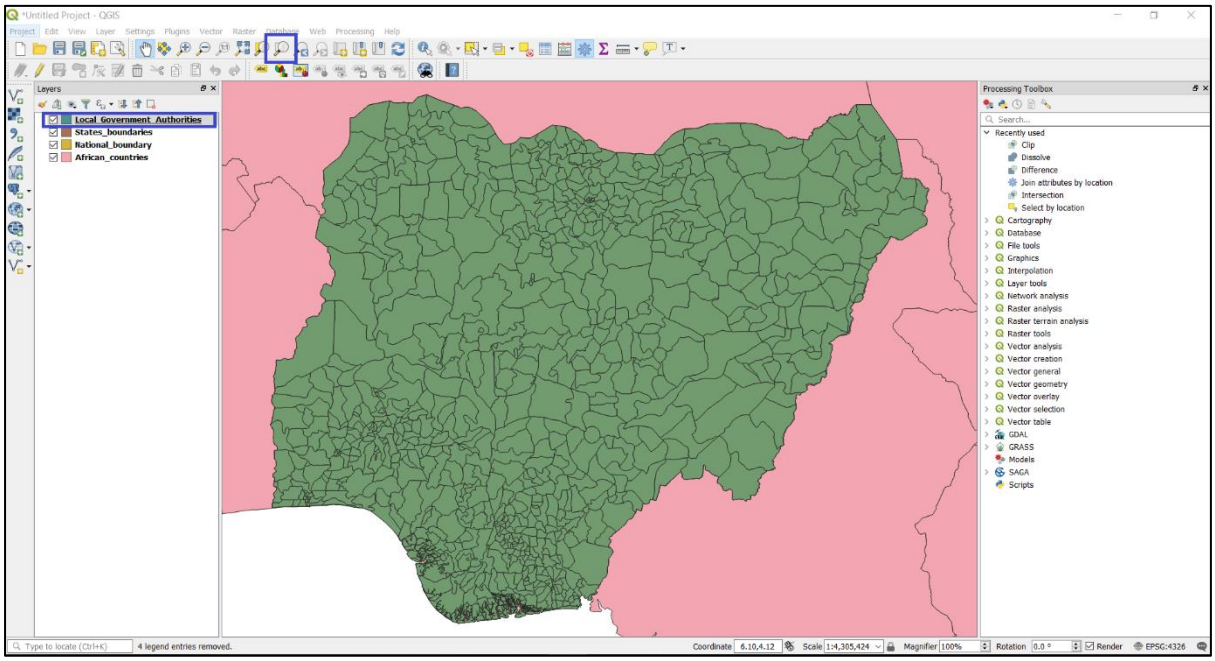
- *Local_Government_Authorties.shp*
- *States_boundaries.shp*
- *National_boundary.shp*
- *African_countries.shp*

We can manipulate the layers by simply dragging them (up or down) to order in the *Layers Panel*:



In theory, this is the ideal arrangement for most layers. However, it is not the **OPTIMAL** because it deprives us for seeing **States**, to which, the **Local Government Authorities (LGA)** belong to. You can zoom to the extents of Nigeria see this notion:

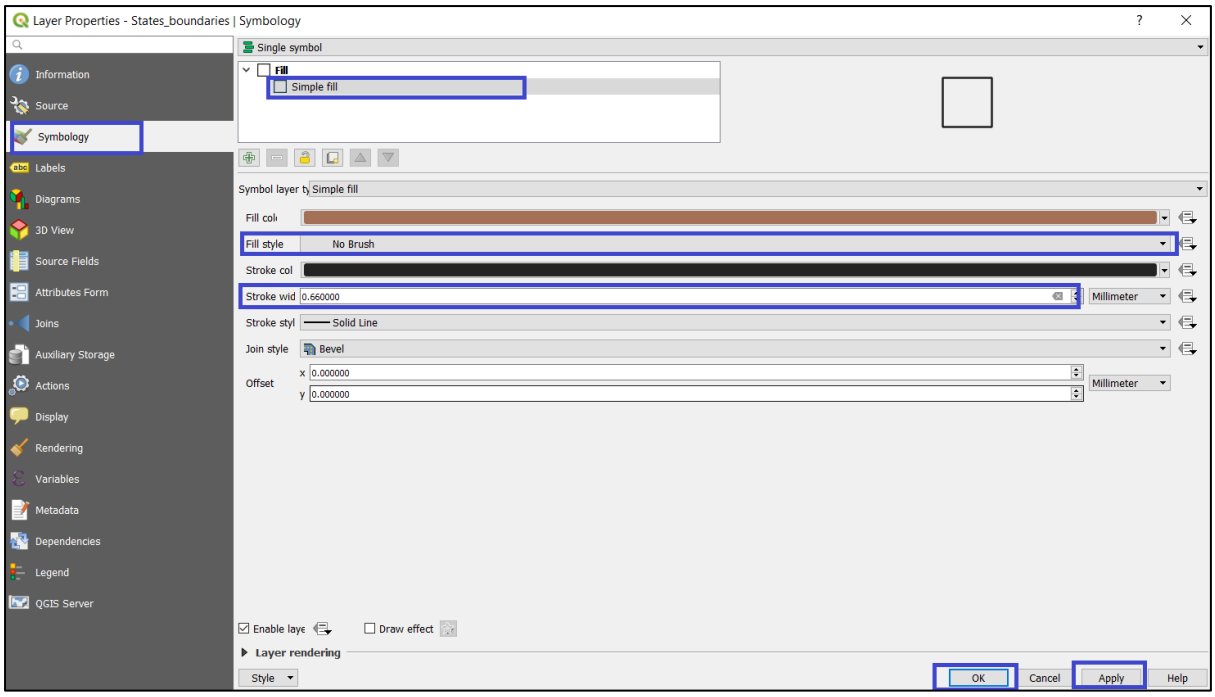
- Click on the *Local_Government_Authority* layer in the Layer Panel to highlight selection
- Click on the *Zoom To* layer icon to view the extent of *Local_Government_Authority*

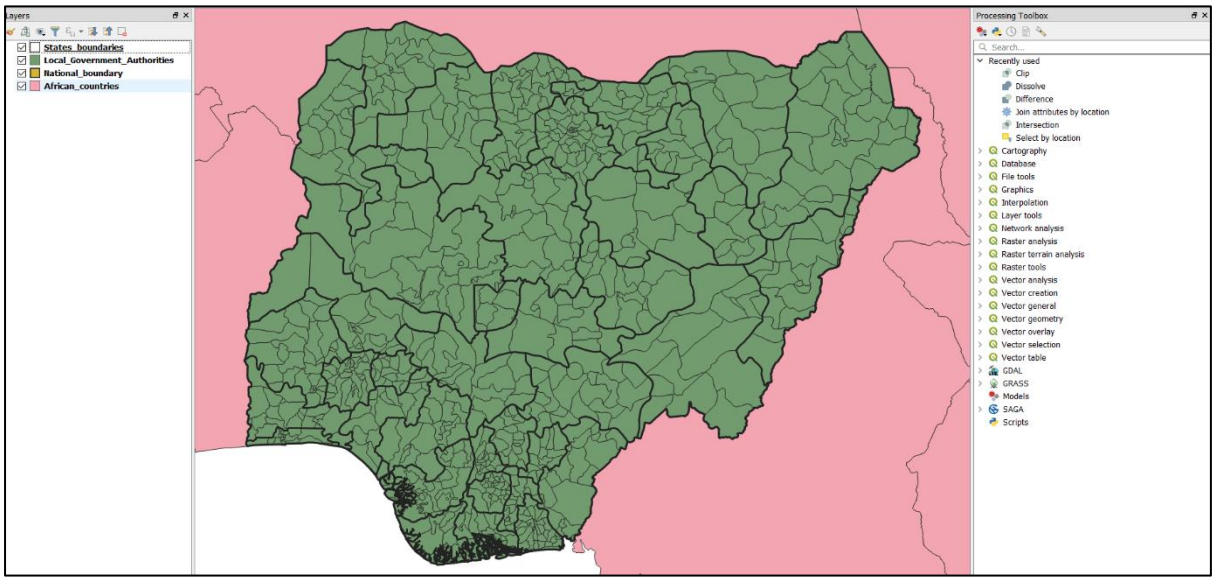


In order to the **States** without entirely covering the **LGAs** - we will need to first superimpose and make this topmost layer and then manipulate its layer properties by rendering it transparent:

- Drag the *State_boundaries* shape file in the *Layers Panel* to the top
- Next, right-click on the *State_boundaries* and select *Properties* to access it *Layer Properties* menu
- Select *Symbology* on the left-hand side of the *Layer Properties* menu
- Select *Simple fill* in the which is located in the top white box on the right-hand side of the *Layer Properties* menu

- We want to change two parameters: *Fill style* and *Stroke width* (i.e. line thickness). In the *Fill style* select *No Brush* to render polygons transparent. Change the *Stroke width* by typing 0.66 (in mm). **Important note**: the first action will let us see through the areas of the **State** polygons so as to visualise the **LGAs** while enabling us to visualise its borders as well. The second action will help us distinguish between the borders.
- Click on *Apply* and *OK*



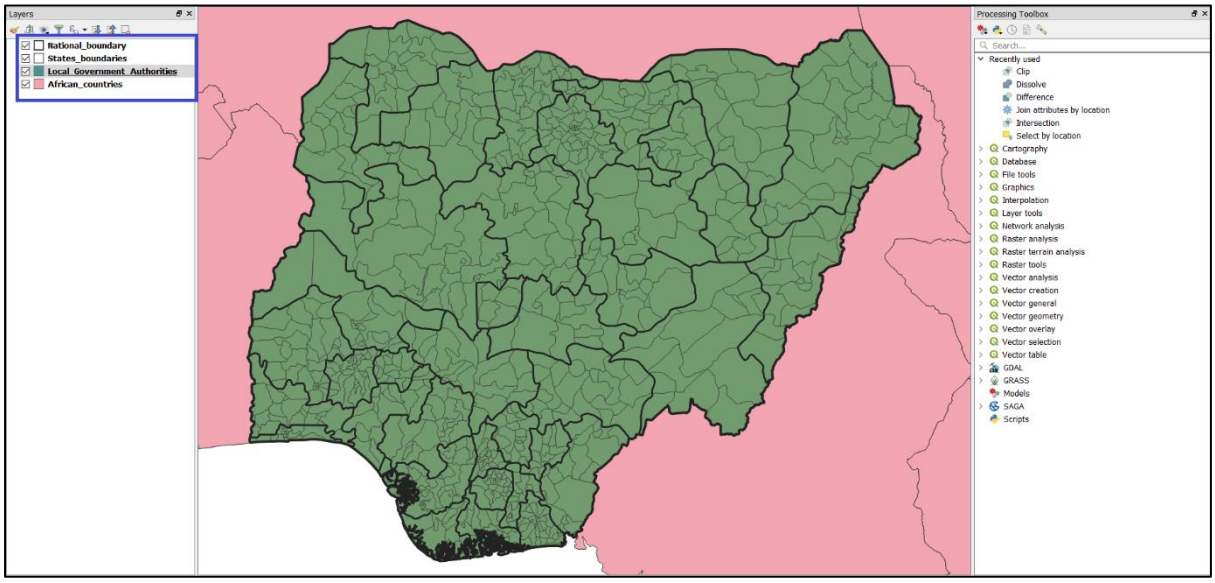


We've render the States layer transparent – we see through it areas to visualise the **LGAs** while, at the same time, enabling us to visualise its borders.

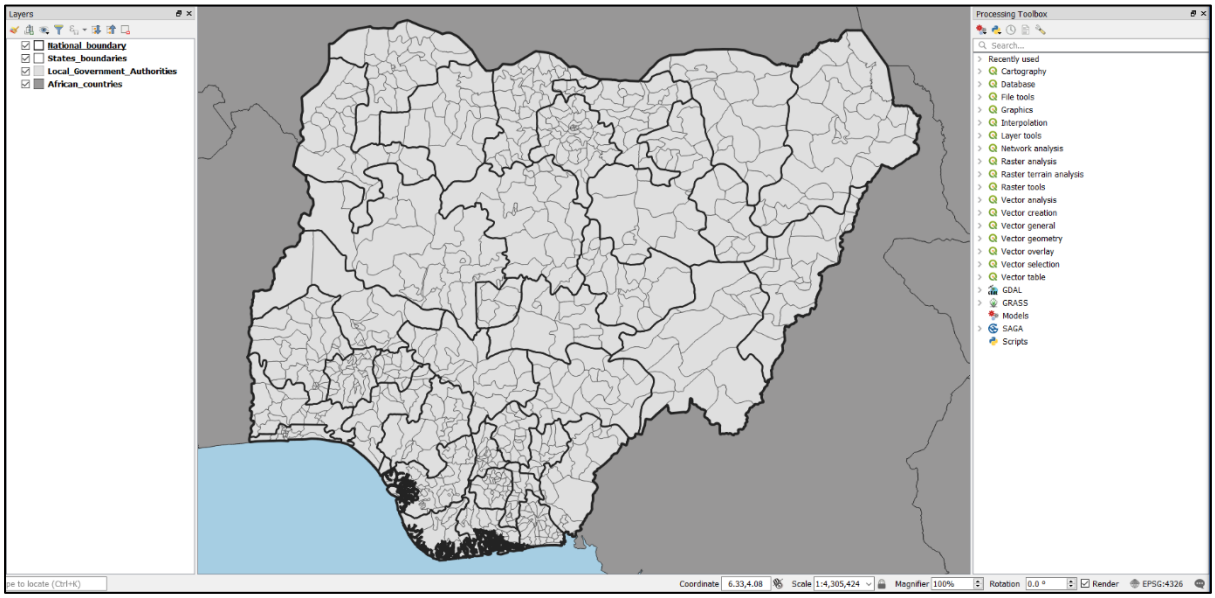
Why don't repeat the above steps for Nigeria's national borders (*National_boundaries*) by making this the topmost layer and applying the following changes: *Fill style* as *No Brush* and *Stroke width* as 1.00 (mm).

Finally, lets add this change to the *Local_Government_Authorities* layer: *Stroke width* as 0.16 (mm).

The resulting layer should be as follows:



This is the best arrangement for these type of vector layers. Let us add some final touches by adding the colour of the sea, and changing the Fill colours for the **LGAs** and **Africa countries** using Light Grey and Dark Grey, respectively. Do you recall the steps used in **Lesson 1**?



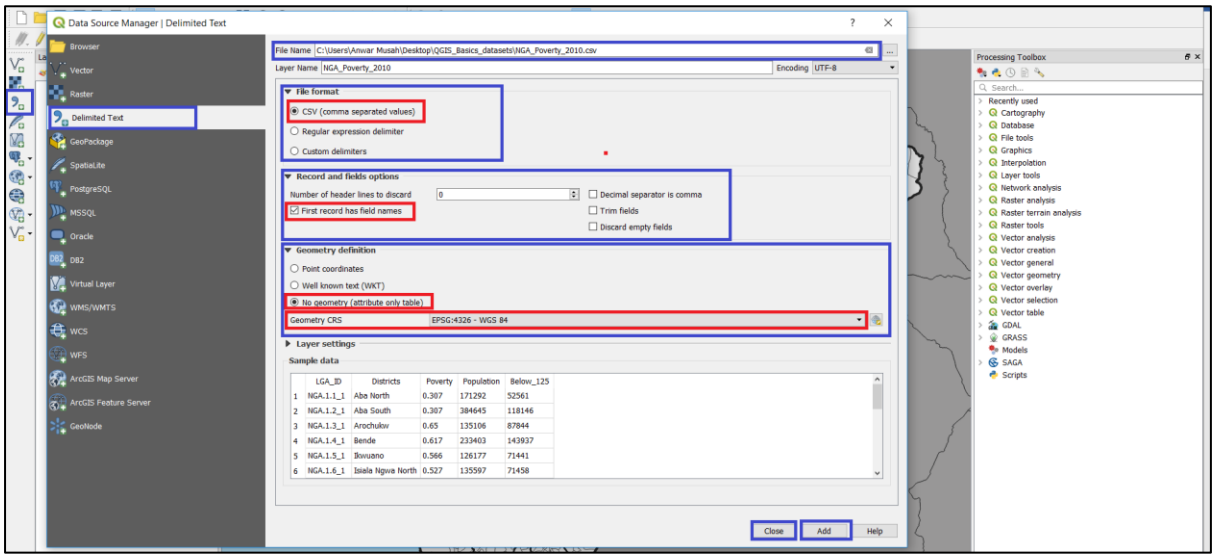
Nice! We have established a good template to which we can construct our showing levels of poverty. Now is great time to save our progress for this project by clicking on the save icon 

Importing non-spatial data and performing spatial joins

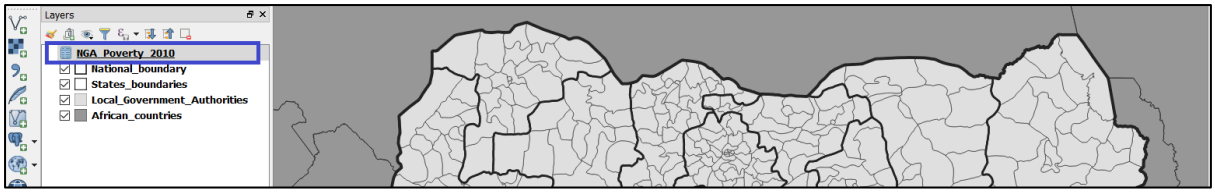
We have provided a non-spatial data as an excel spreadsheet (comma separated values (.csv)) which contains LGA-level prevalence of poverty (the fraction of population living in poverty as defined by $1.26 (= £0.96) a day) in 2010.

We can import this in the following steps:

- Click on the Add delimiter icon and search for data set by clicking on browse button . Select the excel sheet (.csv) *NGA_Poverty_2010.csv*
- Under File Format, click on the check box *CSV (comma separated values)* to tell QGIS we are import a spreadsheet of this format
- Expand the ***Record and fields options*** and make sure the section *First record has field names* is checked. Here, we are telling QGIS that the file has column names.
- Expand the ***Geometry definition*** and make sure *No geometry (attribute only table)* is checked. Here, we are telling QGIS that this is a non-spatial dataset. Make sure as well that the *Geometry CRS* is *ESPG:4326 – WGS 84*
- Click on *Add* and *Close*

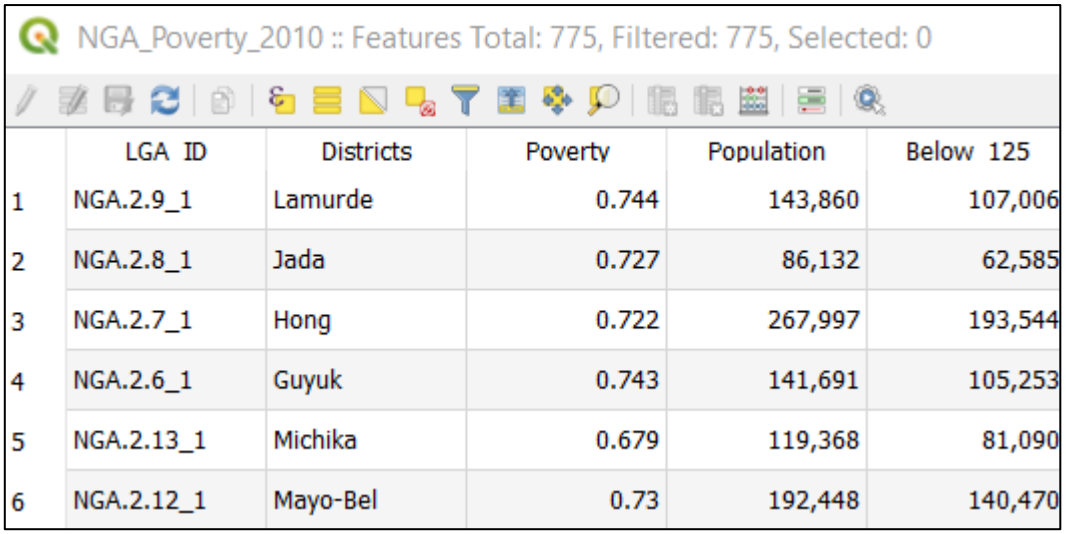


The imported data will appear as an attribute table in the *Layers Panel*.



QGIS allows the user to access the attribute tables of both spatial and non-spatial data. To see the contents to the imported data – you can simply right-click on *NGA_Poverty_2010* in the *Layers Panel* and select *Open Attribute Table*. You can see that the data contains five fields:

- **LGA_ID**: Unique identification code for LGAs
- **Districts**: The name of the LGAs in Nigeria
- **Poverty**: Estimated levels (or prevalence) of poverty in a LGA
- **Population**: Overall number of people in a LGA at 2010
- **Below_125**: Estimated number of people living in poverty in 2010 (below $1.25 (= £0.96) a day)

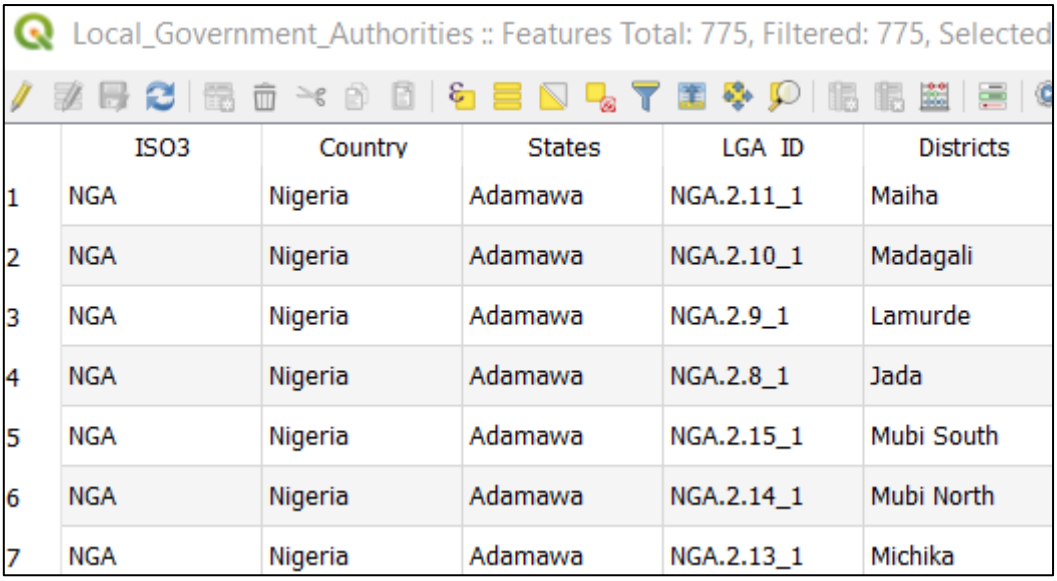


NGA_Poverty_2010 :: Features Total: 775, Filtered: 775, Selected: 0

	LGA_ID	Districts	Poverty	Population	Below_125
1	NGA.2.9_1	Lamurde	0.744	143,860	107,006
2	NGA.2.8_1	Jada	0.727	86,132	62,585
3	NGA.2.7_1	Hong	0.722	267,997	193,544
4	NGA.2.6_1	Guyuk	0.743	141,691	105,253
5	NGA.2.13_1	Michika	0.679	119,368	81,090
6	NGA.2.12_1	Mayo-Bel	0.73	192,448	140,470

We want to map the field **Poverty**; however, we cannot do much with this attribute table unless we merge it with some other spatial data. Now, open the attribute table for the LGA layer by right-clicking on *Local_Government_Authorities* and selecting *Open Attribute Table*. You can see this also contains five fields:

- **ISO3**: A three-digit unique identification for a country
- **Country**: The name country of LGAs
- **States**: The names of Nigerian states
- **LGA_ID**: Unique identification code for LGAs
- **Districts**: The name of the LGAs in Nigeria



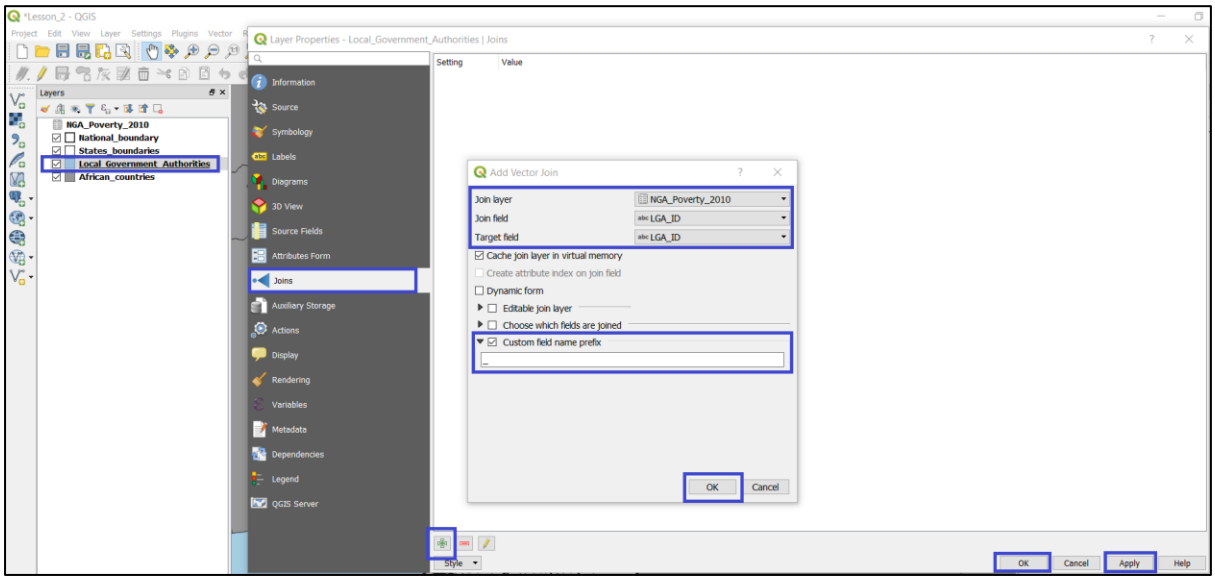
Local_Government_Authorities :: Features Total: 775, Filtered: 775, Selected

	ISO3	Country	States	LGA_ID	Districts
1	NGA	Nigeria	Adamawa	NGA.2.11_1	Maiha
2	NGA	Nigeria	Adamawa	NGA.2.10_1	Madagali
3	NGA	Nigeria	Adamawa	NGA.2.9_1	Lamurde
4	NGA	Nigeria	Adamawa	NGA.2.8_1	Jada
5	NGA	Nigeria	Adamawa	NGA.2.15_1	Mubi South
6	NGA	Nigeria	Adamawa	NGA.2.14_1	Mubi North
7	NGA	Nigeria	Adamawa	NGA.2.13_1	Michika

We can merge the attribute table (i.e. *NGA_Poverty_2010*) with our spatial data (i.e. *Local_Government_Authorities*) using a common field, in which, its **LGA_ID**. To perform this spatial join – you must:

- Right-click on *Local_Government_Authorities* and select *Properties* to access its *Layer Properties* menu

- On the left-hand side of the Layer Properties menu select *Joins* and click on the *green plus sign* to choose the layer (or attribute table) you wish to join with *Local_Government_Authorities*
- Another menu called the *Add Vector Join* with appear. Under *Join layer* select the attribute table *NGA_Poverty_2010*
- Next, under *Join field* select **LGA_ID**. Here, we are telling QGIS that we want to use the field **LGA_ID** from *NGA_Poverty_2010* as our joining field
- Under Target field select **LGA_ID**. Again, we are telling QGIS that we want to use **LGA_ID** from *Local_Government_Authorities* as our joining field
- Check the tick box for Custom field name prefix and expand this section. Place an underscore '_' in the space.
- Click OK on the Add Vector Join menu
- Click Apply and OK to finalise joins



Open the attribute table of *Local_Government_Authorities* to view it contents. As you can see, spatial join has linked the two dataset via **LGA_ID** added the fields from the attribute table (i.e. *NGA_Poverty_2010*)**.** Now, let's save this new spatial dataset as a shape file and name as *LGA_Poverty_Prevalence_2010.shp*.

You can do this by:

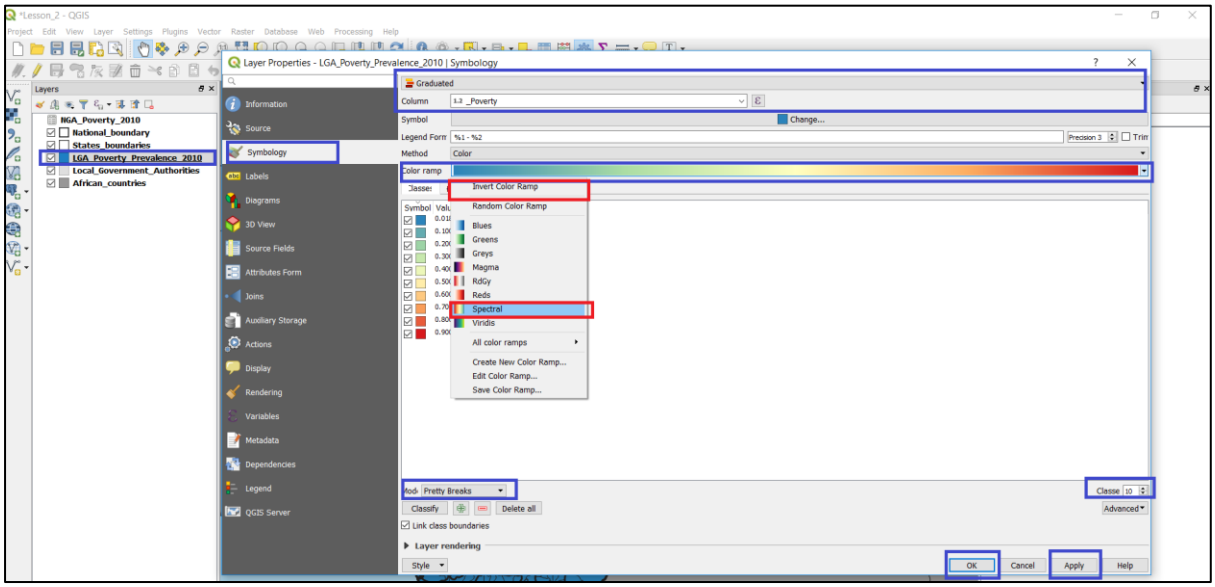
- Right-clicking on *Local_Government_Authorities* and selecting *Export*, and then *Save Features as…*
- The *Save Vector Layer as…* menu will appear. Under *Format* select *ERSI Shapefile*
- Under File name, click on the browse button ... and select the destination to save your shape file. Here, name it as *LGA_Poverty_Prevalence_2010.shp*
- Make sure the *Coordinate Reference System (CRS)* is set to *EPSG:4326 – WGS84*
- Make sure the *Add saved file to map* is checked
- Click *OK*

This should add new shape file containing our estimates to *Layers Panel*. We have a quite a lot data management in QGIS. We are now in the position to construct our poverty maps in the *Display window*.

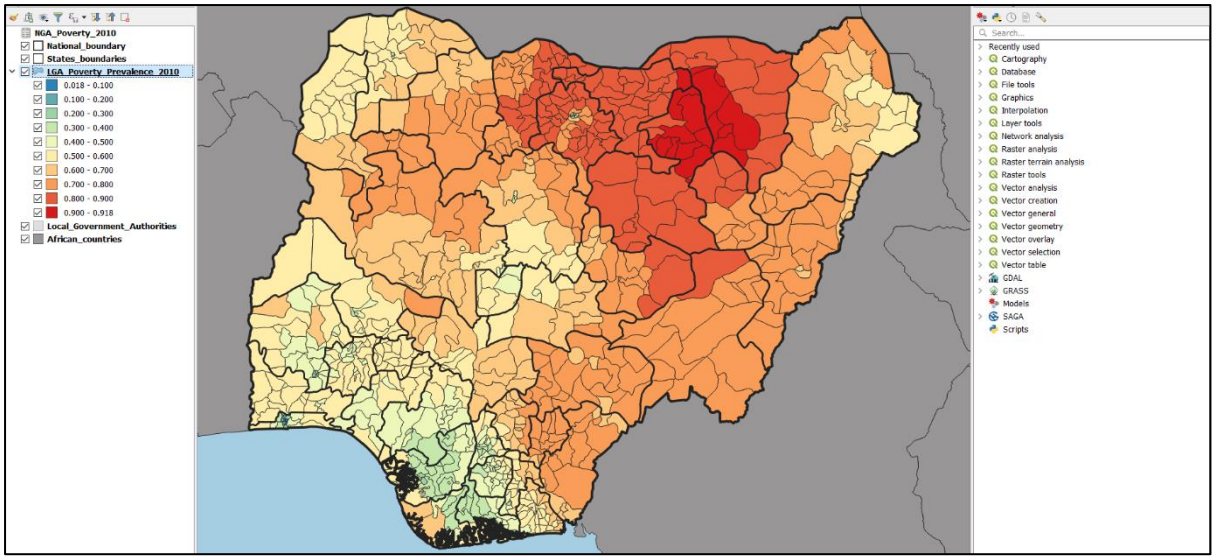
Map construction

We can generate a map showing the burden of poverty in Nigeria. The steps are as follows:

- Right-click on the *LGA_Poverty_Prevalence_2010* and select *Properties* to access its *Layer Properties* menu
- On the left-hand side of the *Layer Properties* menu select *Symbology* tab and at the topmost section of the menu select *Graduated*
- We want to display **Poverty**. In *Column* select the field name "*_Poverty*"
- In *Colour ramp*, click the arrow to expand the selection of colours and choose *Spectral*. Choose *Invert Colour Ramp* as well to invert the order of *Spectral* colours.
- In *Mode*, you can specify the method for which classes are generated (i.e. *equal interval*, *quantile*, *natural breaks*, *standard deviation* or *pretty breaks*). For this example – select *Pretty Breaks* and type *10* in *Classes* to generate *ten* intervals
- Click *Apply* and *OK*



The resulting map should be as follows:



You can see the LGA-level prevalence of poverty in 2010 are represented as a legend under layer LGA_Poverty_Prevalence_2010 with the lowest intensity represented by deep blues and highest as deep reds.

Now that we are done constructing our Atlas, we can end this project by saving it – click on the save icon  to save and overwrite "*Lesson_2.qgs*".

Summary

We constructed a basic Atlas showing the LGA prevalence of poverty in Nigeria. We learnt some steps on how manage layers to get the best arrangement for optimal visualisation. We done further layer manipulation of layer properties and symbology. Finally, we conducted spatial joining of both spatial and non-spatial data sets.

So far, we've only constructed our maps in the *Display window*. The next step is to learn how to create high quality publication style maps in QGIS' Print Composer – this is useful especially if one needs to create maps for articles or share results with other stakeholders or researchers.

Appendix: Lesson 2

Data source(s)

Datafile	Format	Source
African_countries	Shape file	https://gadm.org/download_world.html
National_boundary	Shape file	https://gadm.org/download_country_v3.html
States_boundaries	Shape file	https://gadm.org/download_country_v3.html
Local_Government_Authorities	Shape file	https://gadm.org/download_country_v3.html
NGA_Poverty_2010[1]	CSV	http://www.worldpop.org.uk/data/summary/?doi=10.5258/SOTON/WP00200

Citation(s)

1 Global Administrative Areas (2012). GADM database of Global Administrative Areas, version 2.0. [online] URL: www.gadm.org

2 Tatem AJ, Gething PW, Bhatt S, Weiss D and Pezzulo C (2013) Pilot high resolution poverty maps, University of Southampton/Oxford. DOI: 10.5258/SOTON/WP00200

[1] Prevalence of poverty was calculated to LGA-level from raster data created by WorldPop.org.

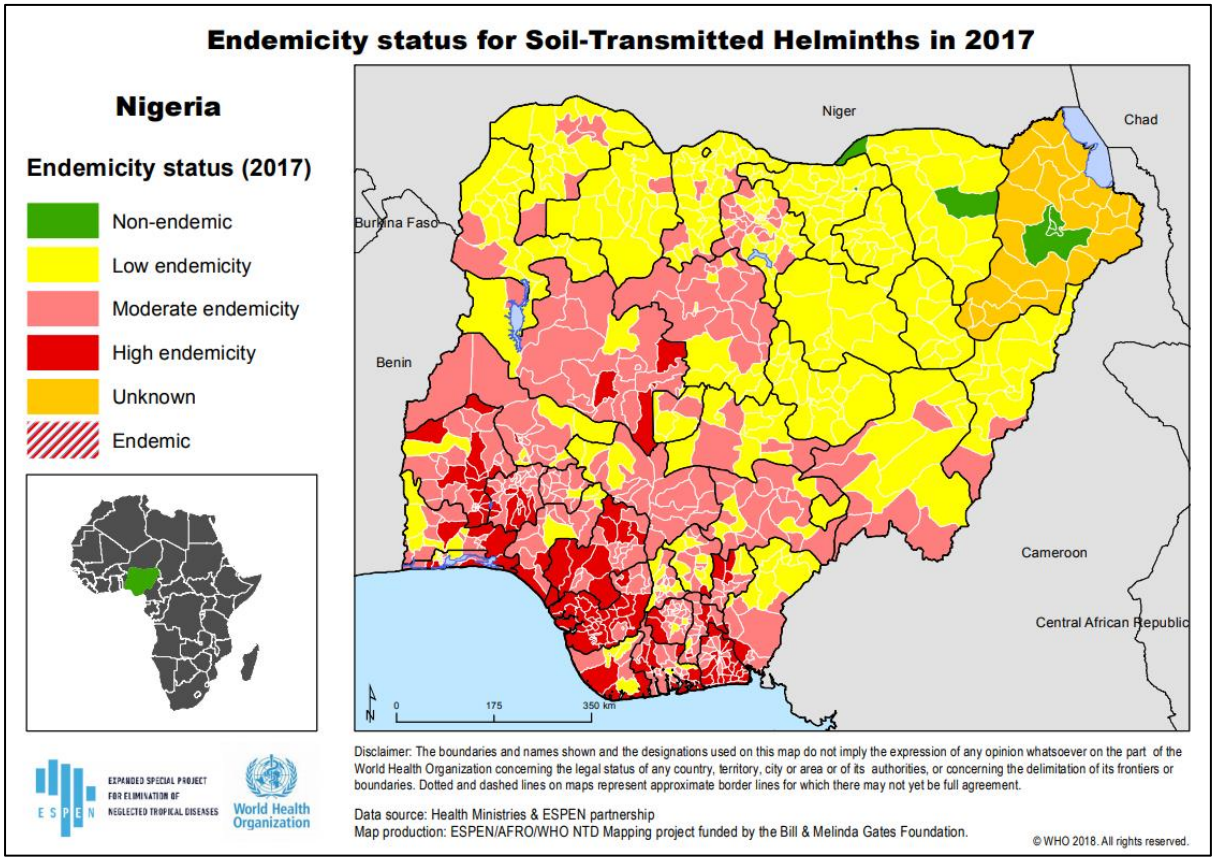
Lesson 3: Visualisation using Print Composer in QGIS

Introduction

Up until this point, we focused on layer arrangement and the constructions of atlas in the *Display window* of QGIS. The maps made in the *Display window* are, however, not in a printable format. In order to share maps whether it's a figure image in an article or for researchers and stakeholders – one can use the **Print Composer** tool to add finishing touches and export the maps to other formats for printing.

You can create expert and professional maps using tool. It provides the user with a blank map canvas to which you can add the constructed map from the *Display window*. You can use this creative tool to add other important features such as the arrow, scale bar, legend, title and map inset.

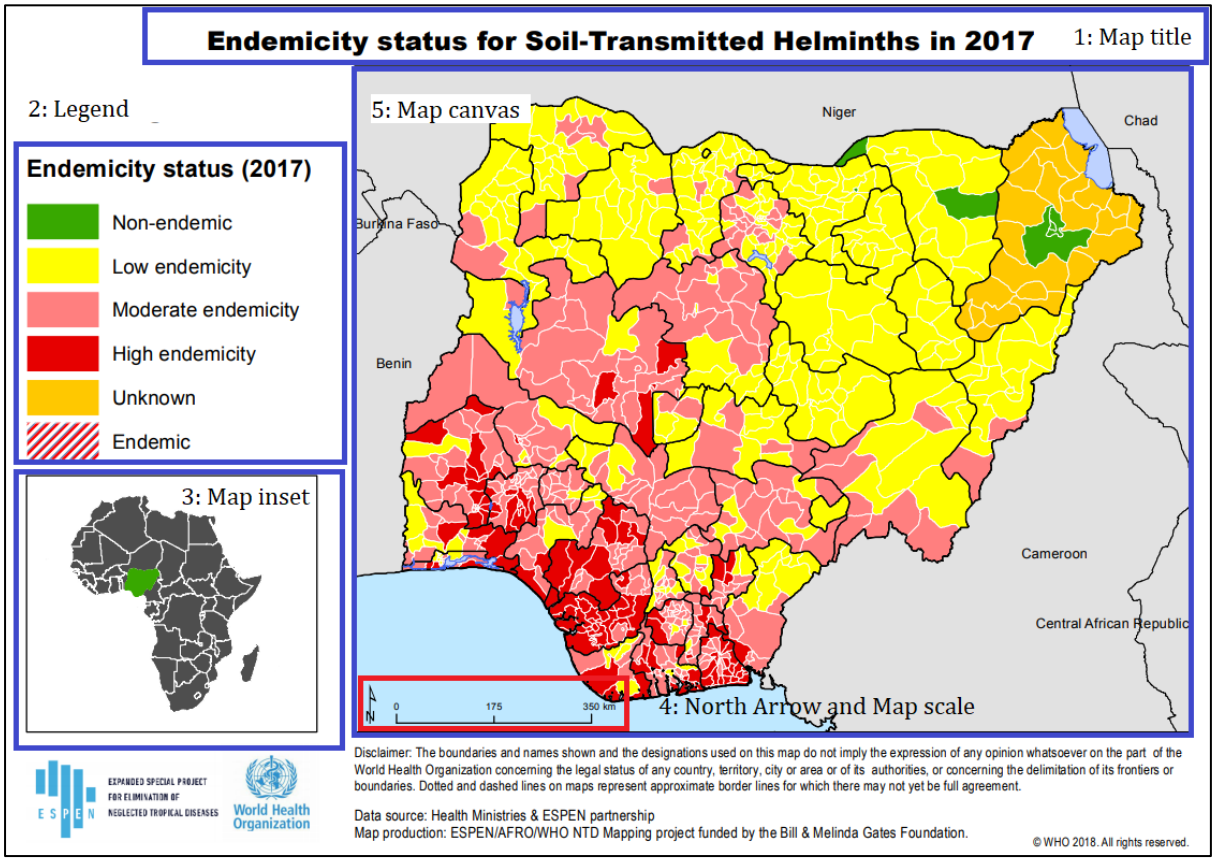
Here is an example of a completed map in **Print composer**:



This is an example of an epidemiological map showing details of the endemicity status of soil transmitted helminth infections (an intestinal parasitic worm) in local areas of Nigeria[2]. Can you spot all the important features and finishing touches for this map?

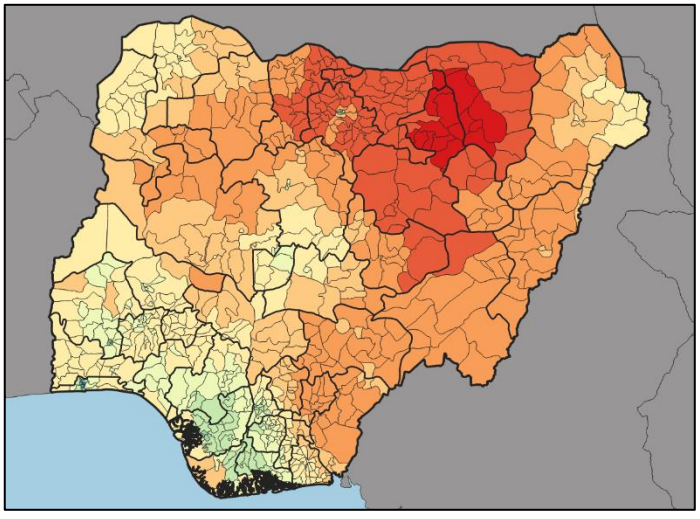
[2] Source image: Expanded Special Project for Elimination of Neglected Tropical Diseases (ESPEN) (http://espen.afro.who.int/countries/nigeria)

Take a look carefully at the image below. We have highlighted all the essential features that should be included in a completed map.



Remember we constructed an atlas in lesson 2 which showed the LGA prevalence of poverty in Nigeria. This lesson continues from where we left off in lesson 2. We are going to use the **Print Composer** to apply the finishing touches and create a printable map for dissemination.

Prerequisites



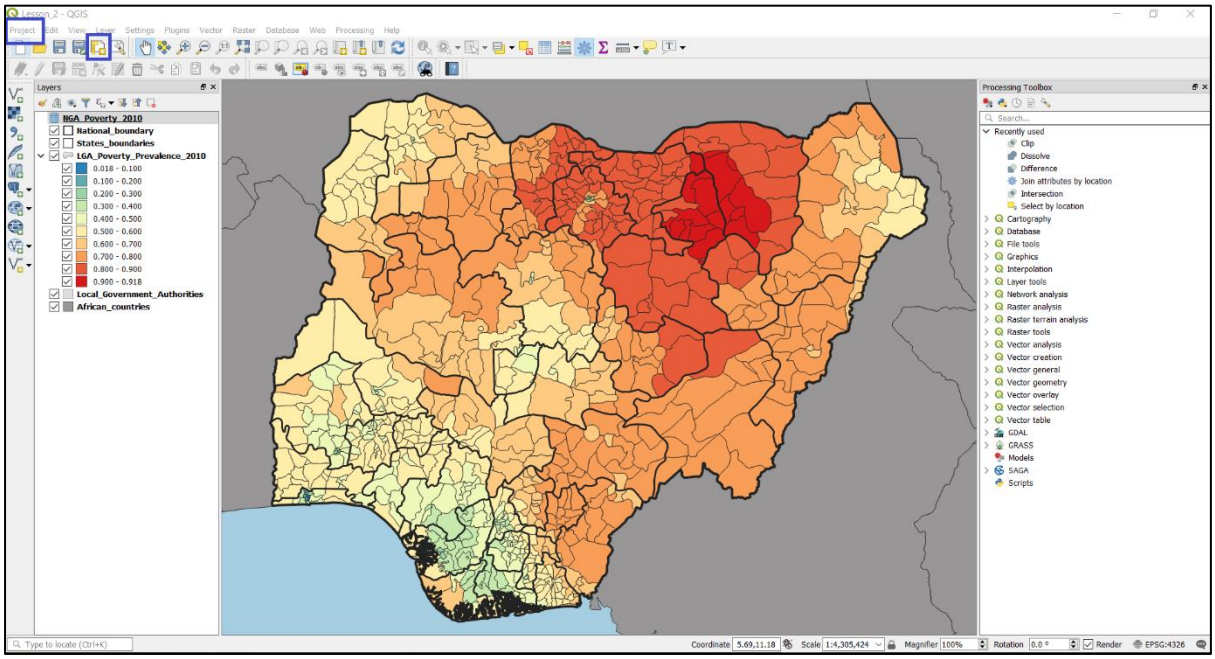
To attempt lesson 3, you need to have downloaded the data sets for lesson 2 and gone through its entire manual to have produced the following map:

You will need to have saved your progress as a *project* and named it as '*lesson_2.qgz*'

We are going to load it for this session. To load the last (or open an existing) project – open *QGIS Desktop 3.2.0* and click on the *Open Project folder* icon located in the menu toolbars. Navigate to the file's location and open *lesson_2.qgz*

Make sure you have the resulting map *LGA_Poverty_Prevalence_2010* is active (see above image)

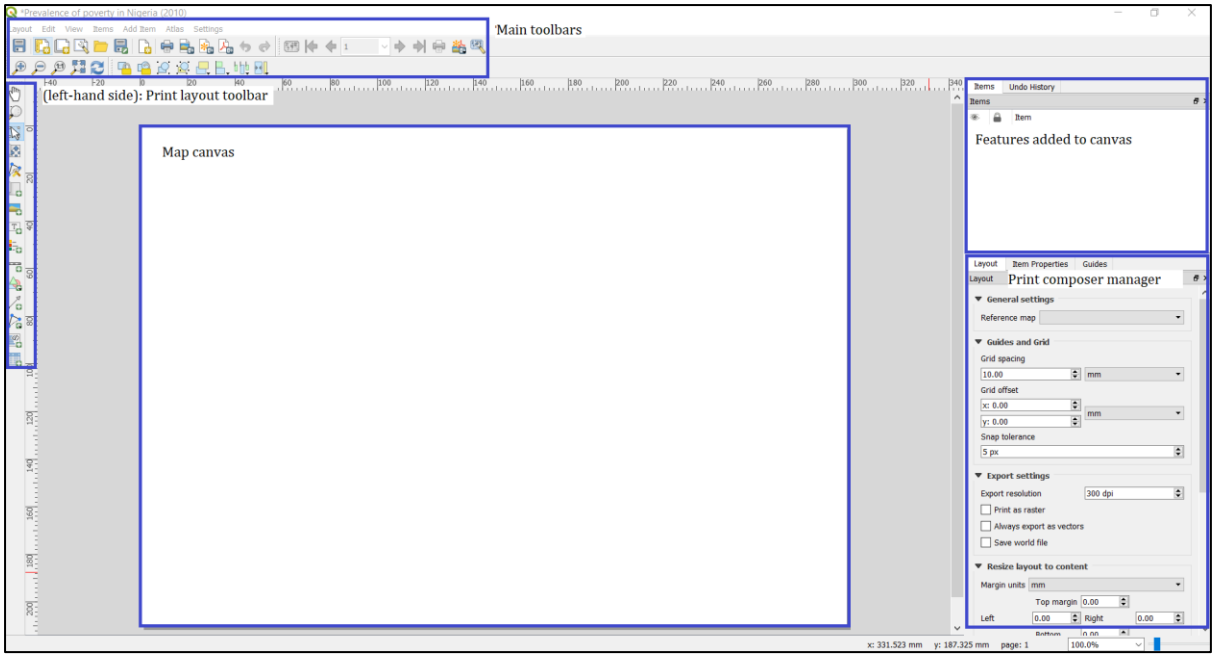
Opening Print Composer tool in QGIS



There are two ways to open the *Print Composer* tool in QGIS. The first and quickest approach is for you to click on the *New Print Layout* icon  located on the menu's toolbar. The alternative way is to click on the *Project* tab, then navigate to the *New Print Layout* and select its tab.

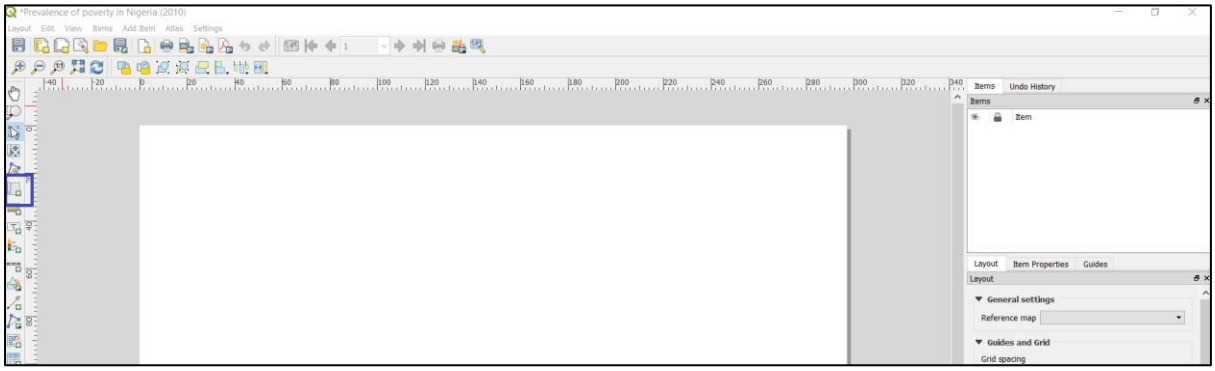
You will be greeted with a small window *Create print layout Title* which prompts the user to enter a unique title for the print layout title. Type in this section: "*Prevalence of poverty in Nigeria (2010)*" and *OK* to open the *Print Composer* window.

The image below provides a quick overview of the layout in *Print Composer* (sections are labelled):

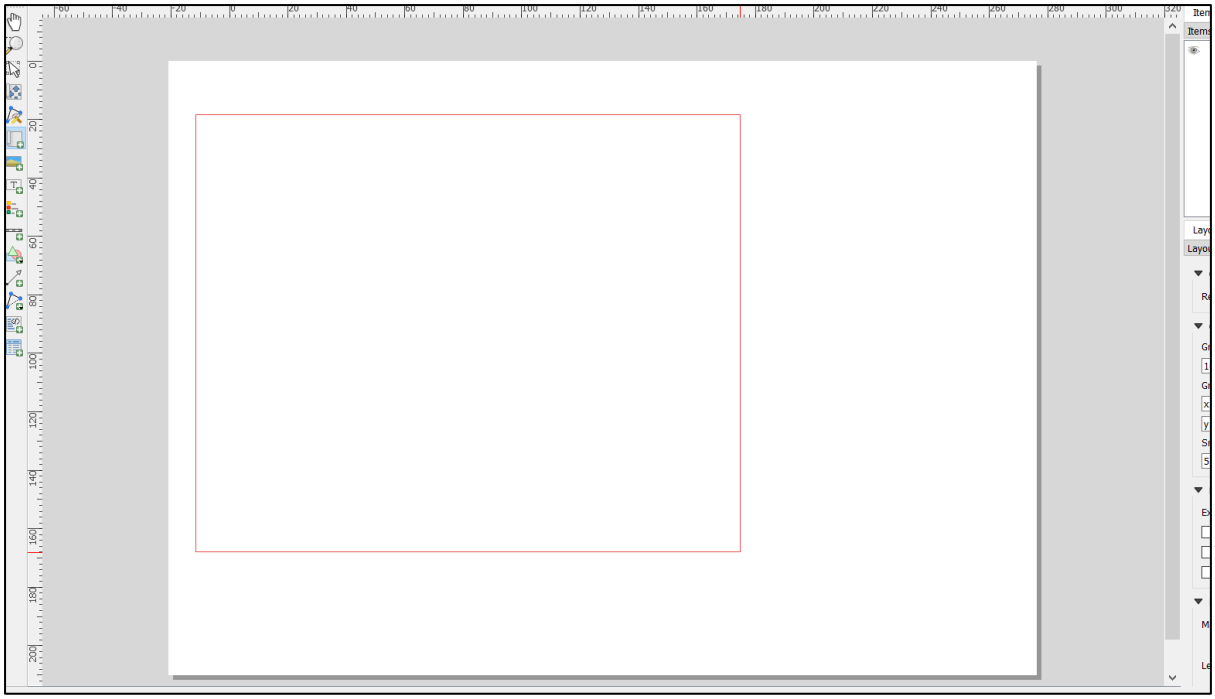


Now, on the left-hand side of the *Print Composer* is the *Print Layout toolbar*. This section allows us to add the information we need to create out publication style map. When using this tool – you will always be working between the *Print Layout toolbar* and *Print Composer Manager* (located on the right-hand side of the panel). The latter is used to make further alterations to the properties of the map.

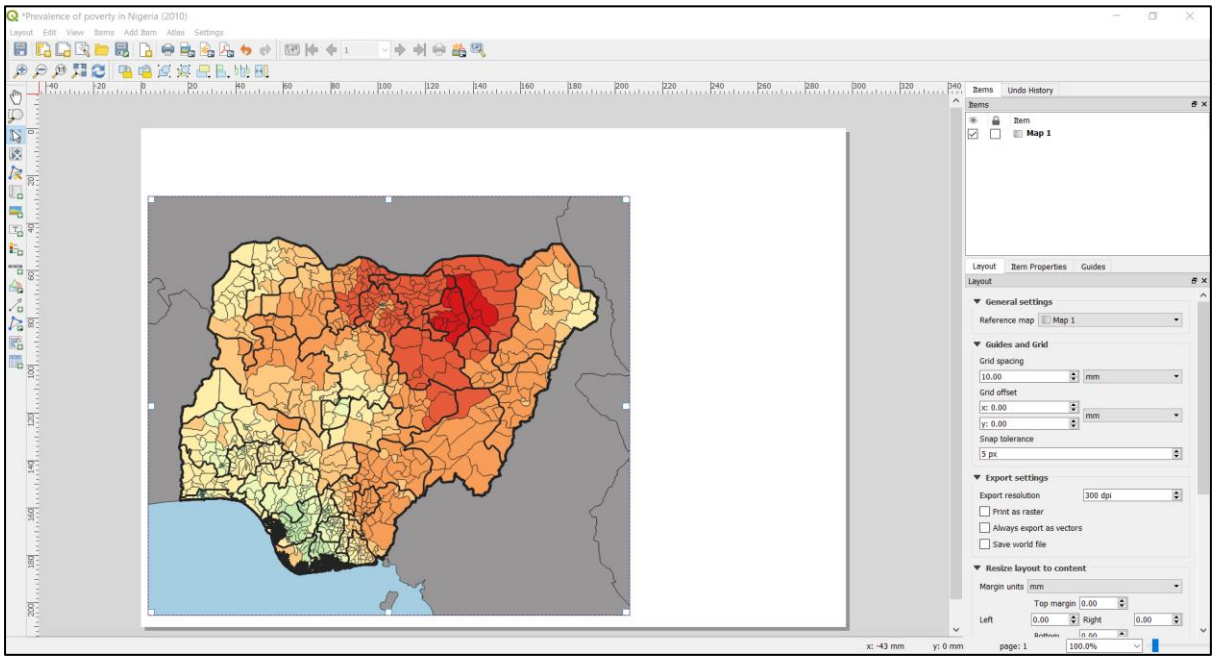
Adding the current map from the *Display window* to *Print Composer*



- To add the current map from the *Display window* to *Print Composer* – click on the *Add new map to the layout* icon located on the left-hand side in the *Print Layout toolbar*
- Click and drag the crosshair cursor on to the map canvas to draw outline of a quadrilateral on map canvas (see image below)



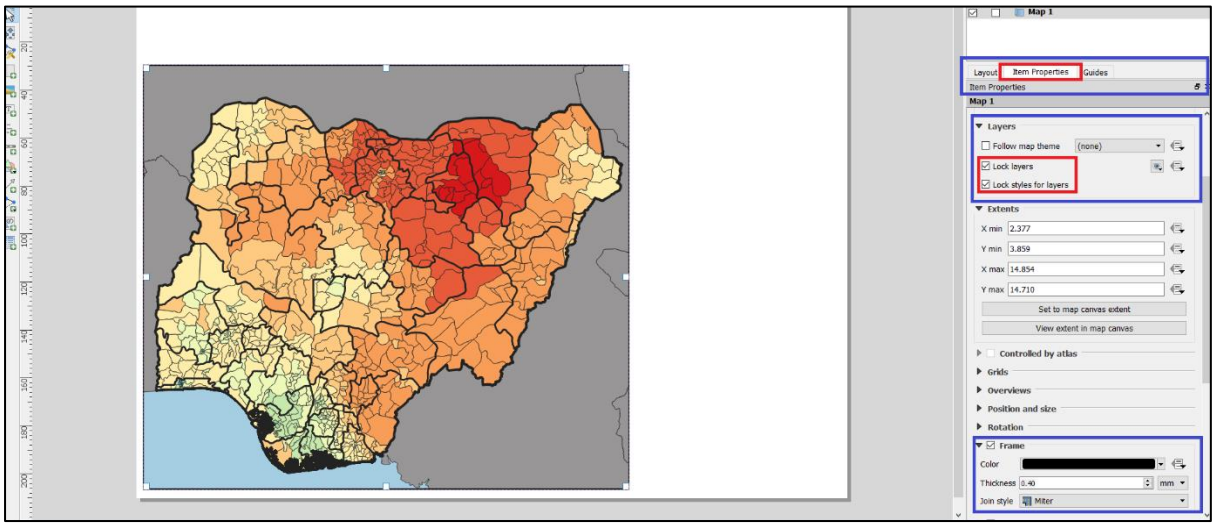
- The image will appear when the crosshair cursor is released. When want to optimise the appearance of our image. We can drag the image to the bottom, left-hand corner of the map canvas, as well as expand its area a bit by dragging its top-right corner.



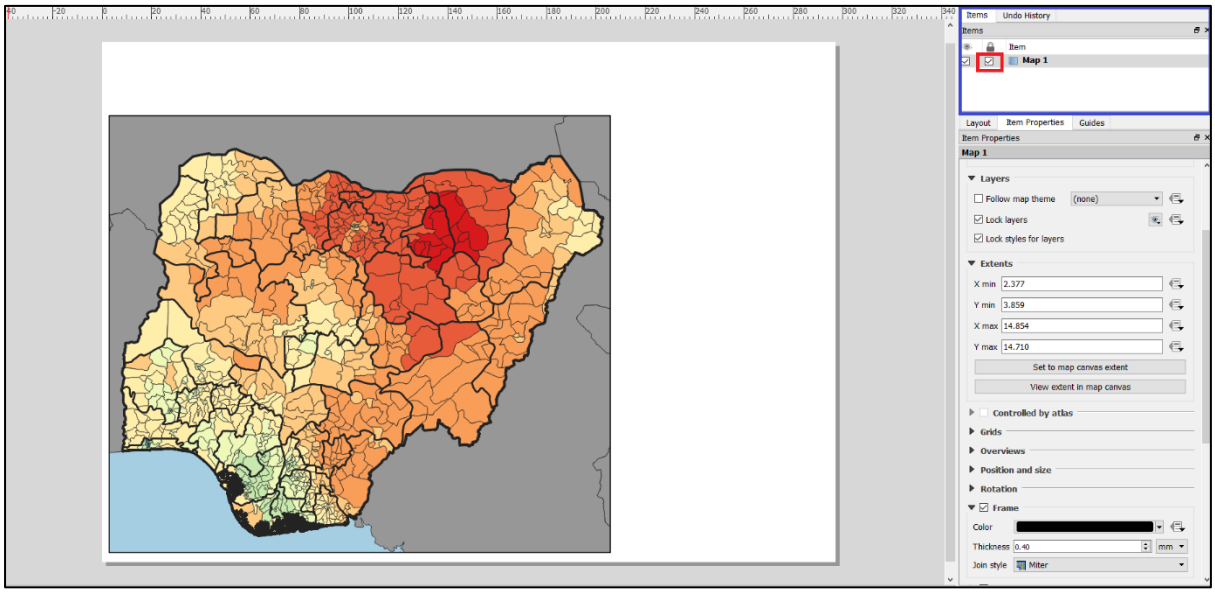
- We can move the contents as well, and zoom in & out to the image by clicking on the *Move item content* icon and dragging the map of Nigeria to place. To zoom-in (or out) gradually – move the cursor on top the image and hold the *CRTL key* and scroll with you mouse upwards to zoom-in, or scroll downwards to zoom-out.

Now – this is a very important step! We have to lock the image in place otherwise, any changes done in the *Display window* will be reflected in the *Print Composer*. This can be done in the *Print Manager* section on the right-hand side panel. Here, you will see three tab labelled as *Layout*, *Item Properties* and *Guides*. Click on *Items Properties* and follow these steps:

- Under *Layers* check the tick box for *Lock layers*, and then check the tick box for *Lock styles for layers* as well
- Scroll down in *Item Properties* and mark the tick box for *Frame* to apply borders around the map (default colour: black). You can choose to increase line's *thickness* to *0.40* mm



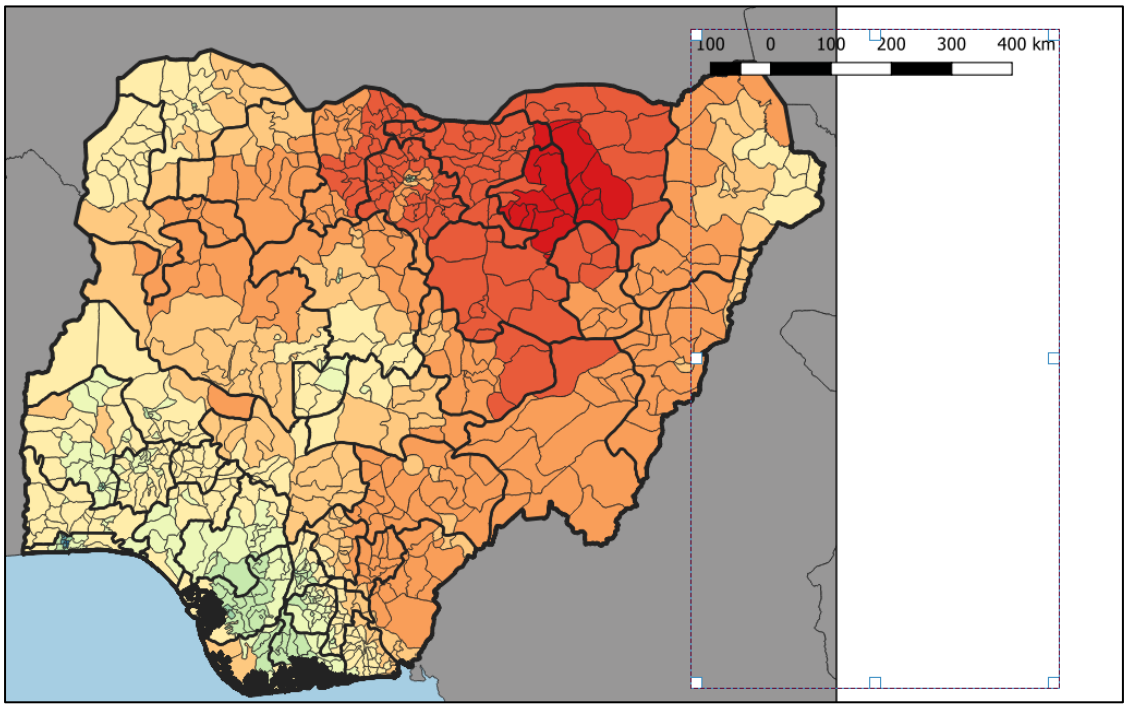
- To complete edits to the added map – there is a panel called ***Items*** located at the top of the ***Print Manager*** panel. This list features added to the map canvas – right now, we only have the map of Nigeria which is called **Map 1**. Click on the tick box of **Map 1** (under the padlock symbol) complete the edits.



Adding a scale bar

It is always good practice to add a scale bar to a map – this provides the reader a visualise indication of the size the feature, as well as the distance between features on map. A scale bar is a line represent major and minor tick divided by intervals.

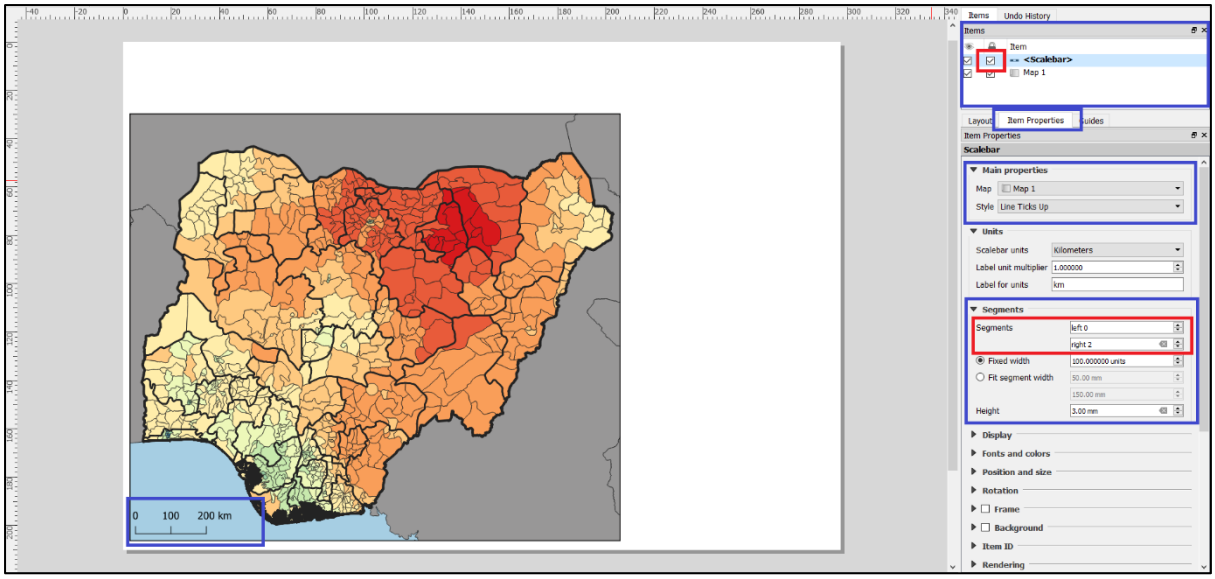
To add a scale bar:



- Click on the *Add new scale bar to layer* icon
- Once the icon is clicked - move the crosshair cursor anywhere on to *map canvas* a click it. This should bring the *New Items Properties* menu. Just click *OK* to proceed
- The scale bar will be added to the map canvas. We can crop away any extraneous areas by simply dragging the bottom upwards to fix the size of scale bar (see above image)

We going make some edits to the scale bar – first, we want it to be positioned at the bottom-left corner inside the map of Nigeria. Also, we want the scale bar to appear as line with upwards ticks, and finally, we need to ensure that the scales are linked with the map of Nigeria.

- Drag the scale bar image to the bottom-left corner inside the map
- For the scale bar go into its *Item Properties* and under *Main properties* – the bit that reads *Map* should be set to the item **Map 1.** This means the dimensions on the scale bar will correspond to what's on Map 1. The bit that reads Style – select *Line Ticks UP*
- Under *Segment* settings – change the way the scale is split: from **left 2** to **left 0** and **right 4** to **right 2**
- In the ***Items*** panel, click on the check box of **<Scale bar>** finalise edits and lock it

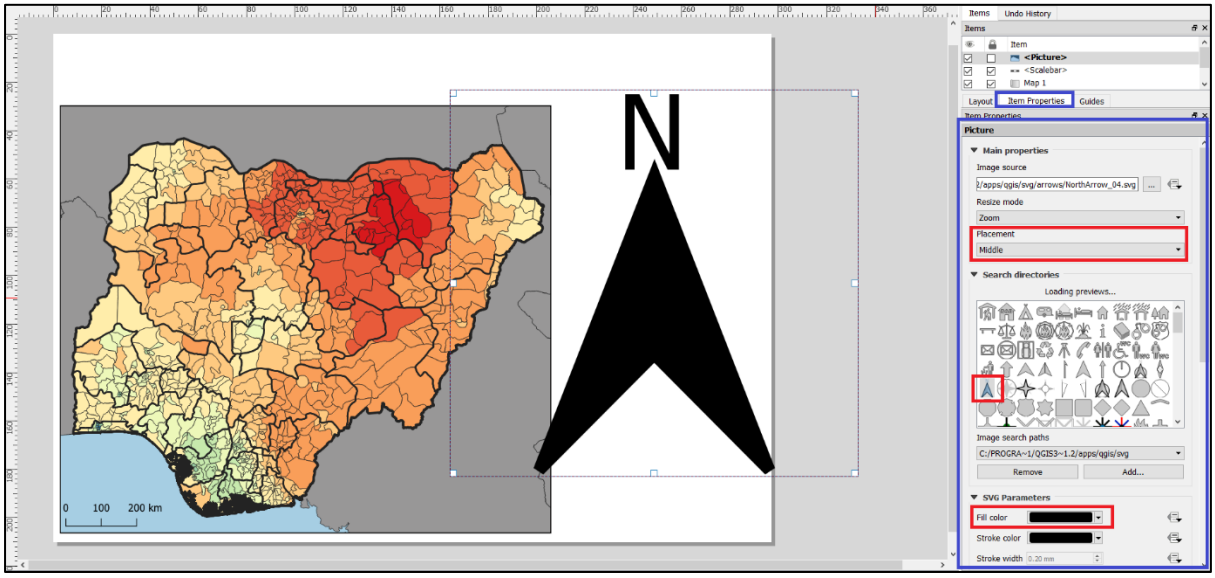


Adding an arrow (or compass)

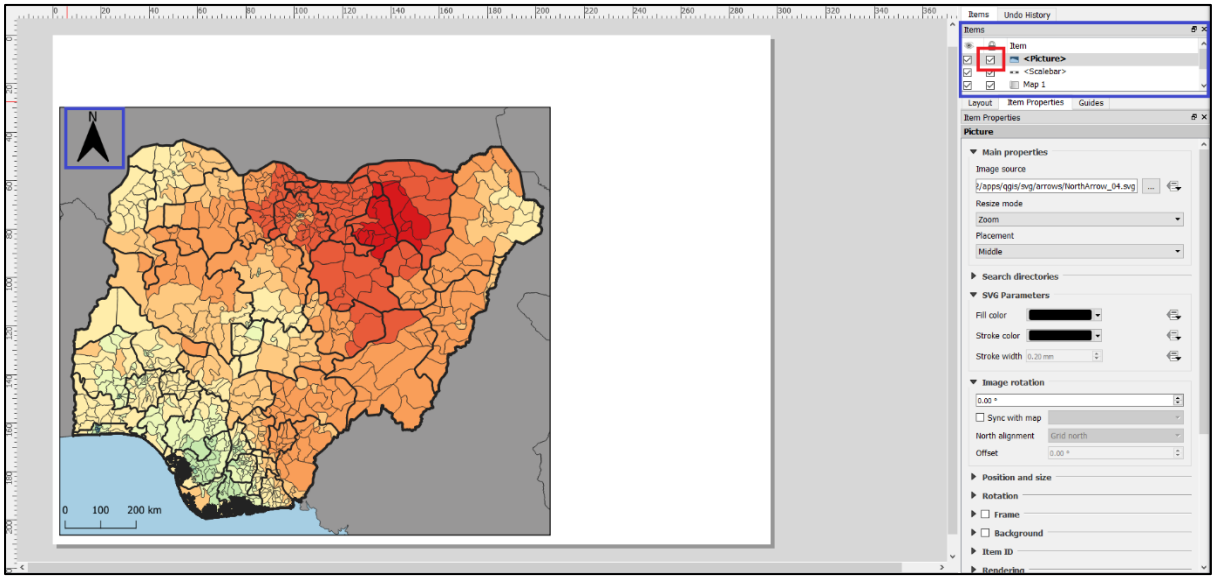
Similarly, it is always good practice to add an arrow (or a compass) to a map – this feature enables the reader have a bearings of direction in which features are facing on a map.

To add an arrow (or a compass):

- Click on the *Add new picture to layer* icon
- Again, once the icon is clicked - move the crosshair cursor anywhere on to map canvas a click it. This should bring the *New Items Properties* menu. Just click *OK* to proceed
- An empty image will be added to the map canvas. Go into its *Item Properties* and Under *Main Properties* – change the *Placement* settings to *Middle*.
- Under *SVG Parameters* – change the *Fill colour* settings to *Black*
- Expand the option *Search directories* to select the appropriate image for our map



- Crop the image to size by dragging inwards one (or any) of the corners to a suitable size. The placement for this compass at the top-left corner inside the map of Nigeria (see image below)
- In the ***Items*** panel, click on the check box of <Picture> to finalise edits and lock it

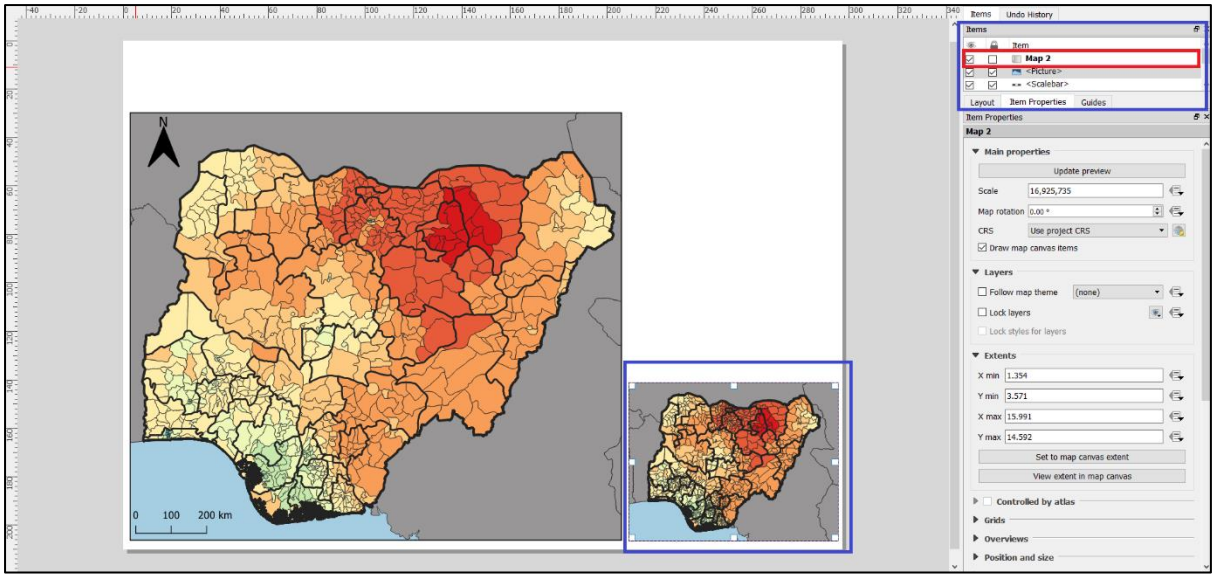


Adding a map inset

A map inset is another important feature in a map. It's a supporting map feature alongside our parent map (i.e. Nigeria). Insets are typically displayed at a higher scale showing a much broader view of the study area.

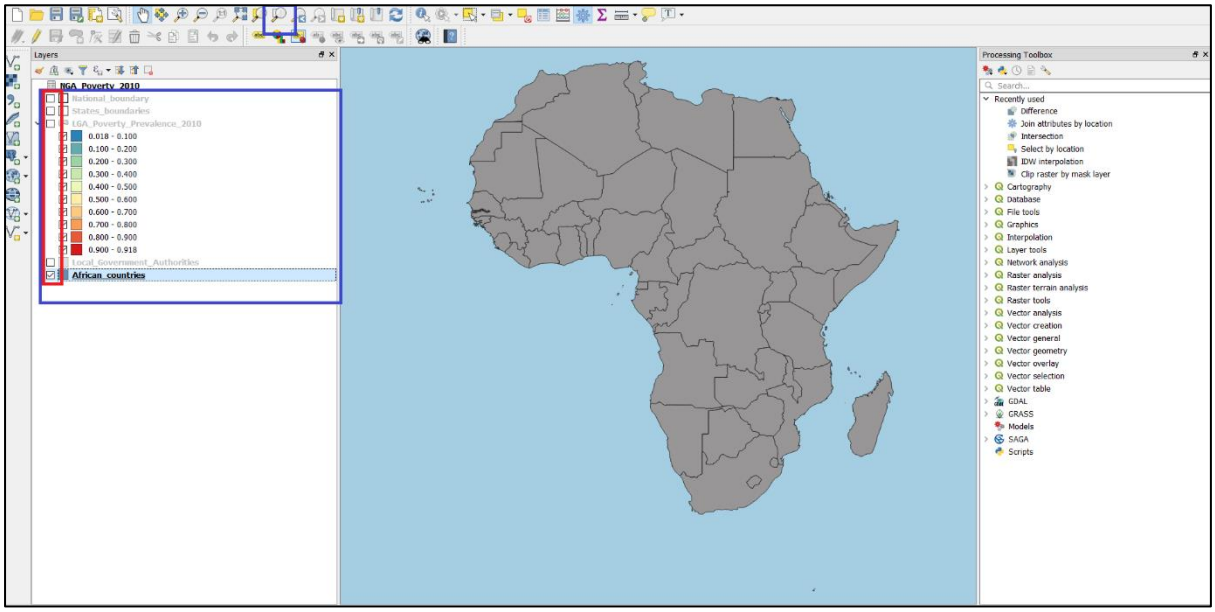
For instance, the epidemiological map shown earlier (**see page XXX**) features a map inset which has Africa as a supporting map highlight where Nigeria is in Africa. This is very useful especially for readers who, for instance, are not from Nigeria and may want to perceive whereabouts of the study location somewhere in the world.

We can add our map inset to bottom-right corner of the map canvas to show the whole of Africa by clicking on the *add new map to layer* icon and drawing the outline to fit in the corner.



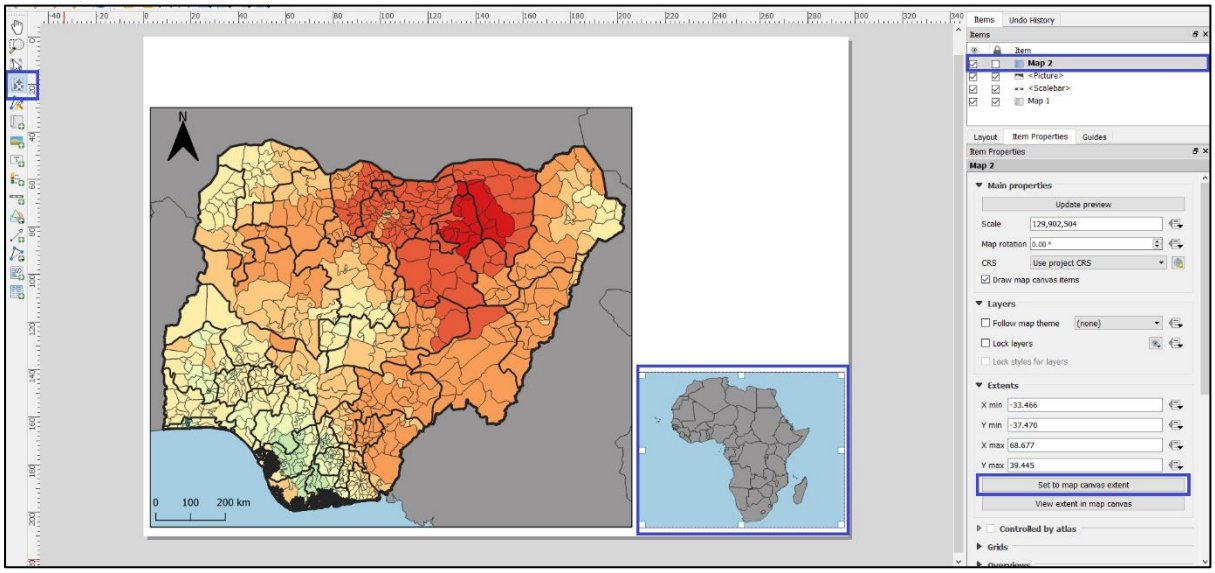
Notice its added Nigeria again – this is because it's the main layer active in our *Layers Panel*. We will need to go back to the *Layers Panel* in our *Display Window* leave only the *African_countries* layer active and deactivate all remaining layers.

- DO NOT CLOSE PRINT COMPOSER WINDOW – just open the Display window and go to the *Layers Panel*
- In the *Layers Panel* deactivate the following by unmarking their tick boxes beside them: *National_boundaries*, *States_boundaries*, *LGA_Poverty_Prevalence_2010* and *Local_Government_Authorities*
- Leave on African_countries active by not unchecking its tick box
- Click on *African_countries* in the *Layers Panel* to highlight selection and then click on *zoom to layer* icon for view its full extent

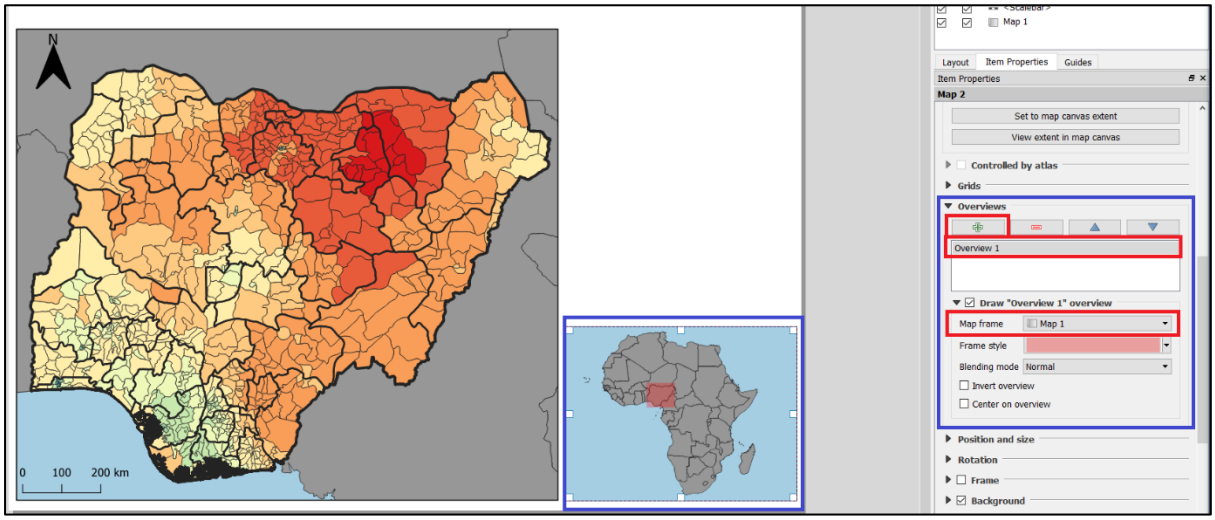


- Now, return to ***Print Composer***. We can update the image to what's displayed on the *Display window* by going into the *Item Properties* menu and clicking on the button *Set to Map canvas extent* which is under the *Extents* settings.

- Again, we can move the contents, and zoom in & out of the image by clicking on the *Move item content* icon and dragging the map of Africa to place. Let's zoom-in (or out) gradually for Africa to fit the window. You can move the cursor to the image and hold the *CRTL key* and scroll with you mouse upwards to zoom-in, or scroll downwards to zoom-out.

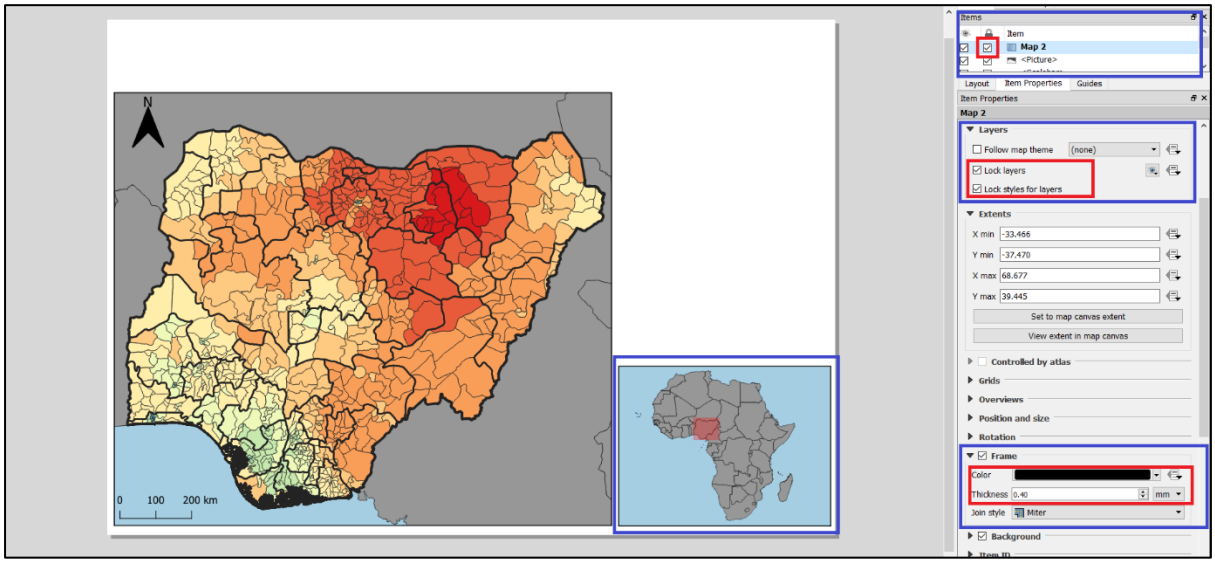


- We are going to link our map inset (i.e. **Map 2**) with the Nigeria image (i.e. **Map 1**). Scroll further down in *Item Properties* and expand the options *Overviews*. Click on the *GREEN PLUS* sign to add an overview – this will be displayed as "*Overview 1*" in the textbox. Click on the settings *Map frame* tab and select **Map 1.** This action will link **Map 1** to the map inset which is named as **Map 2** in the Items panel. You can see a red show of colour highlighting the extent of **Map 1** in our map inset. We have completed our map inset – lets add some final touches to it and the images



- Scroll down in *Item Properties* and mark the tick box for *Frame* to apply borders around the map inset (default colour: black). You can choose to increase the line's thickness to 0.40 mm

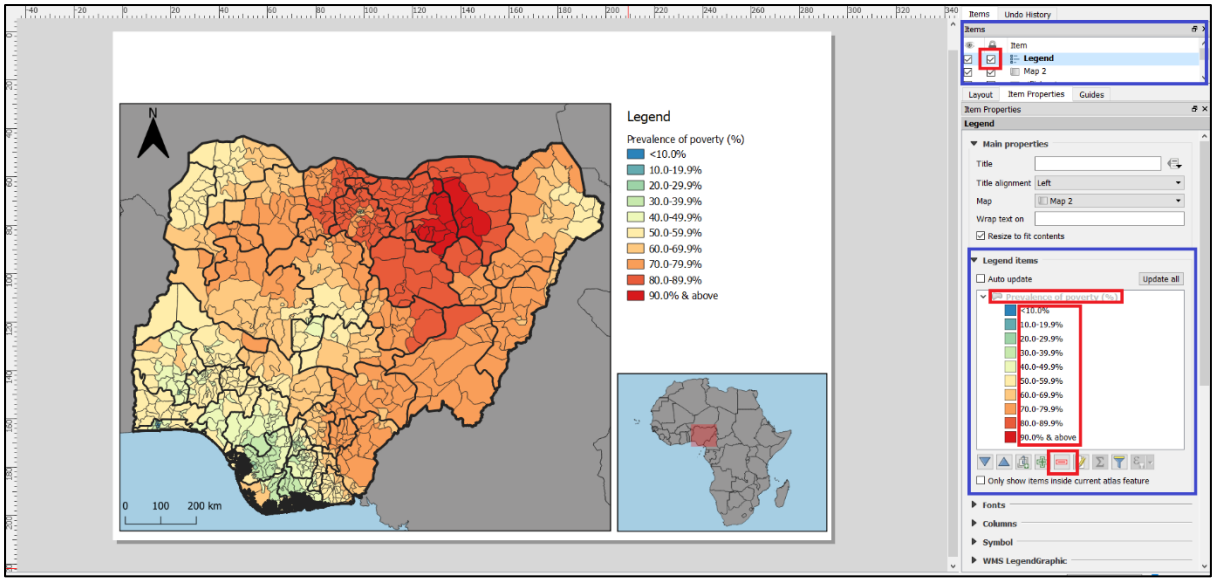
- In the *Item Properties* and under *Layers* check the tick box for *Lock layers*, and then check the tick box for *Lock styles for layers*. This action will lock the image of Africa.
- Finally, to complete edits for our added map inset – click on the tick box of **Map 2** in the ***Items*** panel



Adding Legends

It is compulsory to include keys or legends to maps that describes geographical phenomenon. Here, we are showing the distribution of poverty at LGA-level across Nigeria. We can add our legends in the following steps:

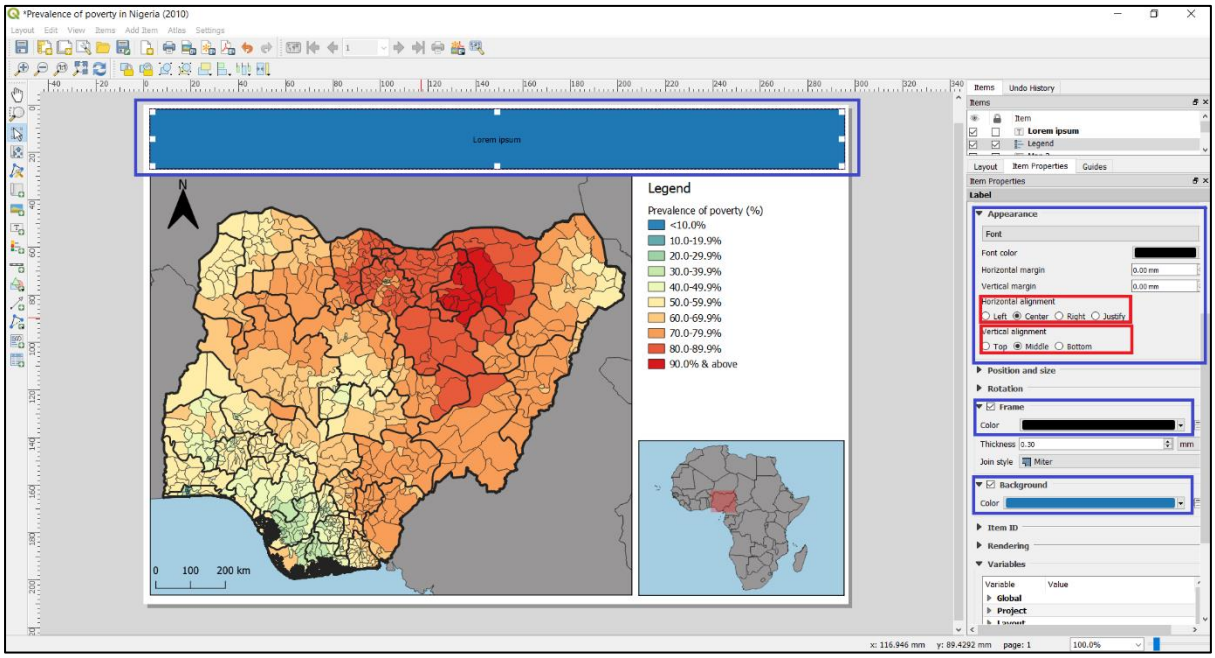
- Click on the *add a new legend to layer* icon
- Again, once the icon is clicked - move the crosshair cursor anywhere on to map canvas a click it. This should bring the *New Items Properties* menu. Just click *OK* to proceed
- This action should the legends on to our template. This will also appear as Legend in the list of items in the ***Items*** panel. Drag the legends into position beside **Map 1** and above **Map 2**
- In the *Items Properties*, under *Legend items* – always untick *Auto Update*!
- We only want include the layer (i.e. *LGA_Poverty_Prevalence_2010*) with the colour ramps in the legend. We can remove everything else by selecting them and then clicking on the *RED MINUS* button
- Change the title's subheading *LGA_Poverty_Prevalence_2010* to "*Prevalence of poverty (%)*" by double-clicking on the subheading "*LGA_Poverty_Prevalence_2010*" in the *Legend items*. A *Legend item properties* menu will appear – type in the textbox "*Prevalence of poverty (%)*"
- Double click on each of the labels associated to the colour ramps in the *Legend items* option – change it accordingly as follows:
    - From "0.018 – 0.100" to "< 10.0%"
    - From "0.100 – 0.200" to "10.0-19.9%" and so on…
    - The last should be changed from "0.900 - 0.918" to "90.0% and above"
- Finally, to complete edits for our legends – click on the tick box of **Legend** in the ***Items*** panel



Adding a title

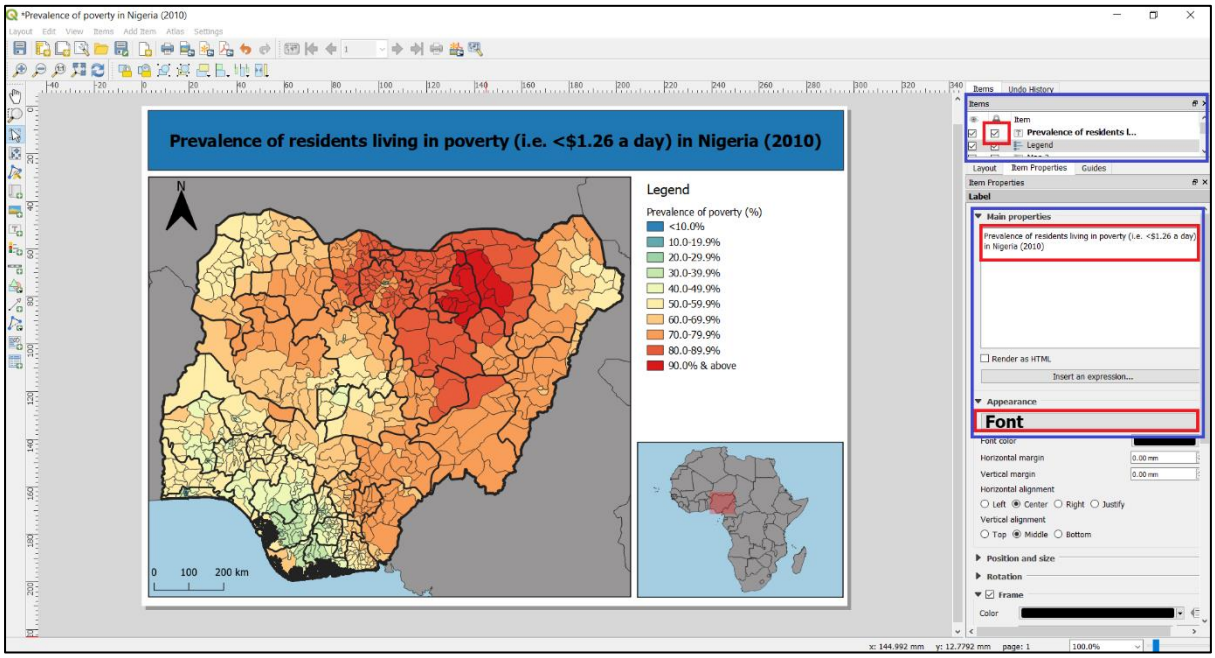
We can place a title at the top:

- Click on the *add labels to layer* icon and draw an area at full length of the map canvas
- Before we add text – In the *Item Properties*: let's give it a *Background* colour of **Deep Blue** and choose its *Frame* colour to be **Black.** Check the tick boxes for *Frame* and *Background* and select the colours **Black** and **Deep Blue**, respectively
- Under *Appearance* setting: check the following for *Horizontal alignment* and *Vertical alignment* as *Centre* and *Middle*, respectively



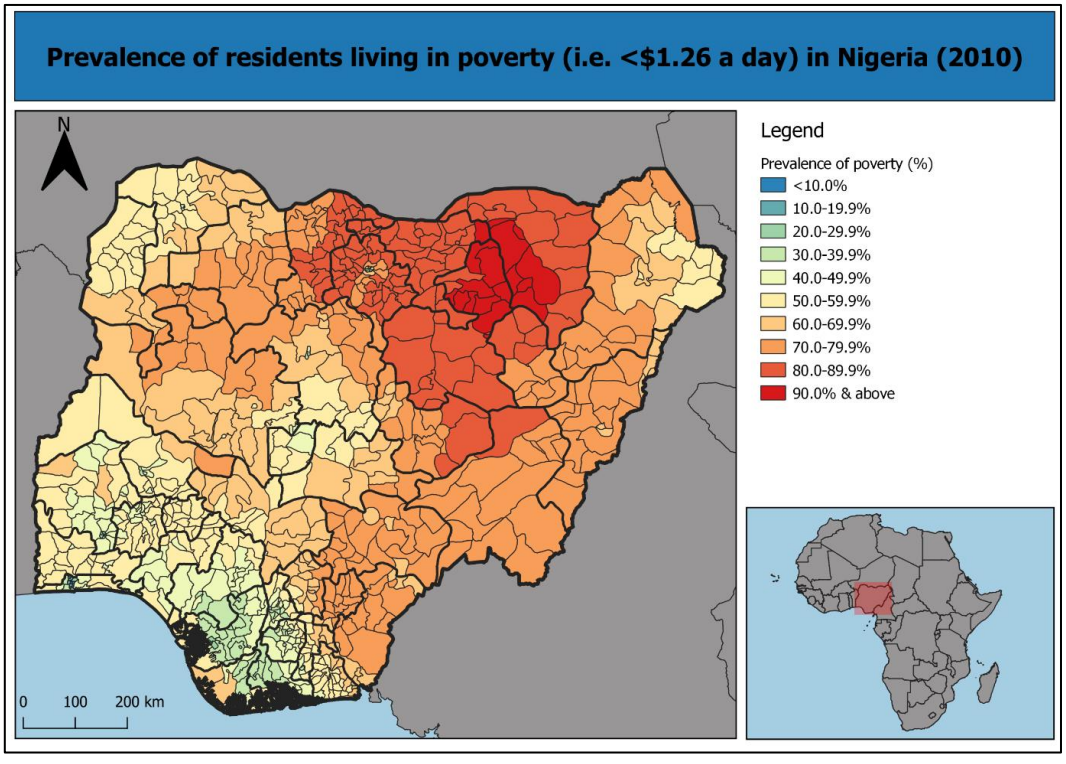
- Scrolling to the top of *Item Properties* menu – there is a textbox under *Main Properties*. The current heading "*Lorem ipsum*". Change this by typing "*Prevalence of residents living in poverty (i.e. <$1.26 a day) in Nigeria (2010)*"

- The font size is very small. Click on the *Font* tab under the *Appearance* settings, and a *Text Format* menu will appear – here, under *Font style* select *Bold* and choose *20* as the text size. Click *OK*
- Finally, to complete edits for title – click on the tick box for the title in the ***Items*** panel



We have completed the construction of the map in Print Composer – we can choose to export the map as a pdf document, SVG or a digital image by clicking on one of the following icons: 

The final product should be as follows:



Summary

We learn the basic features in a map composition and how to construct a map that is publication worthy. The next set of tutorials will be focused more on techniques on data management and spatial analyses – these will typically include analysis of aggregated data and various spatial interpolation approaches.

Lessons 1, 2 and 3 are prerequisites for lessons 4 and 5.

Lesson 4: Mapping of aggregated crime data in QGIS

Introduction

We have data on 1,129 police stations operating in South Africa. In 2010, the South African police dealt with reported incidents of assault.

We are interested in identifying districts that needs special attention by the police due to high risk of victimisation. Therefore, it would be helpful to create maps that shows district-level crime incidence rates of reported assault in South Africa.

To construct a district-level map showing the rates of reported victimisation – you will need to perform spatial aggregation of police stations to obtain overall reported numbers of victimisation within a district. Secondly, you will also need to know the population at risk of being assaulted within a district in 2010 in order to estimate the crime incidence rate.

This tutorial will provide a step-by-step guide for conducting such spatial analysis in QGIS.

If you have not already, please make sure to download the corresponding dataset for lesson 4 by going to our website on http://development-frontiers.com/tutorials/

Important note: Lessons 1, 2 and 3 are prerequisites for this tutorial; therefore, its assumed that the reader knows how to add, import and save spatial data. Its assumed that you understand the science layer management, as well as knowing how to use Print composer.

Load the required vector files in QGIS

The following shapefiles should be added into the *Layers Panel* in *QGIS Desktop 3.2.0*:

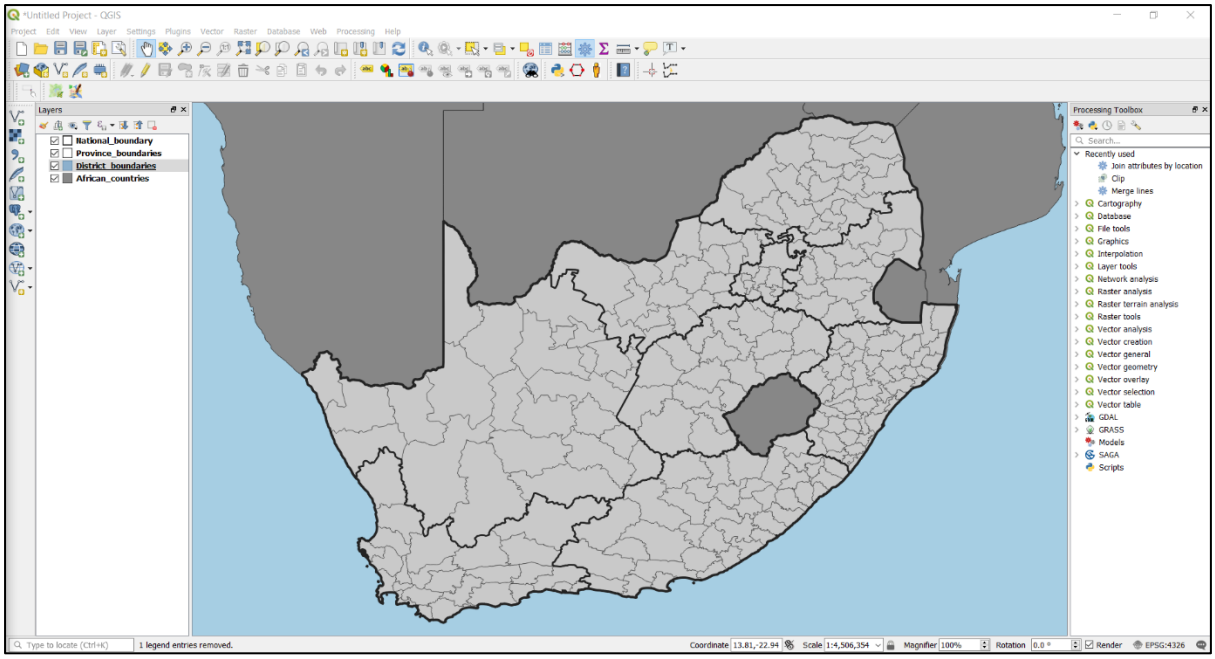
- *African_countries.shp* (contains all African countries)
- *National_boundary.shp* (the national boundary of South Africa)
- *Province_boundaries.shp* (the provincial borders in South Africa)
- *District_boundaries.shp* (the district borders in South Africa)

Do you recall in previous tutorials where we gave tips on the best ways for arranging vector layers in the *Layers Panel*?

Arrange the layers in this order and apply the following changes via their *Symbology* settings in the *Layer Properties* menu:

- *National_boundary* (*Fill Style: No Brush (transparent); Stroke width = 1.00 mm*)
- *Province_boundaries* (*Fill Style: No Brush (transparent); Stroke width = 0.66 mm*)
- *District_boundaries* (*Fill colour: Light Grey; Stroke width = 0.16 mm*)
- *African_countries* (*Fill colour*: *Deep Grey*)

Remember to change the colour of the background colour of the *Display window* to *Blue* to represent the colour of the sea (or oceans). The map in the *Display window* should be as follows:

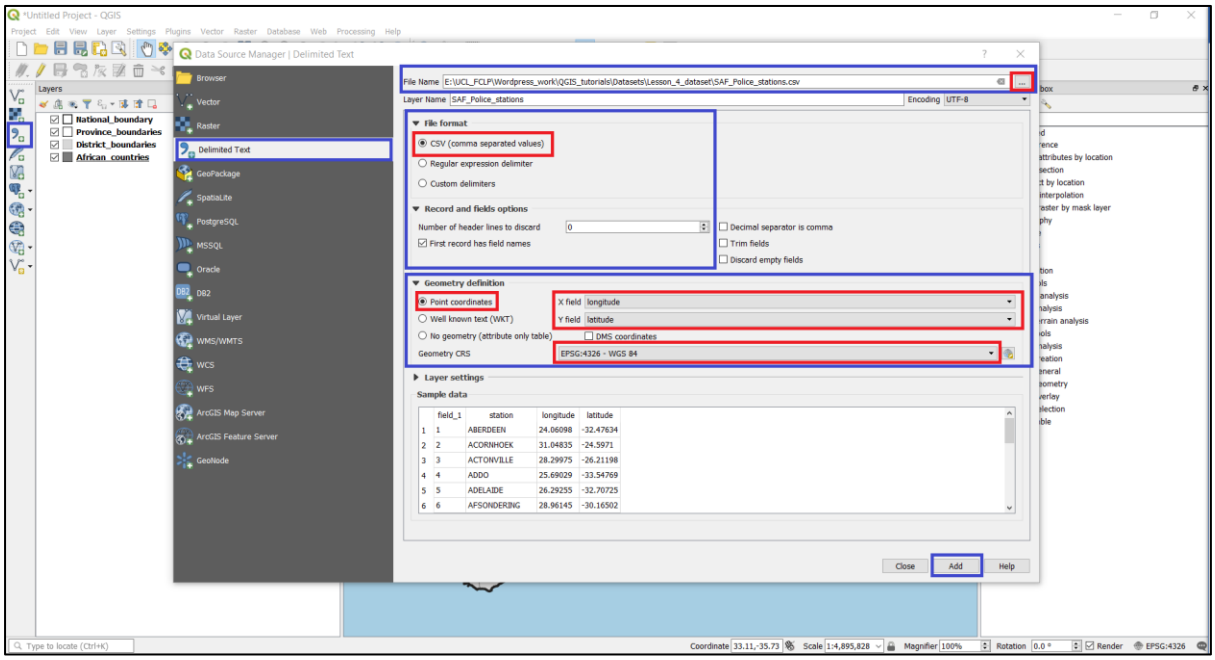


Importing spatial and victimisation dataset

The following datasets can be imported into QGIS:

- *SAF_Police_station.csv* (contains the spatial coordinates of police stations in South Africa)
- *SAF_Reported_assaults_2010.csv* (contains the number of assaults reported by police stations in South Africa in 2010)

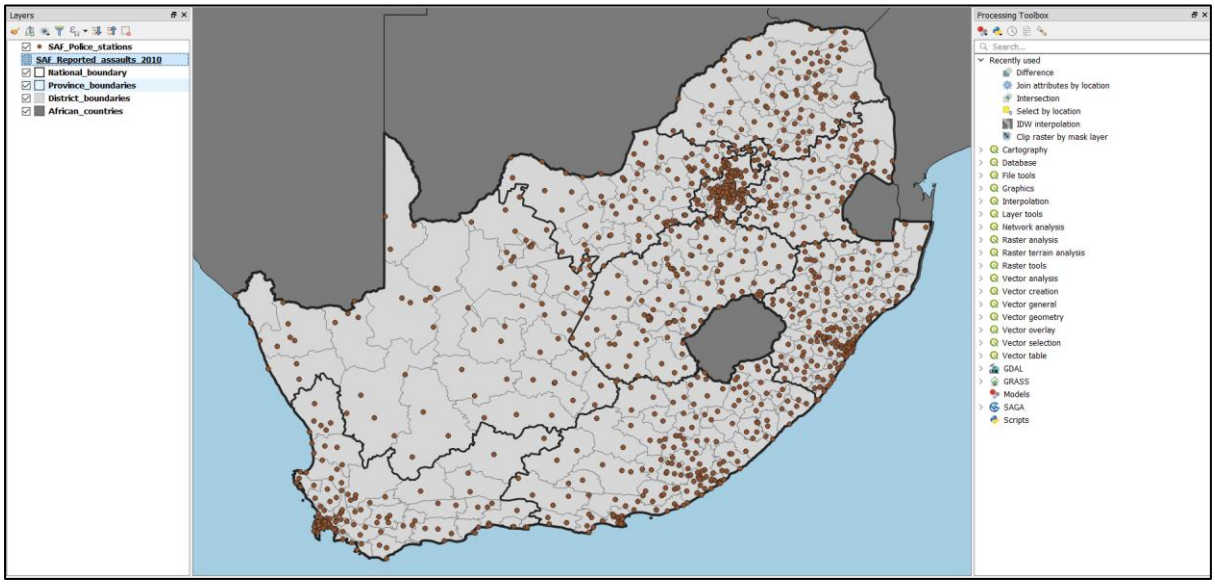
The *SAF_Police_station.csv* is a spreadsheet is spatial data because it contains coordinates on the location of police station. Therefore, when importing it – the user must declare which fields correspond to longitude and latitude. You can do this by:



- Clicking on the *add delimiter* icon on the left-hand side of the *Layer Panel*
- The *Data Source Manager* window will appear. Here, click on the browse button and select the correct file i.e. *SAF_Police_station.csv* as the *File Name*
- Make sure under *File format* settings the *CSV (comma separated values)* option is checked
- Under *Record and fields options* – make sure *First record has field names* is checked to retain the name of the columns
- Under *Geometry definition* settings – make sure the *Point coordinates* option is checked. Here, you need to tell QGIS that the *X field* corresponds with *longitude* and *Y field* corresponds with *latitude*
- Make sure *Geometry CRS* is *ESPG:4326-WGS84*
- Click *add* to import data to the *Layers Panel*

You can repeat the above steps for importing the other dataset (*SAF_Report_assaults_2010.csv*) however, this dataset should be treated as an attribute table. It contains no geometries only criminological information matched to a police station. When importing this dataset – ensure to click on the check box "*No geometries (attribute only table)*" under *Geometry definition*.

The *Display window* should look something like:



The points on the image correspond to the geographical positions of the police stations in South Africa. At the moment, it only exists as a temporary file in QGIS's memory as an imported csv file – we can save as a point shapefile by following these steps:

- Right-click on the layer *SAF_Police_stations* in the *Layers Panel*
- Click on *Save As…* to open the *Save vector layer as…* menu
- The format of a vector file is mostly an *ESRI Shapefile* by default. Under *Format* select *ESRI Shapefile*
- Select the location for the save vector data by clicking on *Browse* button , and name the file as "***ZAF_Police_stations***"
- Save its coordinate reference system under *CRS* as *EPSG: 4326-WGS 84*
- Make sure that the checkbox *Add saved file to map* is checked
- Click *OK* to finish saving the data
- Remove the imported *SAF_Police_stations.csv* from the *Layers Panel*

Joining of spatial police data with reported victimisation records

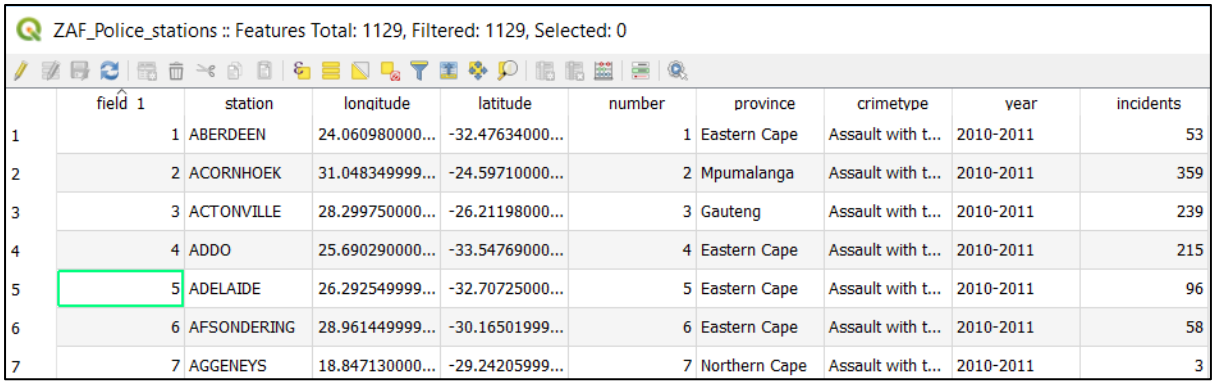
At the moment, the imported *SAF_Reported_assaults_2010* dataset exists as an attribute table without any spatial geometries such as coordinates. We see that it contains the names of the police stations and the number of reported assaults (i.e. incidents) recorded in 2010.

Without any spatial attributes, we cannot display the number of reported assaults on map. To visualise this information on a map, we will need to link the attribute table with the point vector file (*ZAF_Police_stations*) using a common key field.

Notice that the names of the police stations under the field name "*station*" in the assault data corresponds with those in the point vector data (*ZAF_Police_stations*).

We can carry out a spatial join to merge the two dataset. This can be done in the following steps:

- Right-click on the layer *ZAF_Police_stations* and select *Properties* to open the *Layer Properties* menu
- On the left-hand side of the *Layer Properties* menu select *Joins* tab
- Click on the *GREEN PLUS SIGN* to specify which layer (or attribute table) you wish to carry out the spatial join. An additional menu "*Add vector join"* will appear
- Under the *Join layer* selection tab – choose the attribute table *SAF_Report_assaults_2010*. This refers to the table we wish to join with our spatial data (i.e. *ZAF_Police_stations*)
- Under the *Join field* selection tab – choose the field name "*station*". This refers to the field name in our attribute table we want to perform the joins
- Under *Target field* selection tab – choose the field name "*station*". This refers to the field name in our spatial data we want to carry the joining to the attribute table
- Check the checkbox on *Custom field name prefix* and type the symbol under-score "_" in the space. The field names added to our point vector data will be prefixed with an under-score and they will appear as "*_province*", "*_crimetype*", "*_year*" and "*_incidents*".
- Click *OK* on the *Add vector join* menu
- Click *Apply* and *OK* to finalise spatial join


ZAF_Police_stations :: Features Total: 1129, Filtered: 1129, Selected: 0

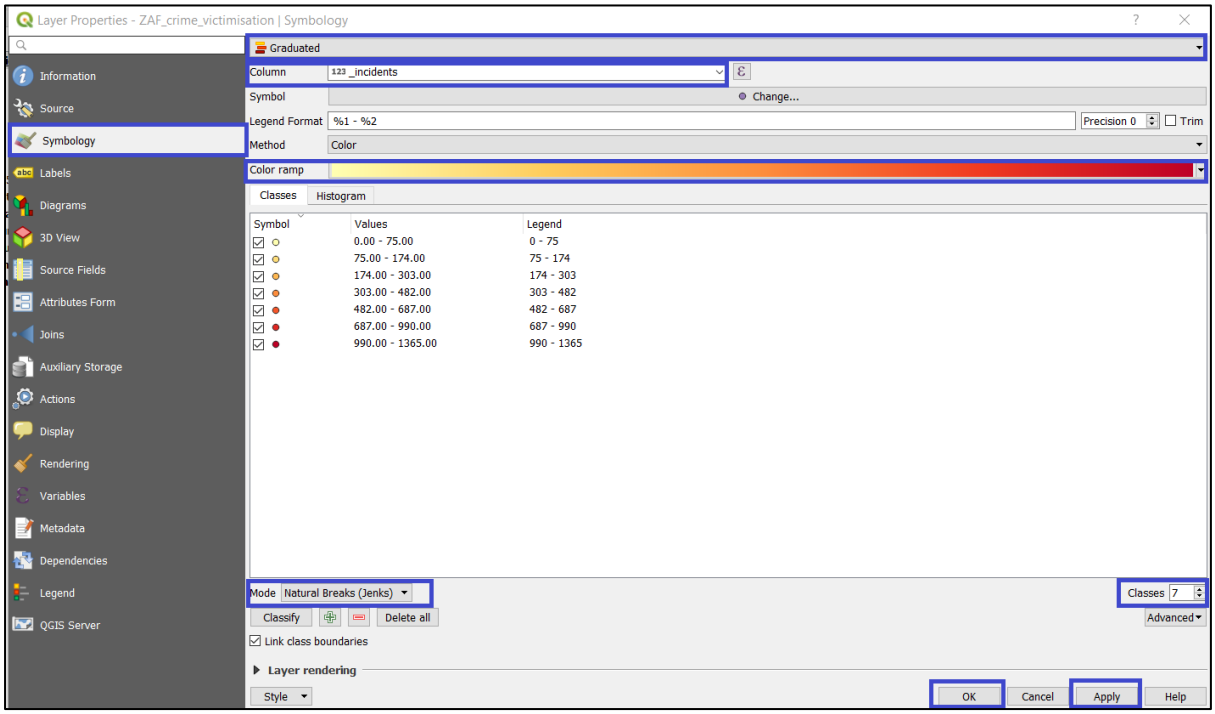
	field_1	station	longitude	latitude	number	province	crimetype	year	incidents
1	1	ABERDEEN	24.060980000...	-32.47634000...	1	Eastern Cape	Assault with t...	2010-2011	53
2	2	ACORNHOEK	31.048349999...	-24.59710000...	2	Mpumalanga	Assault with t...	2010-2011	359
3	3	ACTONVILLE	28.299750000...	-26.21198000...	3	Gauteng	Assault with t...	2010-2011	239
4	4	ADDO	25.690290000...	-33.54769000...	4	Eastern Cape	Assault with t...	2010-2011	215
5	5	ADELAIDE	26.292549999...	-32.70725000...	5	Eastern Cape	Assault with t...	2010-2011	96
6	6	AFSONDERING	28.961449999...	-30.16501999...	6	Eastern Cape	Assault with t...	2010-2011	58
7	7	AGGENEYS	18.847130000...	-29.24205999...	7	Northern Cape	Assault with t...	2010-2011	3

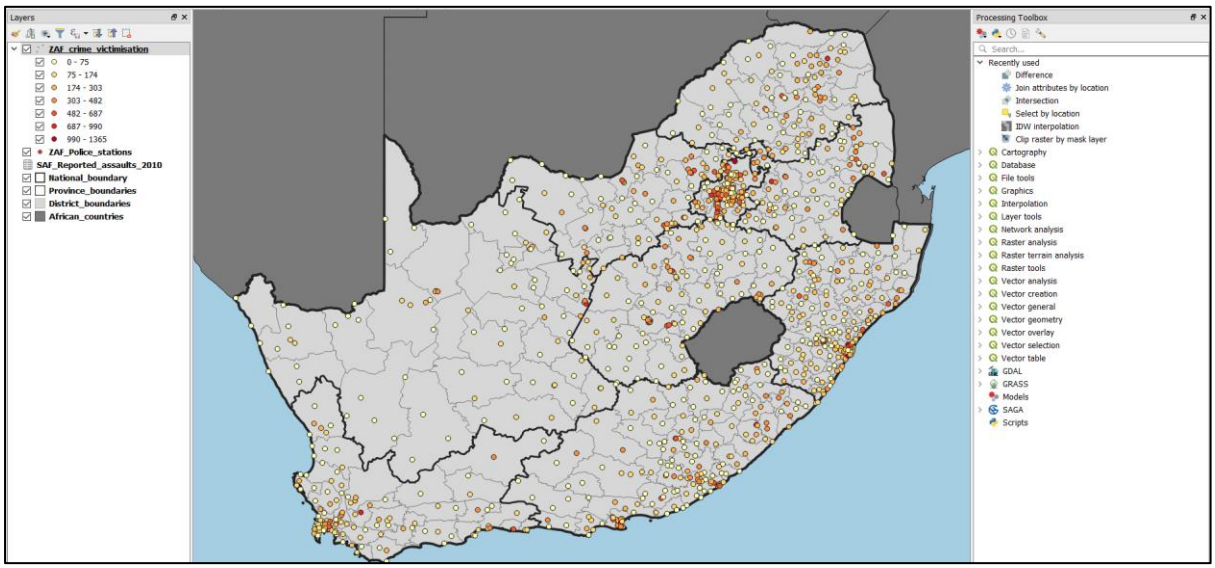
The datasets have been harmonised – save this data as a new shapefile by calling it *ZAF_crime_victimisation.shp*. Finally, in its attribute table – you can remove any redundant variables such as *field_1*, *number*, *_province*, *_crimetype* and *_year* by clicking on *toggle editing* to start editing the vector file and *delete field* tab for removing. Re-click on the *toggle editing* to finalise changes and save it.

Aggregation of point spatial data to polygon

We could use the points to produce a point map showing the number of reported assaults on victims by police stations:

- Right-click on the *ZAF_crime_victimisation* and select *Properties* to access its *Layer Properties* menu
- Choose the *Symbology* tab on the left-hand side of the menu and select *Graduated* on the topmost selection bar
- We want to display number of assaults. In *Column* select the field name "*_incidents*"
- In *Colour ramp* – select the colours *YlOrRd*
- You can specify the method (*equal*, *quantile*, *natural breaks*, *standard deviation* or *pretty breaks*) for generating sets of intervals. For this example – select *Natural Breaks (Jenks)* and type *7* in *Classes* to generate seven intervals
- Click *Apply* and *OK*





As you can see, there are indeed obvious spatial patterns in the number of reported assaults, and through visual inspection – there may be evidence of clustering. However, this map lacks any criminological rigorousness and interest due to the fact that it just total numbers of cases recorded by each police station.

For comparability, we could choose to aggregate the points by district in order to know the overall numbers of attacks that have occurred within a district in the year 2010, and then divide this figure by the estimated population at risk of being victimised within a district during the year 2010 multiplied by 10,000 inhabitants.

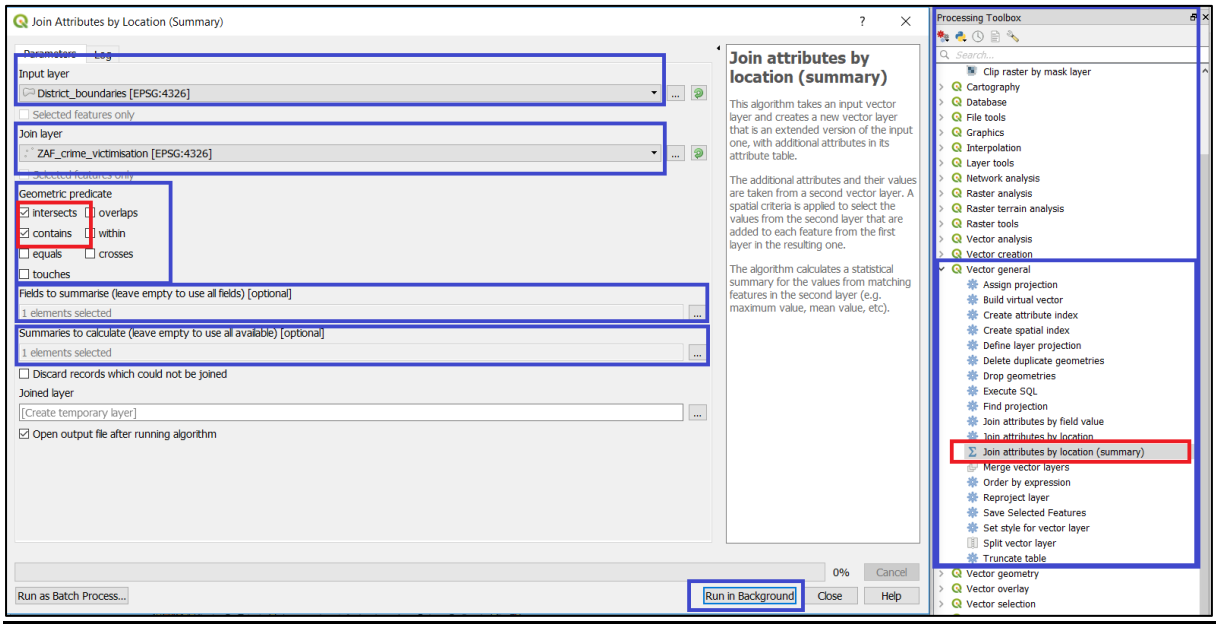
The resulting output is interpreted as district-level crime rates of victimisation (assault) (per 100,000 inhabitants) in South Africa.

To do this calculation, we will need South Africa's population census data for 2010. What's available is population counts gridded at a resolution of 100m (derived from WorldPop database). Using the district vector layers (i.e. *district_boundaries*) – we will generate two shape files:

1. A shape file containing the aggregated counts of assault within a district
2. A shape file containing the estimated population size of 2010 within a district

The final steps will include merging the two layers before calculating the crime incidence rates of victimisation (assault).

Derivation of district-level counts for assault



- In the Processing Toolbox, click on *Vector general* > *Join attributes by location (summary)*
- Under *Input layer* options – select *District_boundaries*. This section refers to the layer we want to use as a template for aggregating our point data
- Under *Join layer* option – select *ZAF_crime_victimisation*. This section refers to the layer we want to aggregate and produce summary statistics from
- We want to aggregate points that fall within, or that intersect with polygon of a district. Under *Geometric predicate* check the checkbox for *intersects* and *contains*

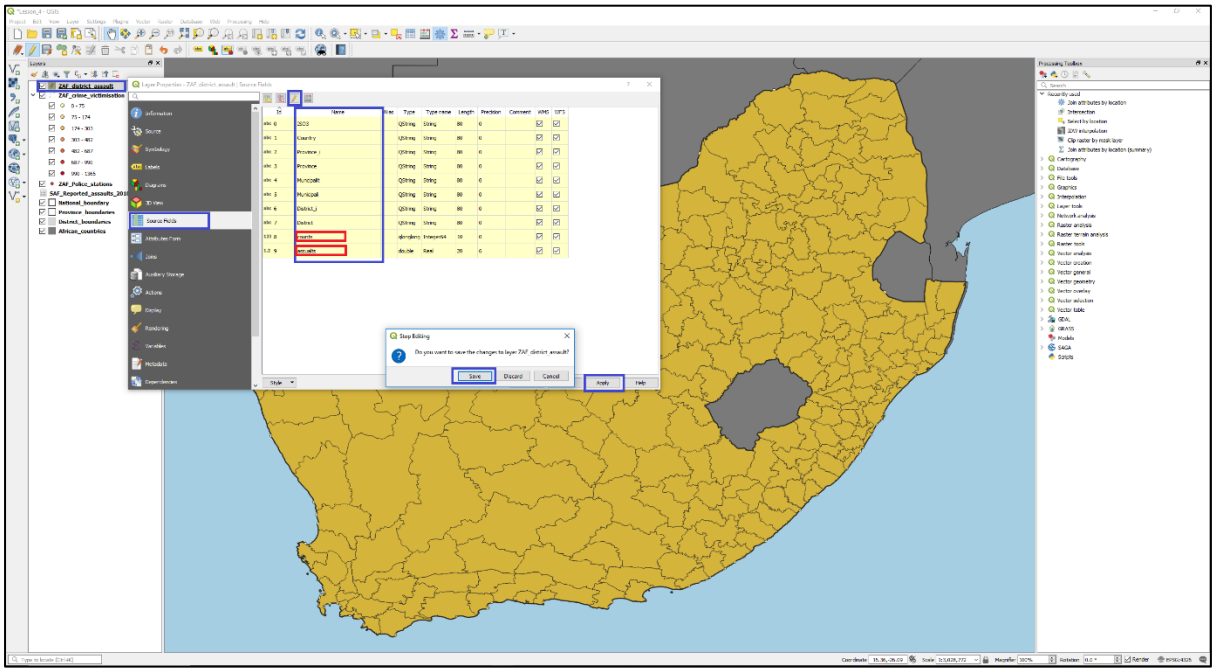
- Under *Fields to summarise (leave empty to use all fields) [optional]* – select *_incidents* only. This is the field we are interested in, we want to aggregate all points within a boundary of a district and then take the summation
- Under *Summaries to calculate (leave empty to use all available)[optional]* – click on the *browse* button ... and then select *sum and counts*.
- Click on *Run in Background* and *Close* when the aggregation is complete – this should produce a temporary layer called *Joined Layer* in the *Layers Panel*. You can right-click on the *Joined Layer* and save it as *ZAF_district_assault.shp*

Checking the attribute table for *ZAF_district_assault* layer we can the new fields called *_incidents* *_inciden_1* – the former refers to the number of points (i.e. police stations) aggregated in a district, and the latter refers to the total number of assaults calculated within a district. Unfortunately, QGIS has a stupid reputation for messing up the column names and renaming them into something that's incoherent after performing a spatial join or aggregation.

	ISO3	Country	Province_i	Province	Muncipalit	Municipali	District_i	District	incidents	inciden_1
1	ZAF	South Africa	ZAF.5_1	Limpopo	ZAF.5.1_1	Capricorn	ZAF.5.1.5_1	Polokwane	5	1,270.000000
2	ZAF	South Africa	ZAF.5_1	Limpopo	ZAF.5.1_1	Capricorn	ZAF.5.1.4_1	Molemole	3	347.000000
3	ZAF	South Africa	ZAF.5_1	Limpopo	ZAF.5.1_1	Capricorn	ZAF.5.1.3_1	Lepele-Nkumpi	4	613.000000
4	ZAF	South Africa	ZAF.5_1	Limpopo	ZAF.5.1_1	Capricorn	ZAF.5.1.2_1	Blouberg	5	276.000000
5	ZAF	South Africa	ZAF.5_1	Limpopo	ZAF.5.1_1	Capricorn	ZAF.5.1.1_1	Aganang	2	173.000000

Let rename *_incidents* to *counts* and *_inciden_1* to *assaults* by going into the *Layer Properties* menu of *ZAF_district_assault* and selecting the *Source Fields* tab:

- Click on the *toggle editing* icon to start editing the shape file of *ZAF_district_assault*
- Under the *Name* column, double-click *_incidents* and rename this to *counts*
- Under the *Name* column, double-click *_inciden_1* and rename this to *assaults*
- Click on the *toggle editing* icon to stop editing the shape file of *ZAF_district_assault*. Here, a *Stop Editing* window will pop-up to prompt you to update this shape file - click on *Save*
- Click *Apply* and *OK*



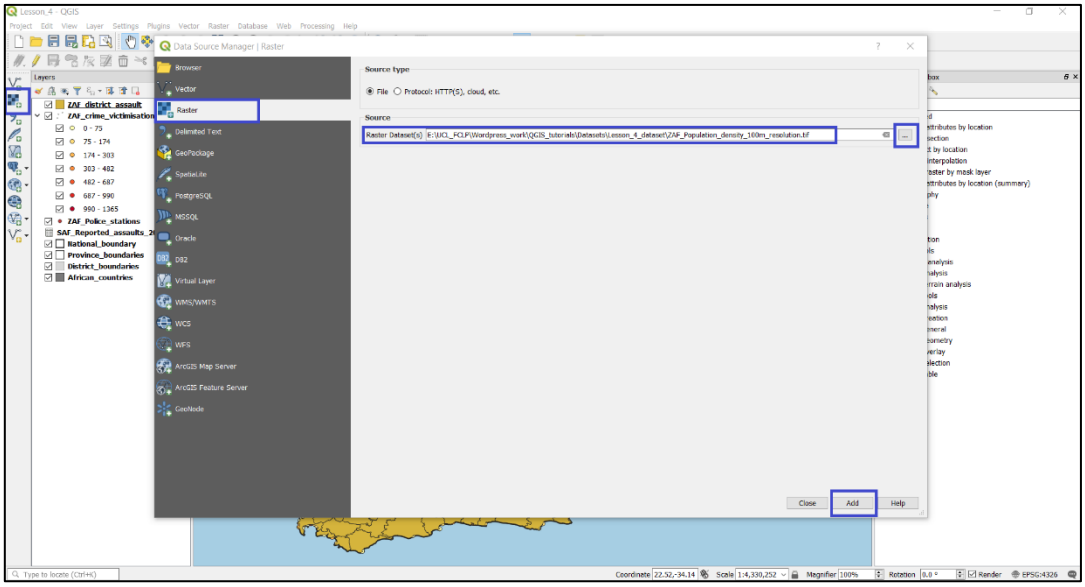
The aggregation for assault by districts are complete. We will return to this layer in a bit. Now, we will perform the same procedure for the raster population 2010 census data.

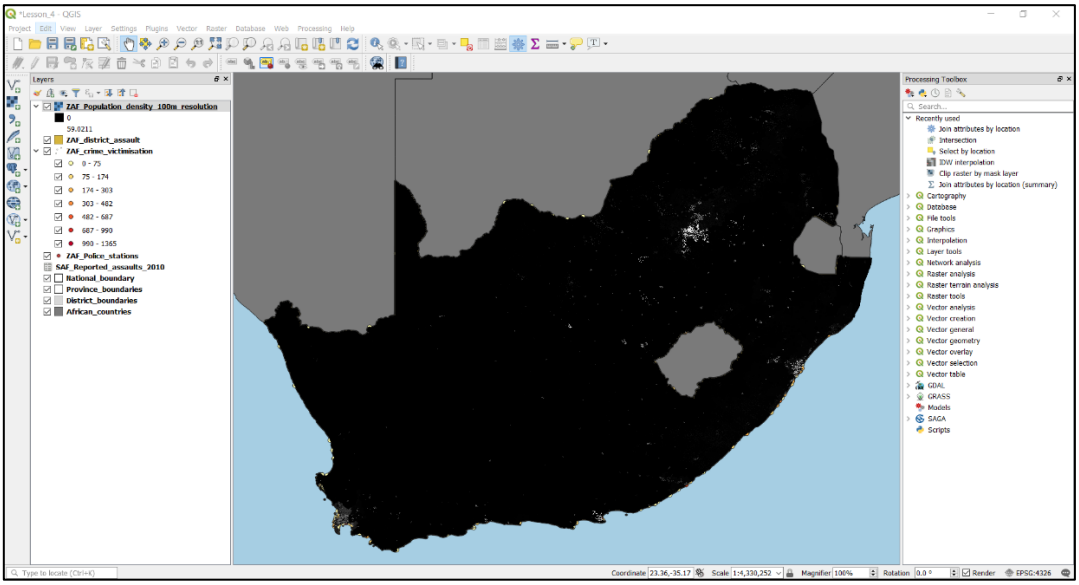
Adding raster data to QGIS

Up to this point, we've been adding only vector (or shape file) data to QGIS display. Here, we will start to add raster data – the information show population density i.e. estimated number of people per grid square at a resolution of 100m (i.e. this means that length and width of a grids are at 100m).

To add raster data to the display window:

- Click on the *Add Raster layer* icon for the *Data Source Manager* window to appear
- Click on the *browse* button to select the desired raster data
- Select the file *ZAF_Population _density_100m_resolution.tif* and click on Open. Important note: Raster data are often stored as a *GeoTIFF* (either as *.tif*, *.tiff*, *.TIF* or *.TIFF*) format
- Click *Add*





When adding raster data to QGIS - it will, by default, always set the colour as black and white. This is because the *render type* (i.e. a setting in the Layer Properties for raster data) is set to as *singleband gray*. The *singleband pseudocolours* allow for more interesting visualisation of the gridded data, and allows one to change the colour ramps to represent continuous or discrete values. However, we will explore more of these setting in the next tutorial.

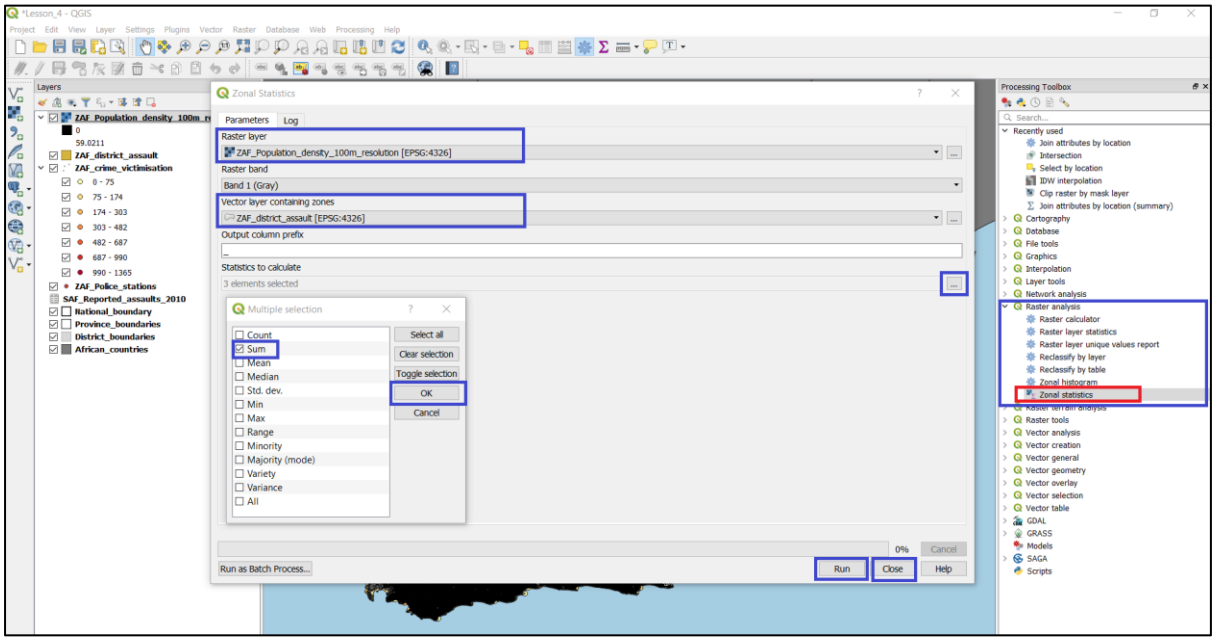
Now, we've loaded our population data, let's proceed to aggregate this to obtain district-level population counts.

Deriving population size of districts – aggregation of raster data by polygons

The procedure for aggregating raster values within polygons are as follows:

In the *Processing* Toolbox panel - click on the tab *Raster analysis* > *Zonal Statistics*

- The *Zonal Statistics* menu for analysis of raster information should appear. Under the *Raster layer* section – select *ZAF_Population_density_100m_resolution [EPSG: 4326]*
- Under the section labelled '*Vector layer containing the zones*' – select *ZAF_district_assault*. Again, this refers to the vector layer we want to use as a template for aggregation in which case – it's the district layer which also contains the aggregated number assaults
- In *Output column prefix* leave as the underscore "_" symbol
- In *Statistics to calculate* click on the *browse* button [...] and a Multiple selection window will show. In this window – only leave the *Sum* checked. Uncheck the remaining options that appear checked. Here, it will the sum the values of the grids falling within a district to produce population size of a district. It will name this field as "*_sum*"
- Click *OK*.
- Click on *Run* (wait for operation to complete) and *Close*



Open the attribute table of *ZAF_district_assault* and you will see a new column has been generated for the 2010 population sizes for the districts called *_sum*. Let's save this as a new shape file and called it *ZAF_assault_victimisation_2010* and after rename the field *_sum* as *pop2010* by going into the *Layer Properties* of *ZAF_assault_victimisation_2010* and clicking on the *Source Field* tab. You do remember how to change a field's name?

Calculating crime rates for assault

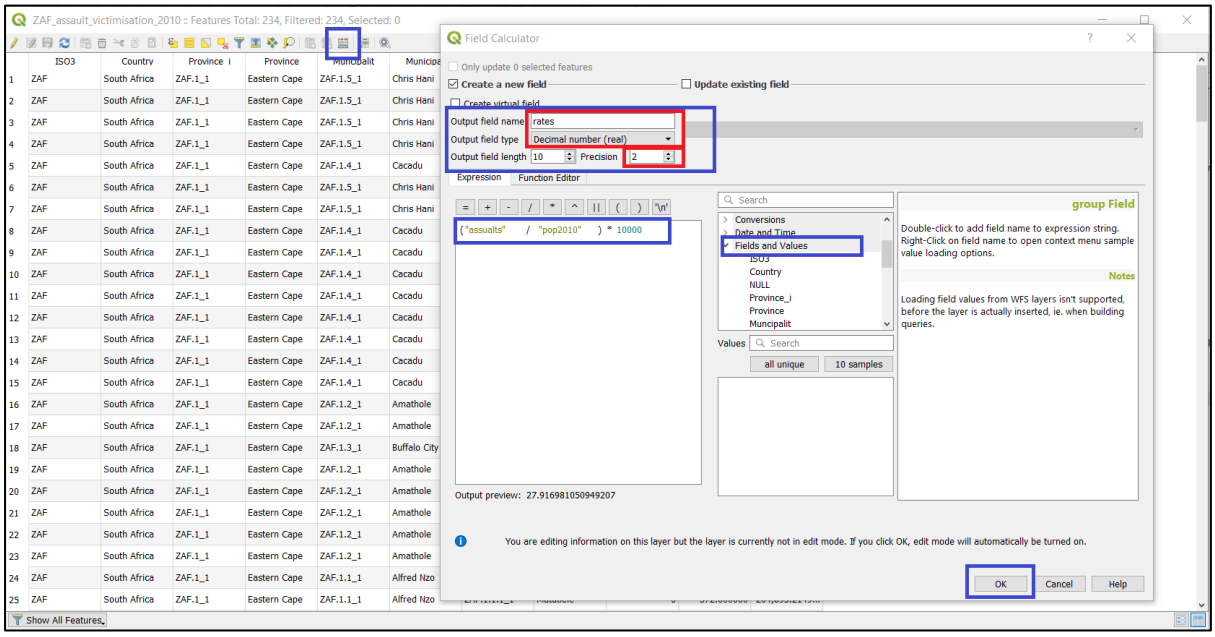
Our layer named *ZAF_assault_victimisation_2010* the clean spatial dataset with the appropriate field names for estimating the district-level crime rates in South Africa.

We can use the given formula to calculate the rates of assault for every district and express the rates of victimisation as per 10,000 inhabitants:

$$\textbf{Crime rates for assaults (per 100,000)} = \frac{\textbf{The reported number of assaults in 2010}}{\textbf{Population at risk of being assaulted in 2010}} \times \textbf{10,000}$$

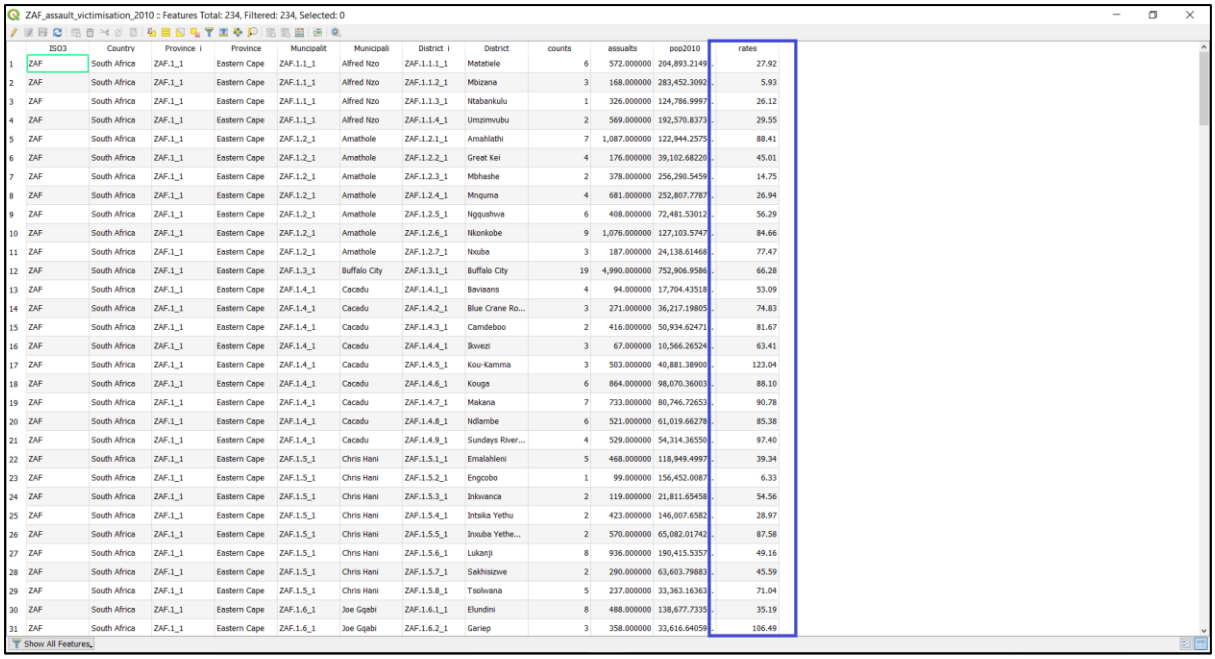
Access the attribute table for *ZAF_assault_victimisation_2010* layer and click on the *field calculator* icon . The *Field Calculator* window will appear – you can derive the crime rates in the following steps:

- In *Output field name* – you can type the name of the field you wish to generate. Here, type "*rates*"
- The field generate exists as a real number and not integer or string. In *Output field type* – select *Decimal number (real)*
- We want the estimates to have only 2 decimal places – in *Output field length's Precision* section type *2*
- Expand the *Fields and Values* by selecting the checkbox. Here, we select the fields in the above formula.
- Click on the field '*assaults*' – this should appear in the *Expression*'s calculator. Here, you can construct your mathematical formula. The formula should look like: *("assault" / "pop2010")*10000*
- Click *OK* to generate the desired estimates



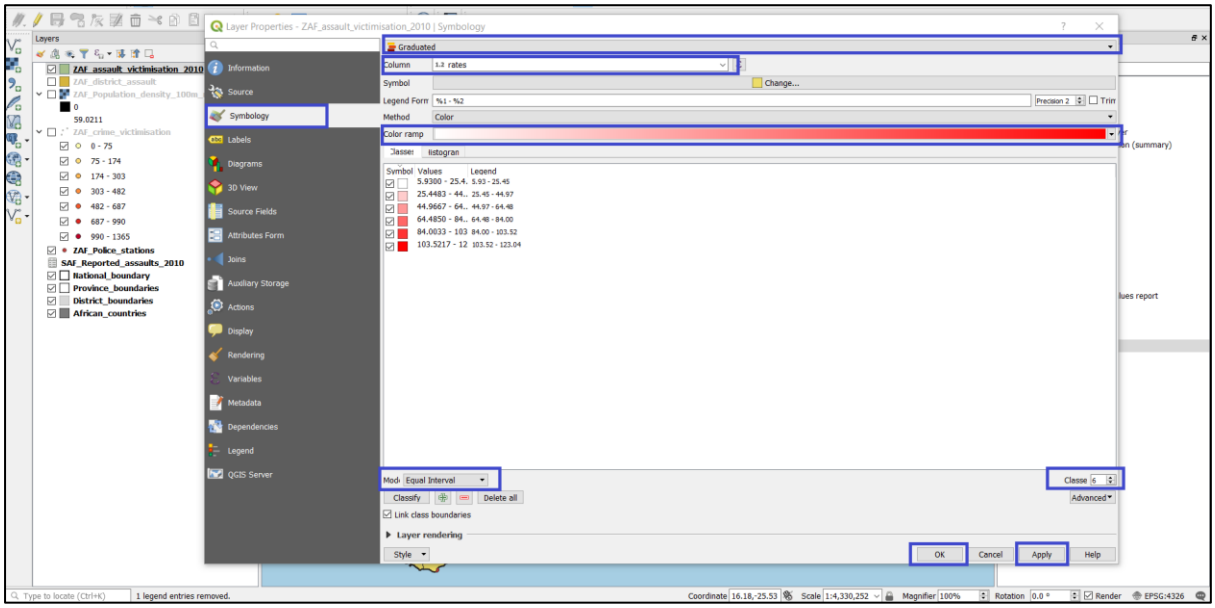
Important note: Every time you use the *Field* Calculator to add new a column through calculations it's similar to applying edits to a vector layer. You must always click on the *Toggle edits* button to stop the edits. This, in turn, will apply any updates as well as save the new column in *ZAF_assault_victimisation_2010*.

The final attribute table should appear as follows:

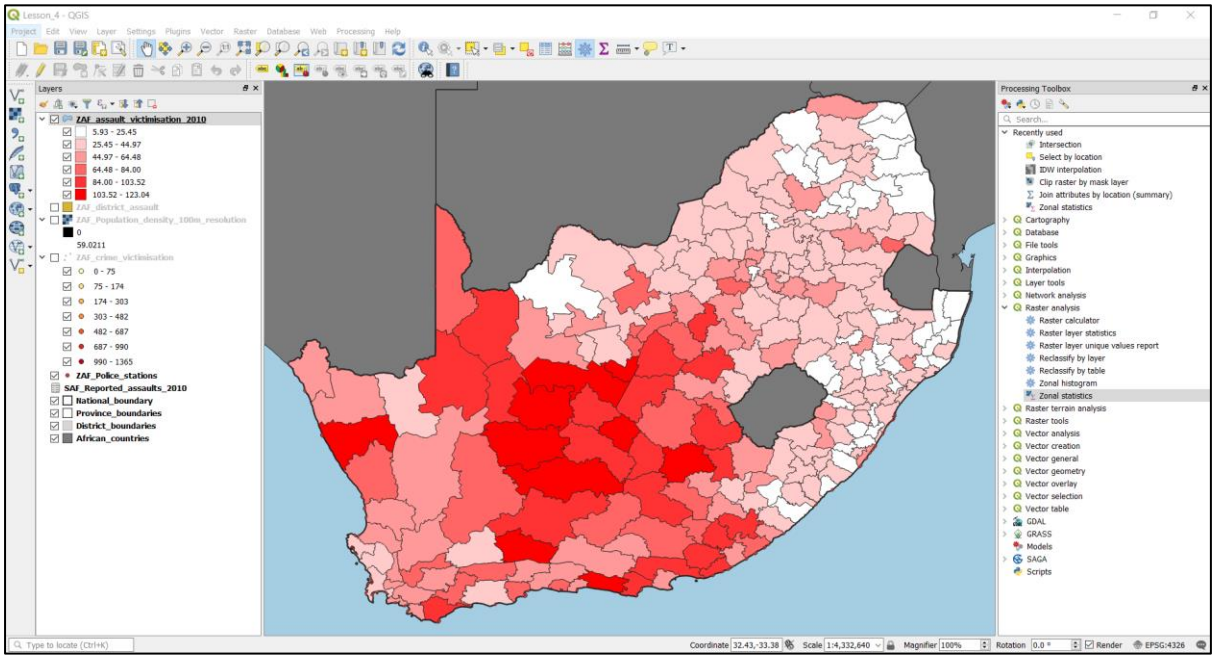


We can finally generate our district-level map on assault rates. It is the same procedure when we created the point maps for the stations earlier on in this exercise. Recall the steps were:

- Right-click on the *ZAF_assault_victimisation_2010* and select *properties* to access its *Layer Properties* menu
- Choose the *Symbology* tab on the left-hand side of the menu and select *Graduated* on the topmost selection bar
- We want to display number of assault across points in space. In *Column* select the field name "*rates*"
- In *Colour ramp* select *Reds*
- You can specify the method for which classes are generated (*equal interval*, *quantile*, *natural breaks*, *standard deviation* or *pretty breaks*). For this example – select *Equal Interval* and type *6* in *Classes* to generate five intervals
- Click *Apply* and *OK*



The final output in the Display window should appear as:



Interpretation of output

In the Layer Panels – you can see the rates of victimisation by assault in 2010 are represented as a legend under layer *ZAF_assault_victimisation_2010*. Districts with the lowest reported rates are those with estimates anything at/below 25.45 per 10,000 inhabitants. Likewise, districts with the highest reported rates are those with anything at/above 103.52 per 10,000 inhabitants.

Bear in mind that the results are on QGIS *Display window* – you will need to go into the ***Print Composer*** tool which allows the user to create high quality publication-styled maps for them to be included in peer-viewed articles. The outputs can also be exported as an *image* (*.png, .jpeg* etc.) or *pdf* document in ***Print Composer*** which can be shared with other stakeholders or researchers. You can refer to earlier tutorials in the series to follow the steps in using ***Print Composer***.

You can save this project by clicking on the *save as* icon in the toolbars and name the project as *ZAF_reported_victimisation_project.qgs*

Appendix: Lesson 4

Data source(s)

Datafile	Format	Source
African_countries	Shape file	https://gadm.org/download_world.html
National_boundary	Shape file	https://gadm.org/download_country_v3.html
Province_boundaries	Shape file	https://gadm.org/download_country_v3.html
District_boundaries	Shape file	https://gadm.org/download_country_v3.html
ZAF_Population_density_100m	Raster	http://www.worldpop.org.uk/data/summary/?doi=10.5258/SOTON/WP00246
SAF_Police_Stations	CSV	https://africaopendata.org/dataset/police-station-coordinates
SAF_Reported_assaults_2010	CSV	https://africaopendata.org/dataset/police-statistics

Citation(s)

1 Global Administrative Areas (2012). GADM database of Global Administrative Areas, version 2.0. [online] URL: www.gadm.org

2 Linard C, Gilbert M, Snow RW, Noor AM, Tatem AJ (2012) Population Distribution, Settlement Patterns and Accessibility across Africa in 2010. PLoS ONE 7(2): e31743. https://doi.org/10.1371/journal.pone.0031743

Lesson 5: Various spatial interpolation techniques in QGIS

Introduction

Spatial interpolation are techniques used to predict values of cells from a sample of existing data points. These data points can in turn, be utilised to determine unknown values for any geographic point.

For instance, suppose I know the land surface temperature value of a single point in a location - from this point, I can use spatial interpolation to predict land surface temperature value of nearby and unknown points etc.

There are wide range of spatial interpolation techniques – these include Inverse Distance Weighting (IDW), Kernel Density Estimation (KDE), and the more advance methods such as Kriging and Model-Based Geostatistics (MBGs).

In QGIS, we will learn how to perform two basic spatial interpolation methods:

- Part 1: Inverse Distance Weighting (IDW)
- Part 2: Kernel Density Estimation (KDE)

In the context of victimisation – the **Inverse Distance Weighting (IDW)** is primarily focused on using point data which measures either prevalence or incidence rates for predicting the burden of victimisation (i.e. continuous). **Kernel Density Estimation (KDE)** specifically uses single-event or a case as point data (i.e. discrete), and is therefore concerned with predicting the density of victimisation.

What all spatial techniques have in common is that they use point vector data to make surface predictions – these predicted values, which are in turn, stored as raster data.

In Lesson 5, we will explore how to use these techniques in *QGIS Desktop version 3.2.0*. The lesson is split into two parts.

If you have not already, please make sure to download the corresponding dataset for lesson 5 by going to our website on http://development-frontiers.com/tutorials/

Important note:

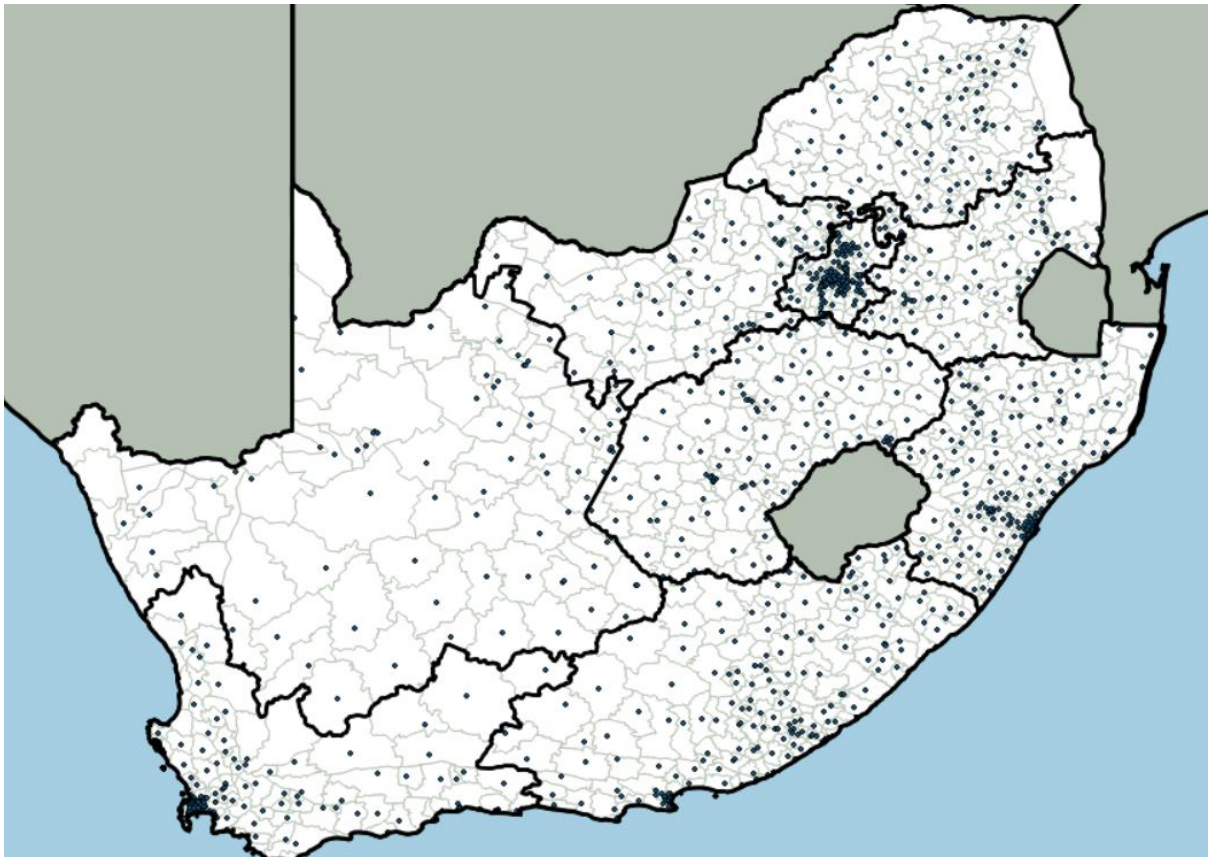
- **The dataset for part 1's lesson is stored in the folder "*part1_idw*"**
- **The dataset for part 2's lesson is stored in the folder "*part2_kde*"**

Important note: Lessons 1, 2 and 3 are prerequisites for this tutorial; therefore, its assumed that the reader knows how to add, import and save spatial data. Its assumed that you understand the science layer management, as well as knowing how to use Print composer.

Let's begin part 1 of Lesson 5 with Inverse Distance Weighting (IDW).

Open *QGIS Desktop 3.2.0* by clicking on the icon  and you will be greeted with a blank window which reads *Recent Projects*. Open a *New Project* for this part of the practical session and save this project as "*Lesson_5_partIDW.qgs*".

Part 1: Inverse Distance Weighting (IDW)



The blue points in the above image represent locations of police stations in South Africa. The grey-coloured boundaries represent the extents of which a police station operates. For each point or police station – we have determined the rates of victimisation in 2010 by dividing the number of reported cases of assault with the overall population at risk of being assaulted within catchment areas of police stations.

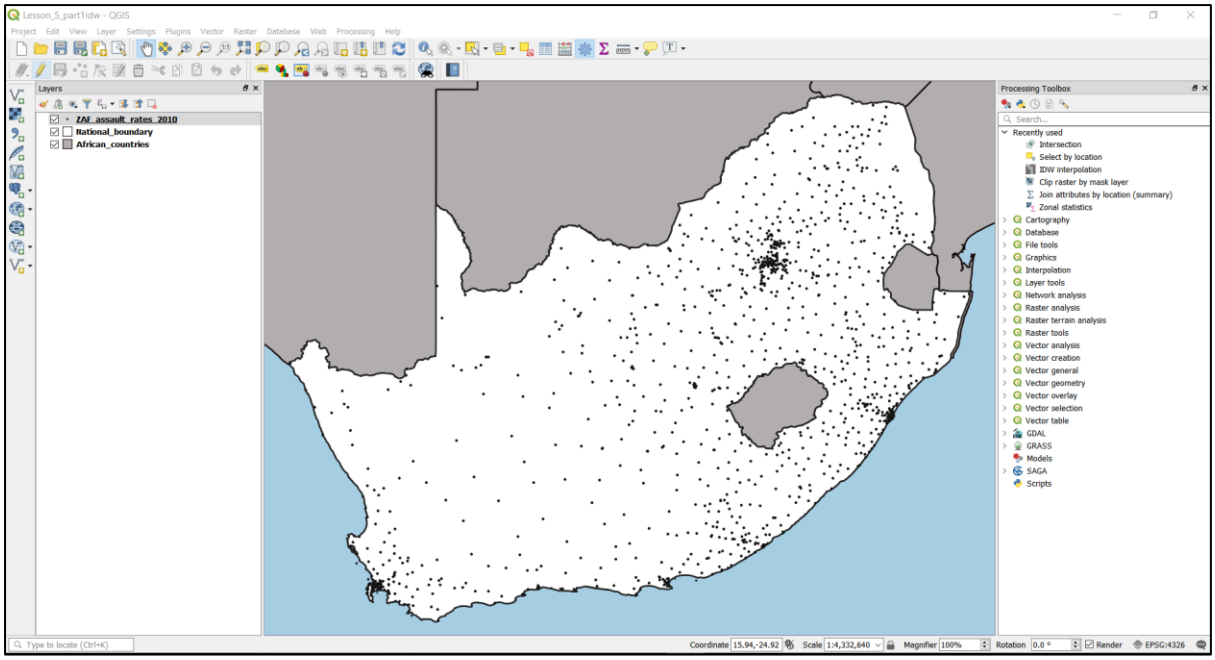
This will give us **point** crime incidence rate data. We can use ***IDW*** to interpolate these estimates over unmeasured surface where there are no data – i.e. white spaces between police stations. This technique uses an explicit assumption that ***points that are close to each one another are alike than points that farther away***. ***IDW*** method uses measured values surrounding an unmeasured point to make predictions. The result output is a continuous surface on a raster map.

Load the required vector files in QGIS

The following shape files should be added into QGIS:

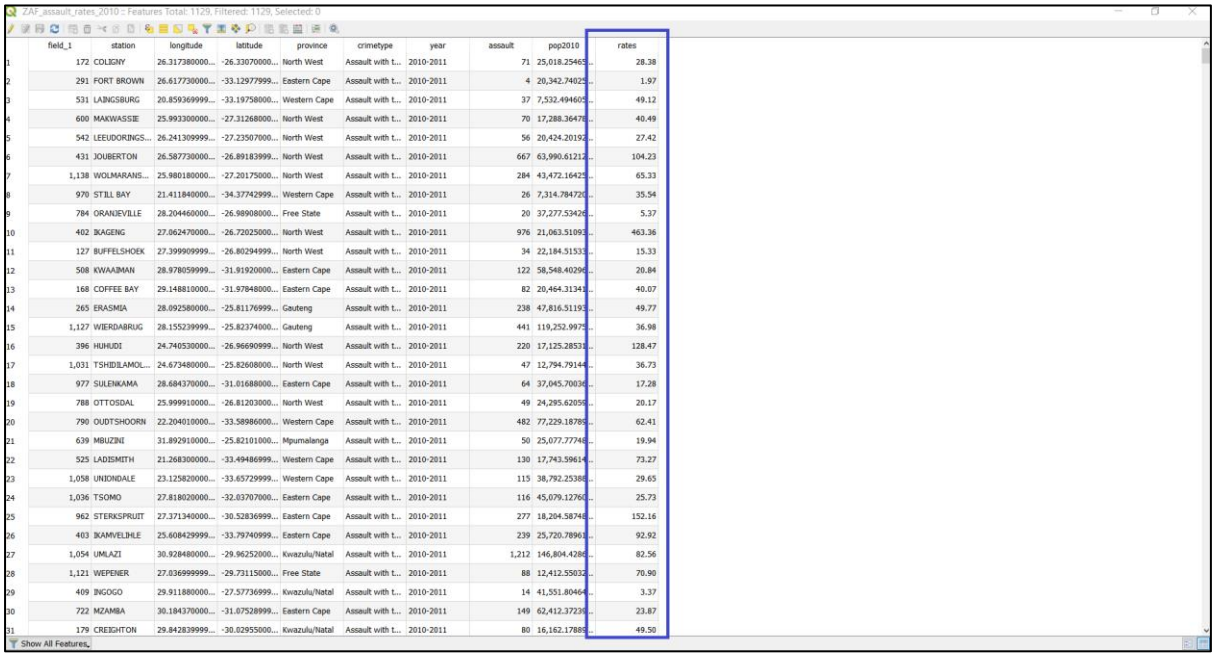
- *Africa_countries.shp* (contains national boundaries of official African countries)
- *National_boundary.shp* (contains the national boundary of South Africa)
- *ZAF_assault_rates_2010.shp* (point vector data containing location of police station in South Africa with their estimated rates of assault per 10,000 inhabitants)

Change the properties of *African_countries* and *National_boundaries* by rendering its fill colours as *grey* and *white*, respectively, and include the colour of the sea.



Using IDWs to predict the rates of assault in South Africa

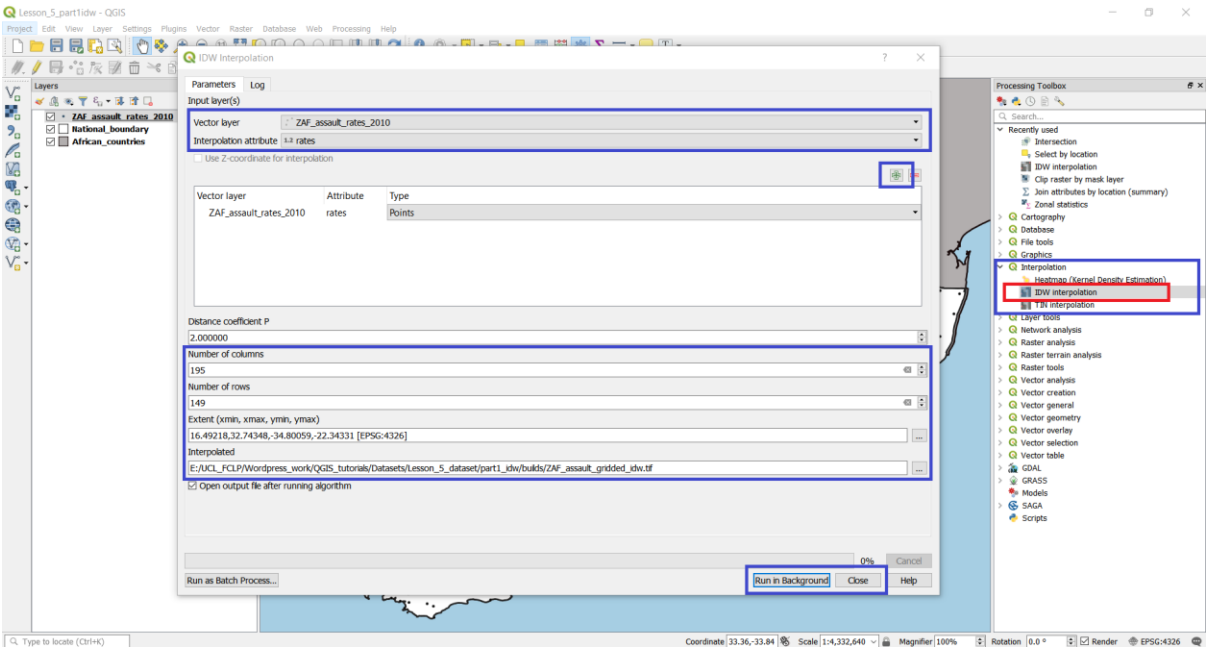
We have determined for each police station the incidence of victimisation via assault (per 10,000) in 2010.



	field_1	station	longitude	latitude	province	crimetype	year	assault	pop2010	rates
1	172	COLIGNY	26.317380000...	-26.33070000...	North West	Assault with t...	2010-2011	71	25,018.25465...	28.38
2	291	FORT BROWN	26.617730000...	-33.12977999...	Eastern Cape	Assault with t...	2010-2011	4	20,342.74025...	1.97
3	531	LAINGSBURG	20.859369999...	-33.19758000...	Western Cape	Assault with t...	2010-2011	37	7,532.494605...	49.12
4	600	MAKWASSIE	25.993300000...	-27.31268000...	North West	Assault with t...	2010-2011	70	17,288.36478...	40.49
5	542	LEEUDORINGS...	26.241309999...	-27.23507000...	North West	Assault with t...	2010-2011	56	20,424.20192...	27.42
6	431	JOUBERTON	26.587730000...	-26.89183999...	North West	Assault with t...	2010-2011	667	63,990.61212...	104.23
7	1,138	WOLMARANS...	25.980180000...	-27.20175000...	North West	Assault with t...	2010-2011	284	43,472.16425...	65.33
8	970	STILL BAY	21.411840000...	-34.37742999...	Western Cape	Assault with t...	2010-2011	26	7,314.784720...	35.54
9	784	ORANJEVILLE	28.204460000...	-26.98908000...	Free State	Assault with t...	2010-2011	20	37,277.53426...	5.37
10	402	IKAGENG	27.062470000...	-26.72025000...	North West	Assault with t...	2010-2011	976	21,063.51093...	463.36
11	127	BUFFELSHOEK	27.399909999...	-26.80294999...	North West	Assault with t...	2010-2011	34	22,184.51533...	15.33
12	508	KWAAIMAN	28.978059999...	-31.91920000...	Eastern Cape	Assault with t...	2010-2011	122	58,548.40296...	20.84
13	168	COFFEE BAY	29.148810000...	-31.97848000...	Eastern Cape	Assault with t...	2010-2011	82	20,464.31341...	40.07
14	265	ERASMIA	28.092580000...	-25.81176999...	Gauteng	Assault with t...	2010-2011	238	47,816.51193...	49.77
15	1,127	WIERDABRUG	28.155239999...	-25.82374000...	Gauteng	Assault with t...	2010-2011	441	119,252.9975...	36.98
16	396	HUHUDI	24.740530000...	-26.96690999...	North West	Assault with t...	2010-2011	220	17,125.28531...	128.47
17	1,031	TSHIDILAMOL...	24.673480000...	-25.82608000...	North West	Assault with t...	2010-2011	47	12,794.79144...	36.73
18	977	SULENKAMA	28.684370000...	-31.01688000...	Eastern Cape	Assault with t...	2010-2011	64	37,045.70036...	17.28
19	788	OTTOSDAL	25.999910000...	-26.81203000...	North West	Assault with t...	2010-2011	49	24,295.62050...	20.17
20	790	OUDTSHOORN	22.204010000...	-33.58986000...	Western Cape	Assault with t...	2010-2011	482	77,229.18785...	62.41
21	639	MBUZINI	31.892910000...	-25.82101000...	Mpumalanga	Assault with t...	2010-2011	50	25,077.77748...	19.94
22	525	LADISMITH	21.268300000...	-33.49486999...	Western Cape	Assault with t...	2010-2011	130	17,743.59614...	73.27
23	1,058	UNIONDALE	23.125820000...	-33.65729999...	Western Cape	Assault with t...	2010-2011	115	38,792.25388...	29.65
24	1,036	TSOMO	27.818020000...	-32.03707000...	Eastern Cape	Assault with t...	2010-2011	116	45,079.12760...	25.73
25	962	STERKSPRUIT	27.371340000...	-30.52836999...	Eastern Cape	Assault with t...	2010-2011	277	18,204.58748...	152.16
26	403	IKAMVELIHLE	25.608429999...	-33.79740999...	Eastern Cape	Assault with t...	2010-2011	239	25,720.78961...	92.92
27	1,054	UMLAZI	30.928480000...	-29.96252000...	Kwazulu/Natal	Assault with t...	2010-2011	1,212	146,804.4286...	82.56
28	1,121	WEPENER	27.036999999...	-29.73115000...	Free State	Assault with t...	2010-2011	88	12,412.55032...	70.90
29	409	INGOGO	29.911880000...	-27.57736999...	Kwazulu/Natal	Assault with t...	2010-2011	14	41,551.80464...	3.37
30	722	MZAMBA	30.184370000...	-31.07528999...	Eastern Cape	Assault with t...	2010-2011	149	62,412.37239...	23.87
31	179	CREIGHTON	29.842839999...	-30.02955000...	Kwazulu/Natal	Assault with t...	2010-2011	80	16,162.17889...	49.50

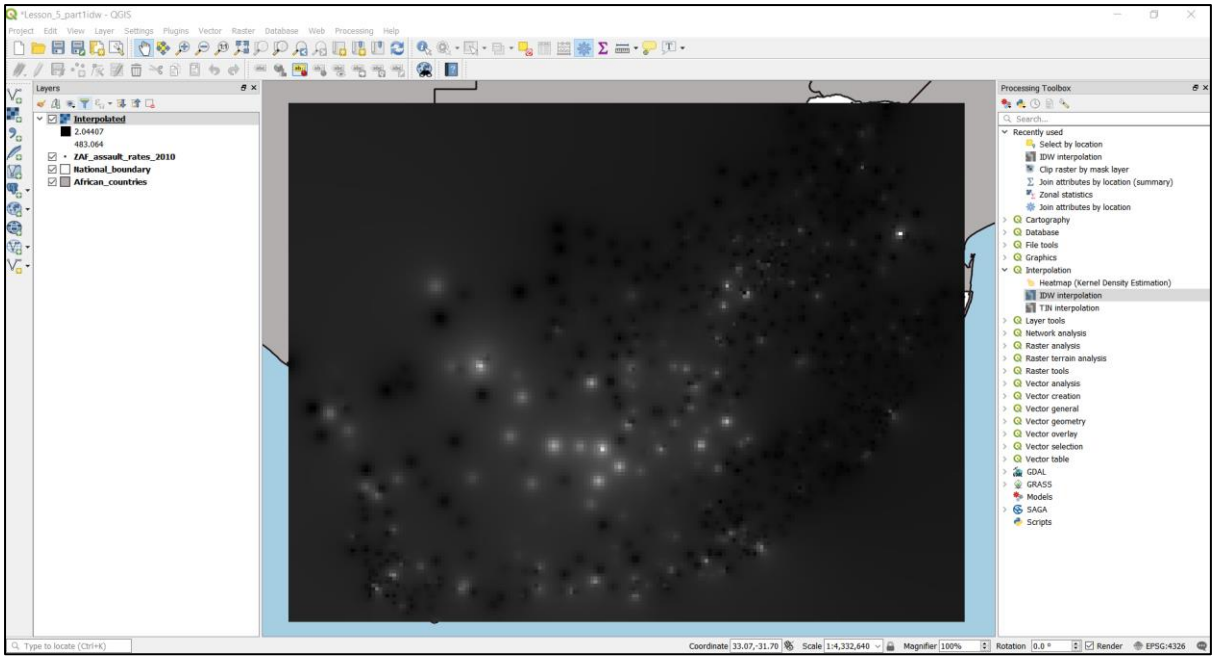
Based on these points, we can predict the rates of victimisation at unmeasured locations. We can use the IDW interpolation tool in QGIS to generate a raster template which the rates of assault can be interpolated over. The resulting surface will be the predicted rates of assault.

This can be achieved in the following steps:

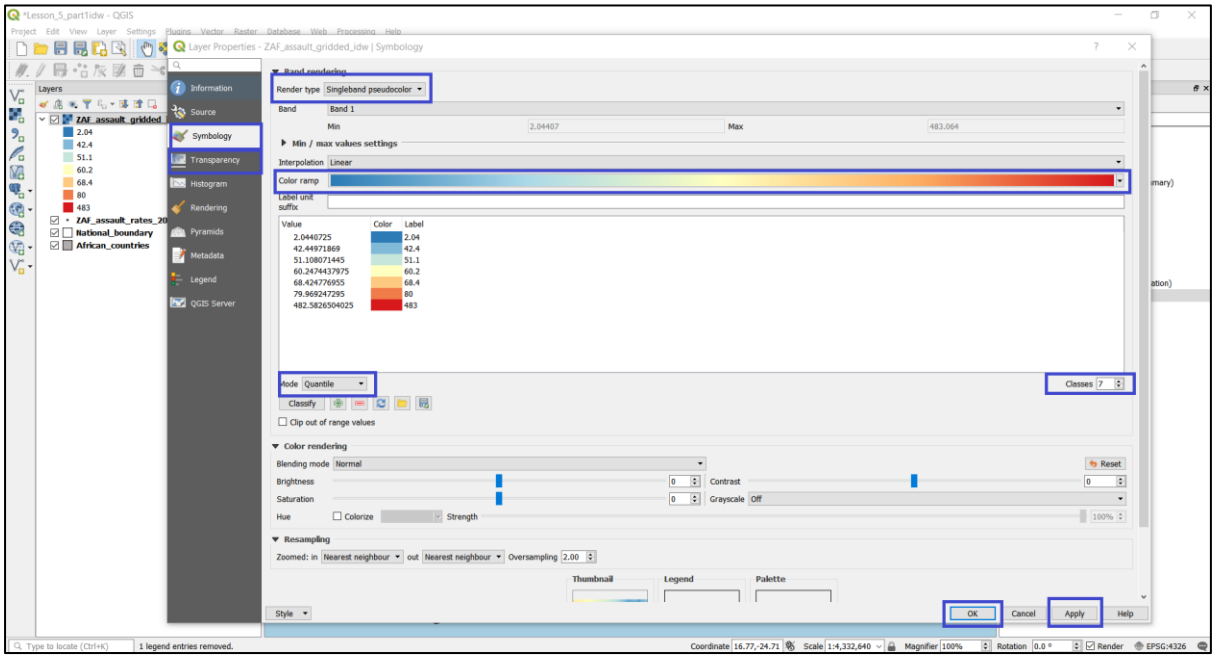


- Under the Processing Toolbox - click on the tabs *Interpolation* > *IDW interpolation* and the *IDW Interpolation* menu will appear
- We need to specify which point layer contains the estimates we wish to spatially interpolate. Under *Vector layer* select *ZAF_assault_rates_2010*
- After specifying the point layer, we need to state which field attribute contains the estimates we wish to spatially interpolate. Under *Interpolation attribute* select *rates* (note: this field must be a real number, and not a string nor integer value!)
- Click on *GREEN PLUS SIGN* to confirm the information we specified in the *Input* section
- In *Number of columns*, type 195. Also in *Number of row*, type *149*. These values will ensure we create a raster gridded that have a resolution of 10km
- We want to interpolate the full extent of the South Africa. In *Extent (xmin, xmax, ymin, ymax)*, select *National_boundaries* layer as the extent for our interpolation grid by first clicking on the *browse* button and selecting the Use *Layer/Canvas extent* option
- In *Interpolated* section, click on the on the radio button and choose the location to export the results. Save it as *ZAF_assault_gridded_idw.tif*
- Click on *Run in Background* and *Close*
- Add the resulting raster to the Layer Panel *ZAF_assault_gridded_idw*

The results should appear as follows:

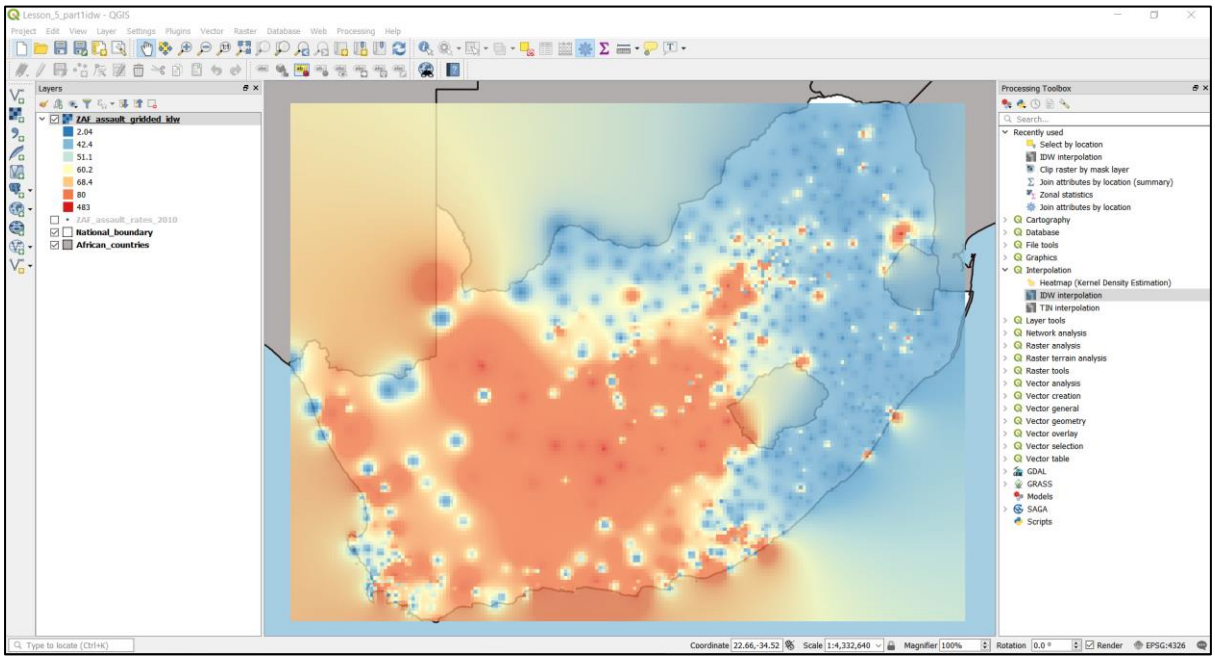


You can see the image is in black and white at the moment. We can clear the appearance and render it to something that can be interpreted by going into the properties of this raster file:



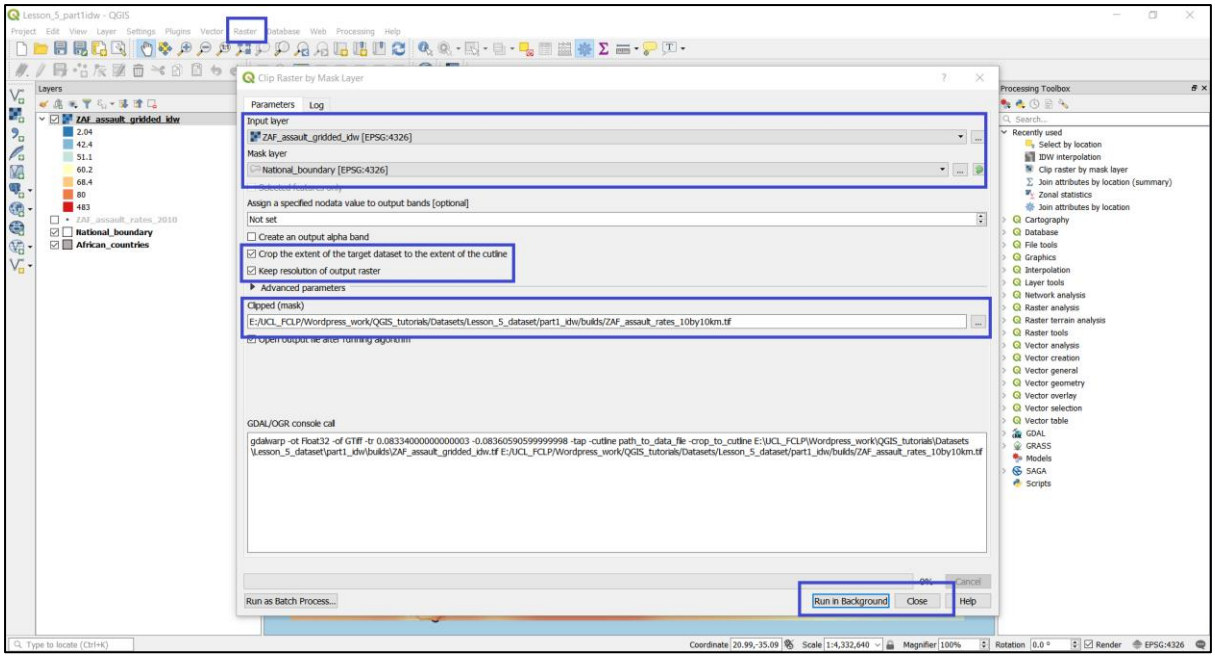
- Right-click on *ZAF_assault_gridded_idw* and select *properties* to access its *Layer Properties* menu
- Click *Symbology* located on the left-hand side of the *Layer Properties* menu to access the band rendering settings. Under *Render type*, select *Singleband pseudocolor*
- Under *Colour ramp*, select *RdYlBu*. The colour palette goes from red to yellow to blue (i.e. low intensity of victimisation from red, and higher as blue); therefore, we need to invert the colour palette accordingly by selecting *Invert Colour Ramp* after choosing *RdYlBu*

- Choose the mode as *Quantile*, and *7* as the number of classes. Do not click on *OK* yet.
- Click *Transparency* located on the left-hand side of the *Layer Properties* menu to access the *Global transparency* settings. You can set the levels of transparency to 80% by moving the slide bar
- Now, click *OK* to finalise changes to appearance of results.



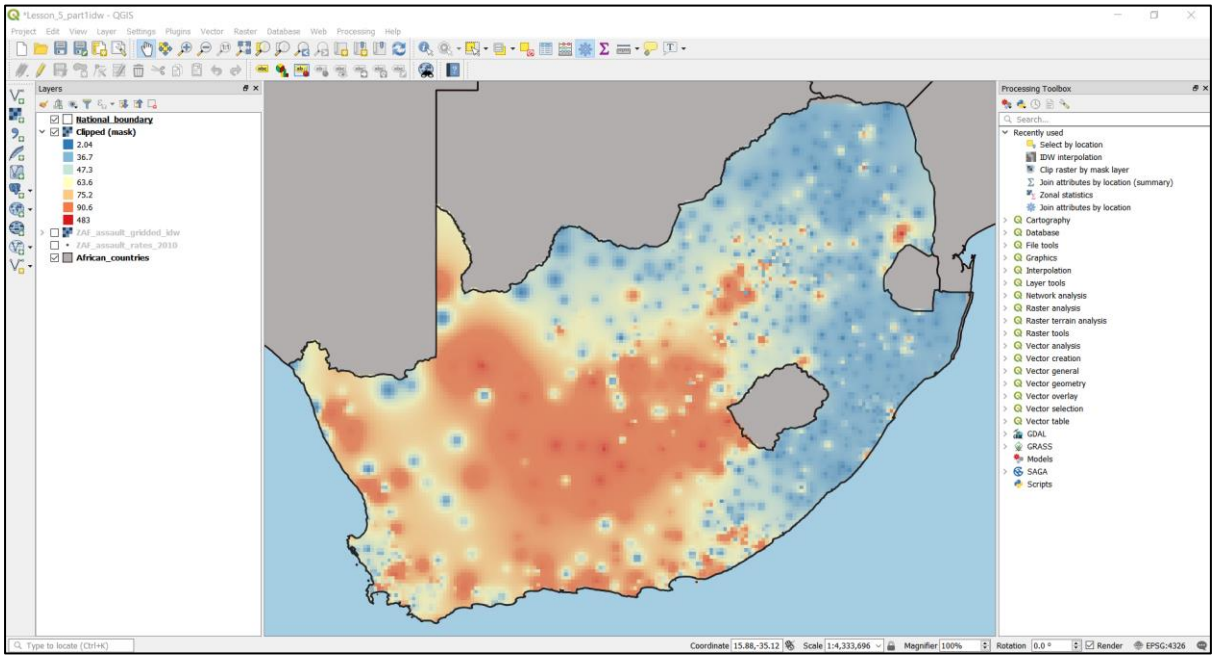
We need to crop the resulting grid to South Africa's national boundaries. This can be done by:

- Click on *Raster > Extraction > Clip raster by mask layer*. The *Clipper* menu will appear
- In the *Input layer* section - select *ZAF_assault_gridded_idw*. Here, you are choosing which raster you wish to crop
- In the *Mask layer* section – select *National_boundary*. Here, you are choosing which to serve as a template for cropping the raster to size
- Make sure to check the option *Keep resolution of output raster*
- In *Clipped (mask)* section, click on the on the radio button and then choose the location to export the results. Save the results as *ZAF_assault_rates_10by10km.tif*
- Click *Run in Background* and *Close*
- Add the resulting raster to the Layer Panel *ZAF_assault_rates_10by10km*



It will add the new clipped layer to the map canvas. However, the image will be in black and white. You have to repeat the above steps of rendering the image into something that can be interpreted appropriately.

The interpolated victimisation should appear as follows:



Interpretation of output

We have produced a map showing the predicted incidence rates of assault in South Africa. An example of interpreting this map – areas with yellow colours indicate that the reported crime rates for assault are 63.6 per 10,000 inhabitants (at resolution of 10km), whereas areas with the lowest intensity of victimisation by assault are predicted to be reported 2.04 per 10,000 inhabitants (at resolution of 10km) and vice versa.

Bear in mind that the results are on QGIS *Display window* – you will need to go into the ***Print Composer*** tool which allows the user to create high quality publication-styled maps for them to be included in peer-viewed articles. The outputs can also be exported as an *image* (*.png, .jpeg* etc.) or *pdf* document in ***Print Composer*** which can be shared with other stakeholders or researchers. You can refer to earlier tutorials in the series to follow the steps in using ***Print Composer***.

Do not forget to save this project and close it.

This concludes part 1 of lesson 5. Now, Let's begin part 2 of Lesson 5 with Kernel Density Estimation (KDE).

Re-open *QGIS Desktop 3.2.0* by clicking on the icon  and you will be greeted with a blank window which reads *Recent Projects*. Open a *New Project* for this part of the practical session and save this project as "*Lesson_5_part2KDE.qgs*".

Part 2: Kernel Density Estimation (KDE)

Crime event data is the actual location in which a crime has taken place and has been georeferenced – for example, the address of a home that's been burgled, graffiti on the wall of someone's property or the location of an arson crime.

One may be particularly interested in wanting to visualise the occurrence of crime events as density measure. We can do this using a useful technical called the ***Kernel Density Estimator (KDE)*** which is typically a non-parametric function that can be used to estimate the density of events (crime) in a setting.

The process for making raster maps with *KDEs* are easy. This tutorial will provide a step-by-step guide for conducting such analysis in QGIS Desktop 3.2.0.

If you have not already, please make sure to download the corresponding dataset for lesson 5 by going to our website on http://development-frontiers.com/tutorials/

Important note:

- **The dataset for part 1's lesson is stored in the folder "*part1_idw*"**
- **The dataset for part 2's lesson is stored in the folder "*part2_kde*"**

Important note: Lessons 1, 2 and 3 are prerequisites for this tutorial; therefore, its assumed that the reader knows how to add, import and save spatial data. Its assumed that you understand the science layer management, as well as knowing how to use Print composer

Load the required vector files into your Project

There was wave of vandalism in Kenya – arsonists targeted and burnt more than 100 schools in 2016. We have available a list of 121 schools that were burnt by arsonists in 2016. The schools that were victimised in such manner have been geo-located and are examples of point event data.

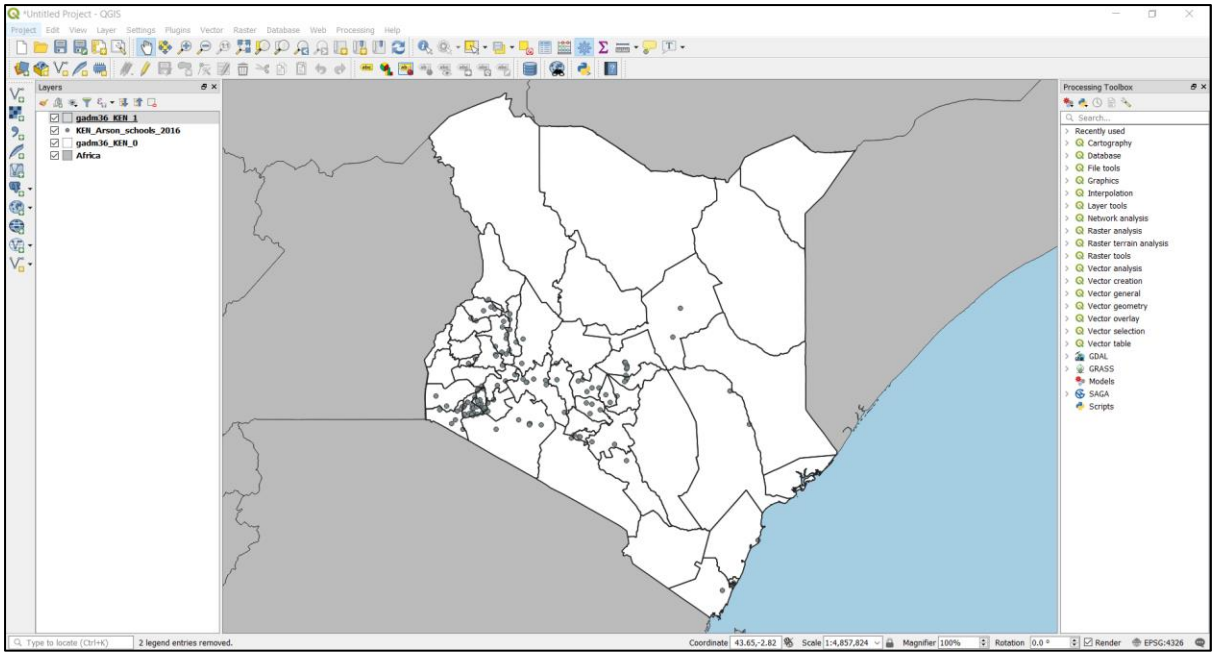
Suppose that authorities are interested in knowing the density of schools burnt within certain areas (at resolution 10km) then KDEs will be a good approach for dressing this problem.

Let's begin by creating our atlas for Kenya and visualising the distribution of schools that were burnt in 2016

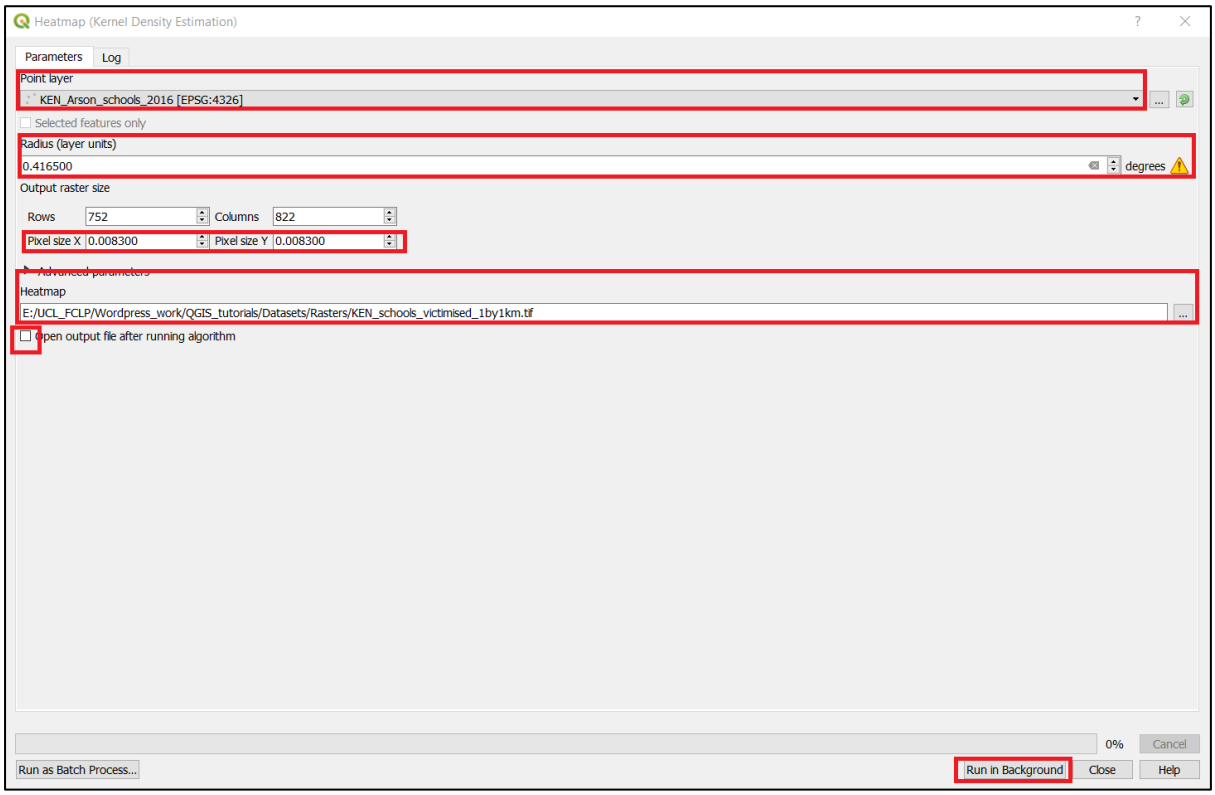
The following shape files should be added into QGIS:

- *Africa.shp* (contains national boundaries of official African countries)
- *gadm36_KEN_0.shp* (contains the national boundary for Kenya)
- *gadm36_KEN_1.shp* (contains the county boundaries for Kenya)
- *KEN_Arson_schools_2016.shp* (point vector data containing location of schools that were torched by arsonists in 2016)

The data should appear as follows:



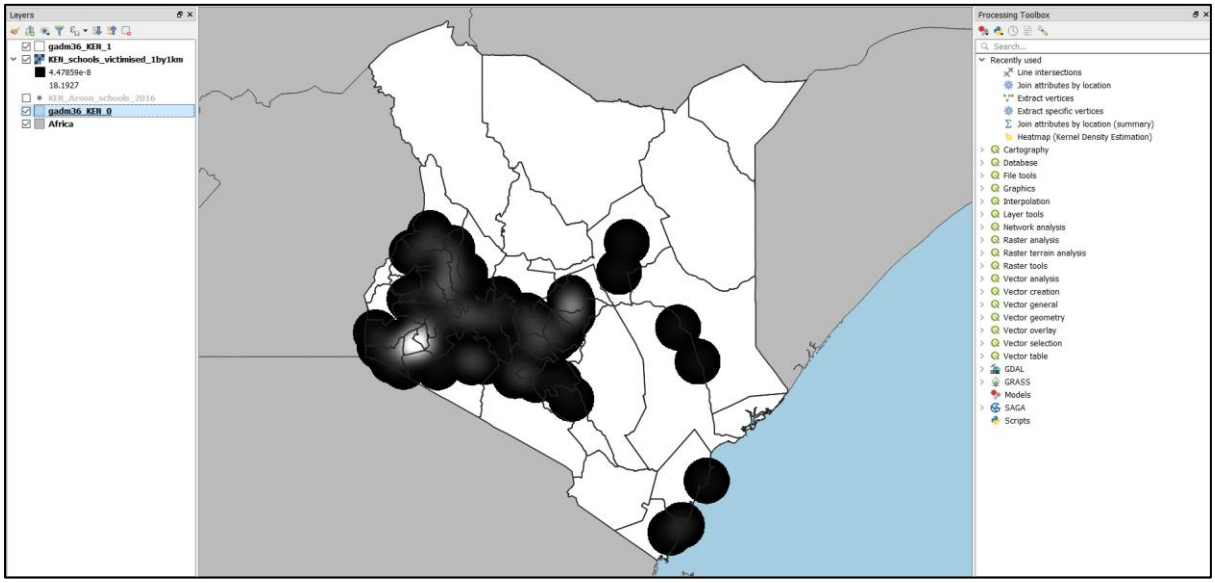
In the *Processing Toolbox* (located on the right-hand side of the window) – click on *Interpolation* to expand the option. Select *Heat map (Kernel Density Estimation)* and a window should pop-up allowing us to specify the parameters for conducting such interpolation technique. Do the following:



- Click on the tabs *Heat map (Kernel Density Estimation)* and its menu will appear
- We need to specify which layer contains the point data we wish to spatially interpolate. Under *Point layer* select *KEN_Arson_schools_2016*
- We need to specify the search radius. For this exercise, we are using 50km as the value. **Important note:** the point data's coordinates projection system is in WGS84 which uses

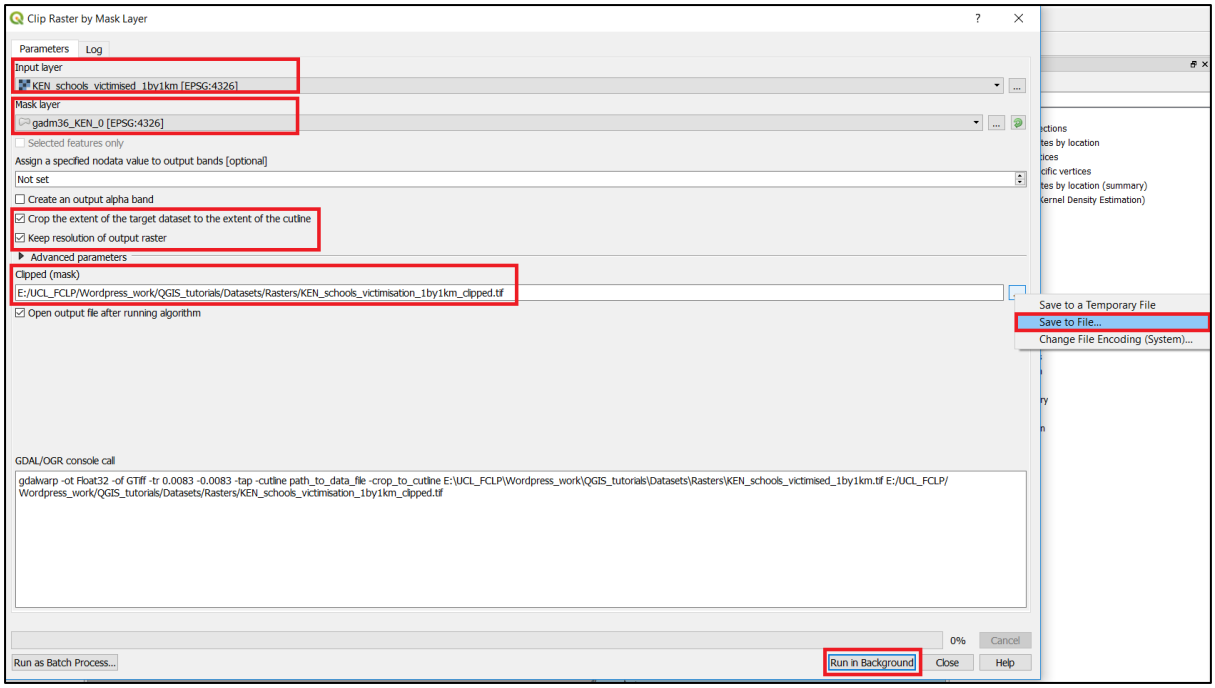
decimal degrees. Now, 0.0008333 decimal degrees (approximately at the equator) in WGS84 is equivalent to 100m. Therefore, 1km is 0.008333, 10km is 0.08333, 100km 0.8333 and etc. In *Radius (layer units)* section, enter the search radius value as *0.4165 (~50km)*

- We want to generate 1-by-1km grids. We can do this by specifying the *Pixel size* for *X* and *Y* as *0.00833 (~ 1km)*.
- In *Heat map section* under *Advanced parameters* click on the on the radio button and choose the location to export the results. Name it as *KEN_schools_victimised_1by1km and save it.*
- Uncheck box *Open output file after running algorithm*. We are doing this because QGIS will automatically load-in the result raster file, and name it as *Heatmap*. We want to load the result which we named as *KEN_schools_victimised_1by1km*
- Click *Run in Background*
- Once the analysis is complete – load the resulting raster *KEN_schools_victimised_1by1km.tif* into QGIS' window by clicking on the icon *Add raster*



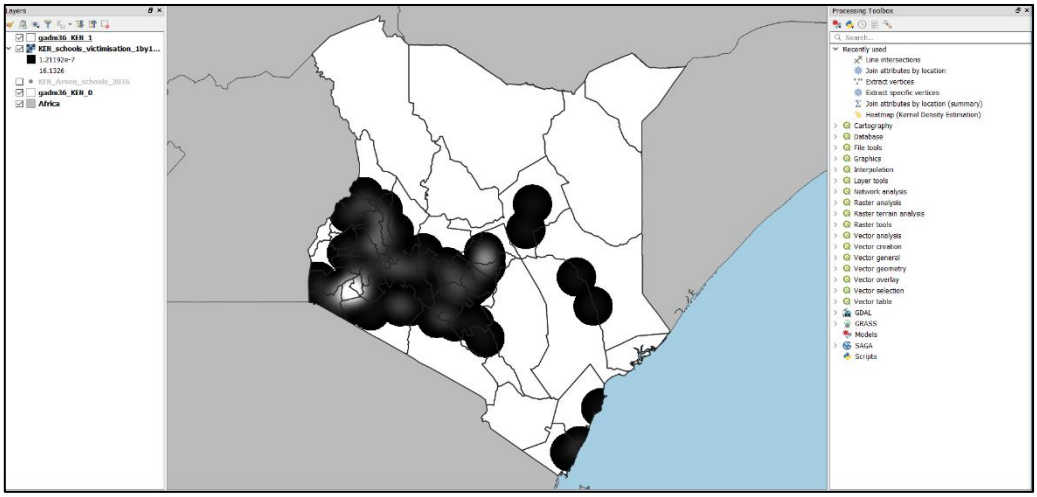
We need to crop the resulting grid to Kenya's national boundaries. You can do this in the following steps:

- Click on *Raster > Extraction > Clip raster by mask layer*. The *Clip by Mask Layer* menu will appear
- In the *Input file* select *KEN_schools_victimised_1by1km*. Here, you choose which raster you wish to crop
- We need to specify that our template for cropping the raster is the *gadm36_KEN_0 file*. Under *Mask layer*, select *gadm36_KEN_0*
- Make sure to check the box *Keep resolution of output raster*. We want to maintain the dimensions of our output which is at a resolution of 1km
- The section "*Clipped (mask)*" is prompting the user to choose a location to save their new cropped raster file. Click on the button and then select "*Save to File…*". Name the file as *KEN_schools_victimisation_1by1km_clipped* and it will be saved as a *.tif*
- Click *Run in Background* and *Close*



The new clipped layer will be added to the map canvas. However, it will be the temporary version (i.e. stored in QGIS' memory) and not one you saved as *KEN_schools_victimised_1by1km_clipped*. You can remove ALL that is currently loaded into your *Layers Panel* and then, reload your saved output (i.e. *KEN_schools_victimised_1by1km_clipped*) into the panel.

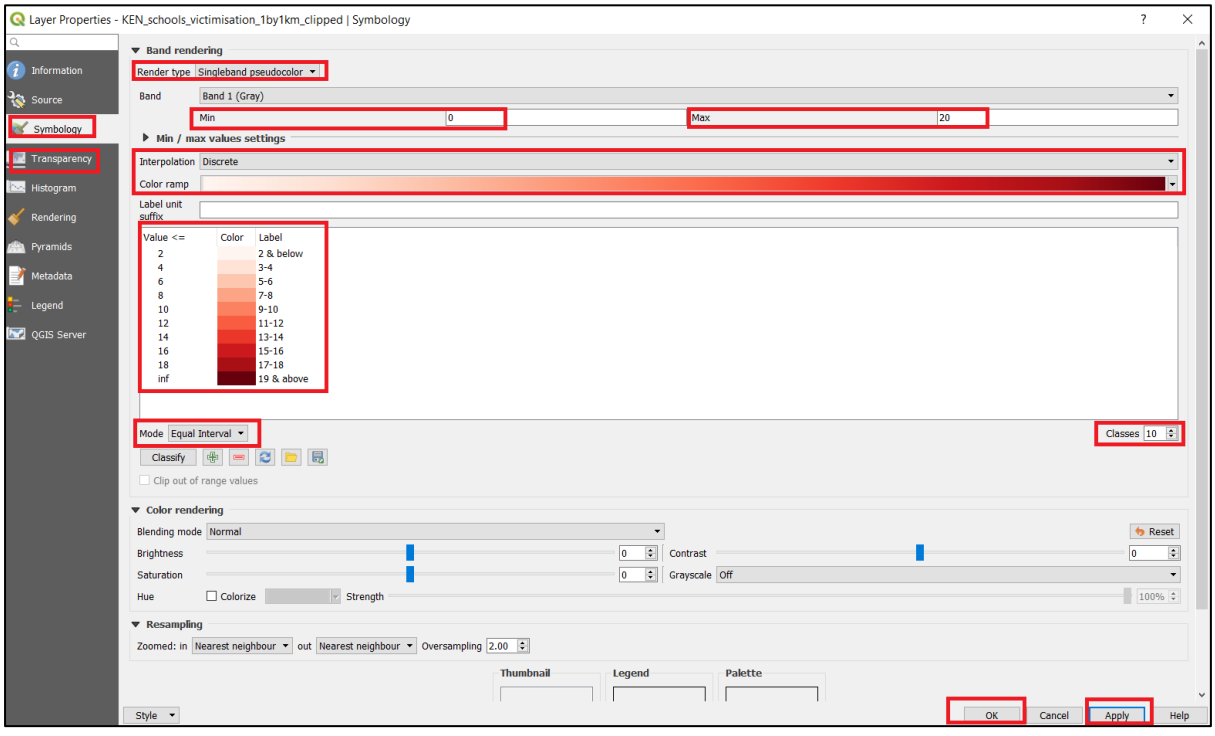
Make sure to move raster output beneath the layer *gadm36_KEN_1* in the *Layer panels*. Also, deactivate the *KEN_Arson_schools_2016* layer by unchecking it. The output should look as follows:



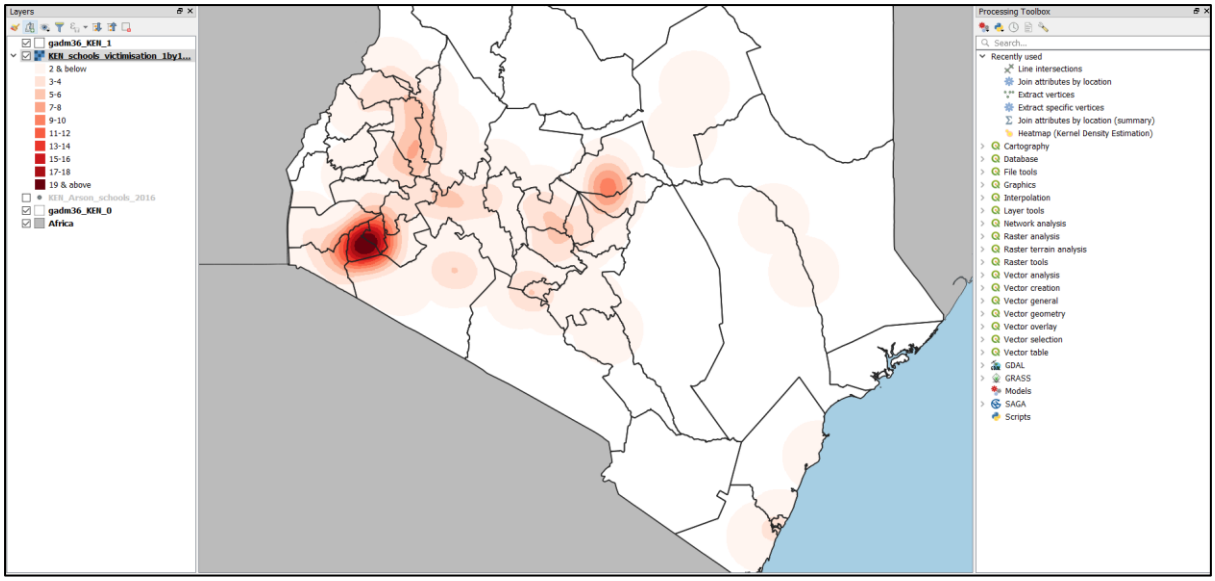
As you can see the resulting image is in black and white at the moment. We can clear the appearance and render it to something that can be interpreted by going into the properties of this raster file. Since, we are dealing with cases/events in makes sense to use legends that contain discrete values i.e. 1, 2, 3, 4 and so on.

- Right-click on *KEN_schools_victimised_1by1km_clipped* and select *properties* to access its *Layer Properties* menu
- Click *Symbology* located on the left-hand side of the *Layer Properties* menu to access the band rendering settings. Under *Render type*, select *Singleband pseudocolor*

- Under *Band* in *min/max* section – notice that maximum value predicted by the KDEs was 18.1927, and the minimum value predicted is something negligible. Let's modify this by typing *0* as the minimum value in the *Min* section. Now, type *20* as the maximum value in the *Max* section. We are using the range from *0* to *20* to create our legends that hold discrete values
- Under *Interpolation*, select *Discrete*
- Under *Colour ramp*, select *Reds*. The colour palette goes from *lightest of reds* to the *darkest of reds* (i.e. lowest intensity of victimisation is represented by lightest of reds, and highest victimisation are the darkest of reds)
- Under *Mode*, choose *Equal Intervals* and select 10 as the number of classes. You will see a notation *inf* at the last category. Do not be alarmed – it indicates any value from-to-infinity. In our case its 18 and above. Change the label of *inf* to "*19 & above*". **Important note:** The first category in the legend corresponds to any grid that has *≤2* schools that were burnt. The next category corresponds to 3-4 schools that were burnt, the next 5-6 and so on. The labels for the categories have been modified accordingly (view image to see changes)
- Click *Transparency* located on the left-hand side of the *Layer Properties* menu to access the *Global transparency* settings. You can set the levels of transparency to *80%* by moving the slider in the left direction
- Now, click *Apply* and *OK* to finalise changes to appearance of results.



The resulting layer using KDEs should appear as follows:



Interpretation of output

We have produced a map showing the number of schools that were victims to arson attacks during 2016 in Kenya. The map reports the number of schools burnt per 1km^2. An example of interpreting this map – areas with the darkest reds indicate that 19 schools (per 1km^2), at least, were burnt in 2016. Whereas, areas with the lightest red colour indicates that most at, 2 schools (per 1km^2) were targeted and burnt down by arsonists.

Bear in mind that the results are on QGIS map canvas – you will need to go into the ***Print Composer*** tool which allows the user to create high quality publication-styled maps for them to be included in peer-viewed articles. The outputs can also be exported as an *image* (*.png, .jpeg* etc.) or *pdf* document in ***Print Composer*** which can be shared with other stakeholders or researchers. You can refer to earlier tutorials in the series to follow the steps in using ***Print Composer***.

Do not forget to save this project and close it.

This concludes part 2 of lesson 5

Appendix: Lesson 5

Data source(s)

Datafile	Format	Source
African_countries.shp (or Africa.shp)	Shape file	https://gadm.org/download_world.html
National_boundary.shp	Shape file	https://gadm.org/download_country_v3.html
ZAF_assault_rates_2010.shp	Shape file	1.) https://africaopendata.org/dataset/police-station-coordinates 2.) https://africaopendata.org/dataset/police-statistics
gadm36_KEN_0.shp	Shape file	https://gadm.org/download_country_v3.html
gadm36_KEN_1.shp	Shape file	https://gadm.org/download_country_v3.html
KEN_Arson_schools_2016.shp	Shape file	https://africaopendata.org/dataset/burning-school-in-kenya

Citation(s)

1 Global Administrative Areas (2012). GADM database of Global Administrative Areas, version 2.0. [online] URL: www.gadm.org