

Introduction to Basic GIS Operations using QGIS

Q-GIS BASIC SETUP AND INTERFACE, DATA EXPLORATION, MAP MAKING

DR. SURESH MUTHUKRISHNAN, FURMAN UNIVERSITY, GREENVILLE, SC, USA

Overview, Objective, and Skills

Introduction: Welcome to the wonderful world of Geographical Information Systems (GIS)! QGIS is an Open Source Geographic Information System. The project was born in May of 2002 and was established as a project on Source Forge in June of the same year. In a world of expensive software systems, dedicated volunteers who are passionate about geospatial technologies have developed QGIS as a viable and highly capable alternate option for anyone with access to a personal computer. QGIS currently runs on most Unix platforms, Windows, and macOS, which is an added advantage since most commercial software work only on select operating systems. QGIS is developed using the Qt toolkit (<https://www.qt.io>) and C++. This means that QGIS feels snappy and has a pleasing, easy-to-use graphical user interface (GUI). QGIS aims to be a user-friendly GIS, providing common GIS functions and advanced spatial analysis tools. The initial goal of the project was to provide a GIS data viewer. QGIS has reached the point in its evolution where it is being used by many for their daily GIS data-viewing and analysis needs. QGIS supports a number of raster and vector data formats, with new format support easily added using the plugin architecture. QGIS is released under the GNU General Public License (GPL). Developing QGIS under this license means that you can inspect and modify the source code, and guarantees that you, our the end user, will always have access to a GIS program that is free of cost and can be freely modified.

Learning Objective: Main goals of this exercise are: 1) downloading and installing the correct version of QGIS, 2) provide an overview of QGIS user interface and Program Layout and 3) learn basic data management and and exploration methods

Skills Introduced and Practiced: 1) Adding and removing GIS data layers, 2) Data extraction, symbology. 3) Spatial and attribute search, and 4) Map layout design and map printing.

QGIS Download and Installation:

There are several ways of installing QGIS software on your computer machine. In this Lab session we shall go through the most basic way of installation which is through downloading the correct version based on your computer specification. QGIS Project has ended up developing several QGIS versions, but for this course we shall use QGIS version 3.22.

Steps for downloading and installing QGIS:

Go to QGIS Download Site: <https://qgis.org/en/site/forusers/download.html>

Download the **QGIS Standalone Installer Version 3.22** (Long Term Release). This is about **1 GB in file size**. So, you might have to start the download process and let it go through.

When download is complete, go to the Downloads folder or where you saved the download and double click the file to start the installation process. Follow the steps to complete installation process.

Congratulations!!! You have just installed QGIS Software on your computer.

B. Basic GIS Data Management:

GIS projects involve use of a variety of files and lots of data. Being organized and developing the habit of good file and folder management structure on your computer is critical. Every project or lab activity that you do as a GIS specialist should have its own working directory. All data that are related to that project should be always saved in that folder.

For this module, you need to store all your GIS related data in the C: Drive of your computer. Therefore, please create a new folder in your C: Drive and give it a name: ADDA_GIS_Labs.

It is recommended that you also think of a meaningful name for your files and folders. It might be good to create a folder for each day, Say DAY_1. Inside that folder you need to create another folder for the title of each Lab session that you are doing for that particular day. However, make sure that the folder names are not very long. For example, in this Lab session the name is very long. Therefore you may shorten the name as follows: Downloading_QGIS. You will notice that I am putting an “underscore” (_) between folders and I don’t have space. This is not a rule for your folder names but it is just good practice in GIS. Spaces in file or folder names can sometime cause unnecessary problems when using specific spatial analysis tools. It is highly recommended that you start following similar system.

C. An overview of QGIS and Program Layout

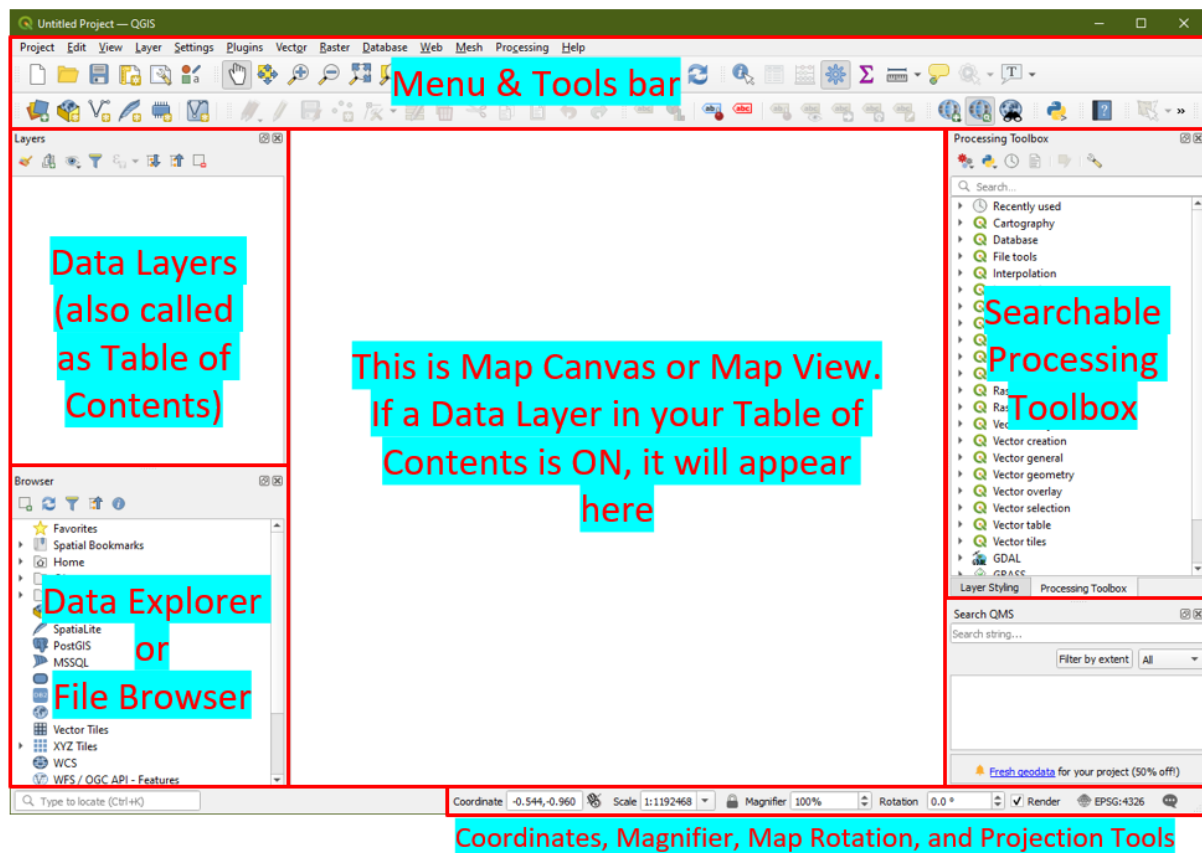
To open the QGIS software, on the windows start menu search for **QGIS Desktop 3.22.X** and click on it. Then the QGIS interface as shown in the next page will appear. The interface has different sections are shown below.

When you open QGIS, you will get a window that resembles the image to the right

Get yourself familiarized with various parts of this. Learn the terminologies used to refer to them. This will make your life easy when you are talking to someone and trying to get help solve your problems

If you point your mouse cursor over any of the buttons within the toolbar, you will see a popup text that describes what that button does. Explore.

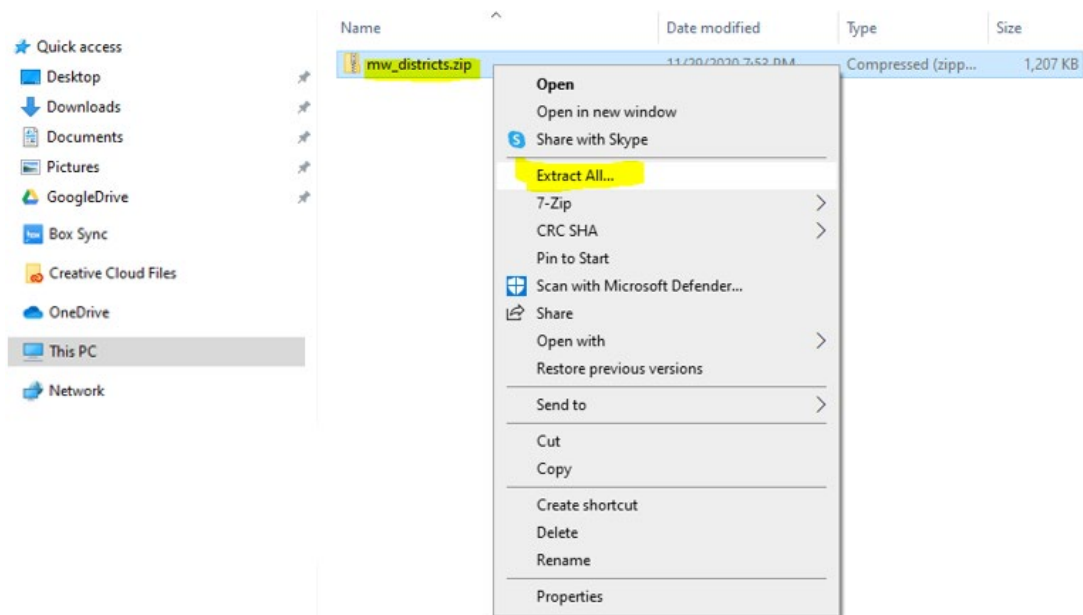
Restoring Toolbars or Panels: If you accidentally closed any of these, then all you do is click the menu **View → Toolbars** or **View → Panels** and look for the one that you need to restore.



D. Downloading and Uncompressing .ZIP files

Most of the data needed for your work will be provided on Moodle as a compressed file (zip file) with a file extension of .zip. On Windows Computers, there is a built-in option to uncompress a zip file. Alternately, you can also download and use freely available software 7-Zip (<https://www.7-zip.org/download.html>).

Once you have downloaded the zip file containing the data needed for your lab exercises from Moodle, find it and move it to your lab folder. Then open the lab folder and Right Click and then select Extract All... option to extract the contents into a new folder. Make sure it is getting saved within your lab folder.

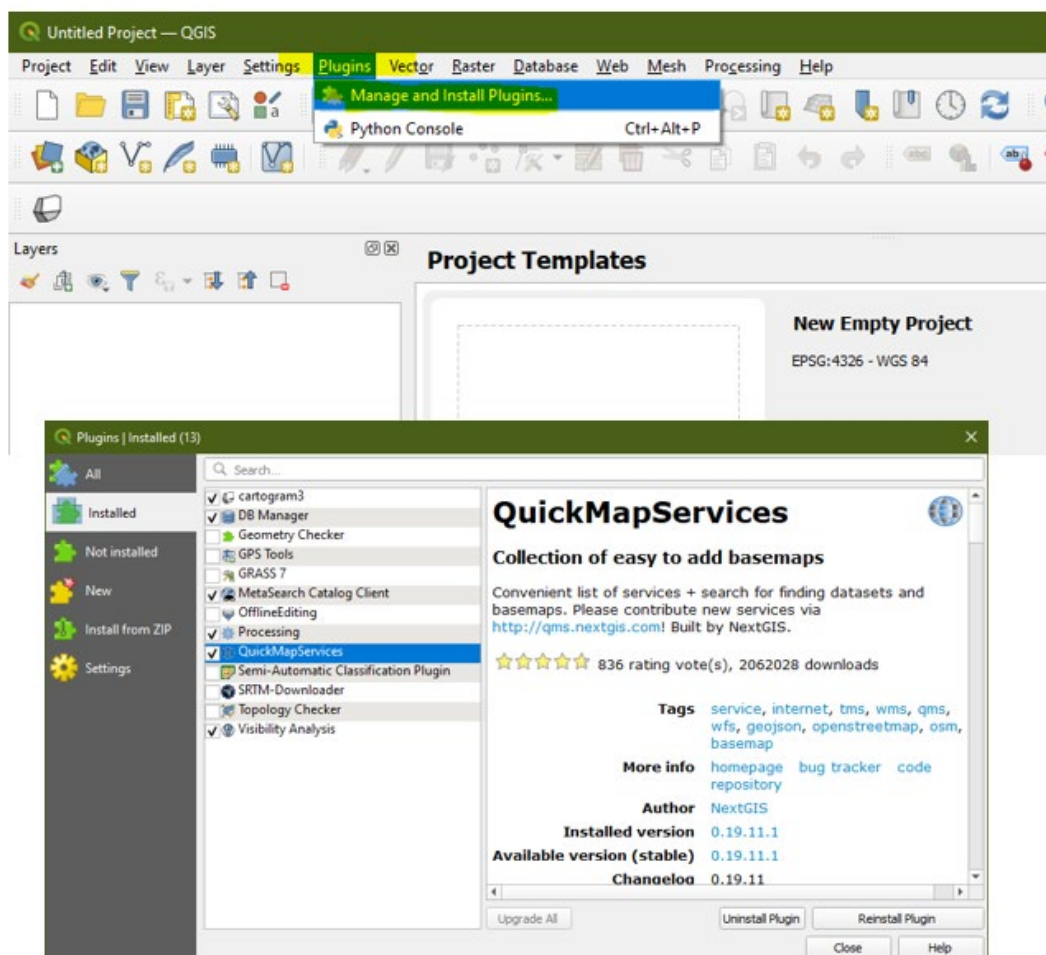


E. Installation of plugins:

As an open-source software platform, QGIS allows anyone to write codes (using Python) and develop new tools that can be downloaded and used within QGIS. These additional tools are provided as **plugins** that can be downloaded directly from within QGIS (like an App Store for your mobile phone). Plugins allow you to extend the functionality QGIS offers. In this section, you'll be shown how to activate and use plugins. Plugins are a very important component in the usage of QGIS. Some plugins come pre-installed with QGIS, for other plugins, you need to install on your own.

For you to be able to access the repository of plugins **you need to be connected to the internet**, or if you downloaded them previously, they can be installed direct from zip files within the plugin installation menu. It is of paramount importance to understand the kind of plugins which you want to install for use within your project.

1. Click on **Plugins** Menu and select **Manage and Install Plugin**. This will open a new window that will show what is already installed and what can be searched and downloaded
2. For today, go ahead and search for plugin "**QuickMapServices**". This plugin allows you to bring Google or other such maps as background into your project. When you find it, select the plugin and click **Install Plugin** button on the bottom right corner of the plugins window.



F. Basic Data Exploration and Map Making

For the rest of this lab, you will go through some basic functions like opening files and formatting them to make them look good.

Data Used:

1. Major Cities in CSV file format
2. Malawi Country Boundary (shape file)
3. Malawi District Boundary (shape file)
4. Malawi and Neighboring Countries Boundary (shape file)
5. Malawi Water Bodies (shape file)
6. Africa Countries (shape file)

Data Sources:

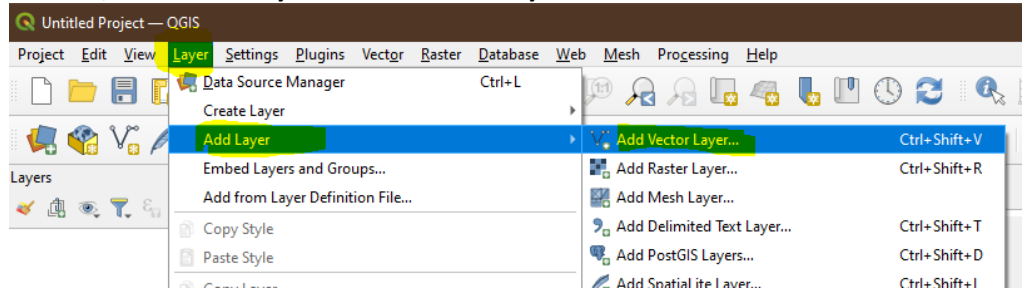
Data used in this exercise (provided on Moodle) were obtained from the following sources. You don't need to download any data from these sources but in the future, if you need to do any work in your own location, you can look for basic layers from these sources.

- Administrative Boundaries Data: <https://www.diva-gis.org/datadown>
- Data layers from Open Source Maps: <https://download.geofabrik.de>

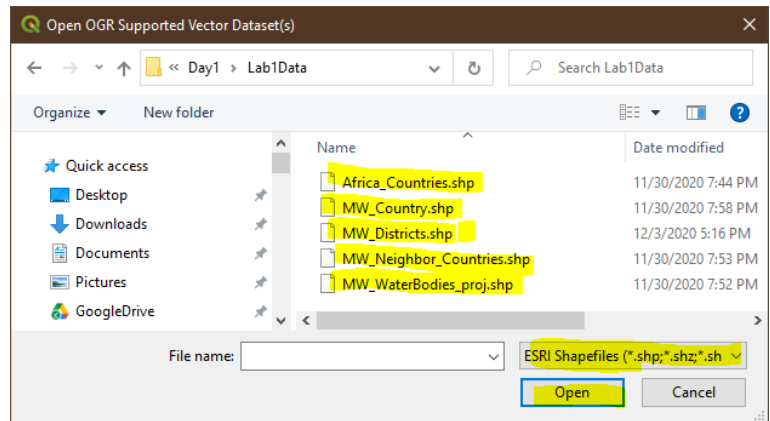
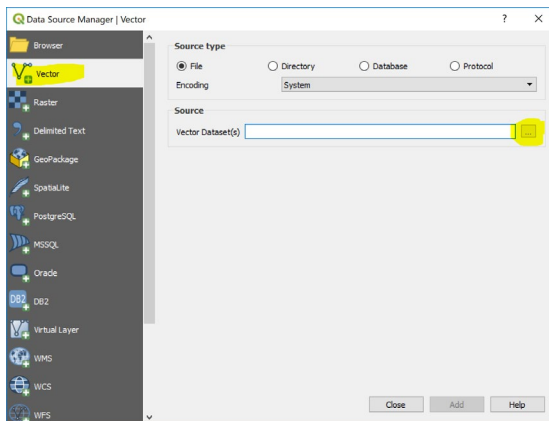
Opening Data and Displaying Data:

In this part, we are going to download GIS data from Moodle and open several layers of GIS data so we can explore the contents and use them to make a map eventually.

1. Download **Lab1Data.zip** file containing the data needed for the exercise from Moodle to your computer.
2. Right click on the Zip file and select **Extract All** to extract the data files to your lab folder.
3. Open Q-GIS from the Start Menu on your computer (click on the **Windows logo** located on the left bottom corner of the screen and search for QGIS).
4. Click "**Layer**" Menu, select **Add Layer** → **Add Vector Layer**



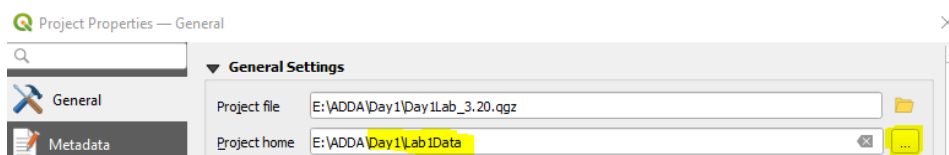
5. Navigate to your lab data folder.



6. We are looking for files with extension **.shp**. You can sort the files by file type to make it easy to select.
7. You can multiple select layers by holding control + click the files to select these files: **Africa_Countries.shp**, **MW_Country.shp**, **mw_districts.shp**, **MW_Neighbor_Countries.shp**, **MW_WaterBodies_proj.shp**.
8. Click **Open** to accept the selection.
9. Back on the **Data Sources Manager** window, click **Add** button to add the layers to your map.
10. Click **Close** to get out of the add data dialog. Your project window should display all the layers as shown below. Explore what each layer shows. On the table of contents, turn different layers **ON** and **OFF** to see what lies under other layers. When done exploring, turn all layers except Malawi Country.
11. Right click on **MW_Country** → **Zoom to Layer(s)**. This will bring Malawi to occupy the whole map area.
12. Click **Project** → **Save** to save your project. Get to the habit of saving your project frequently as you make progress. This will ensure that if the program crashes or computer turns off due to power outage, you will be able to recover everything until the last save.

Default Home Folder: Now, let's set default project directory so that it makes it easier for you to add or save files to your current lab folder. This is something you should do for each lab you do.

13. Click menu **Project** → **Properties**. Under **General** tab, set **Project Home** folder to your lab folder.



Adding Point Data from a table

In addition to adding GIS shapefiles to the map project, location information in the form of GPS coordinates or latitude/longitude values from a (excel or similar) data table can be imported into GIS and converted into a GIS shape file.

For this exercise, we will create a new GIS layer showing locations of major cities in Malawi. I created the list of major cities with their coordinates in an Excel document and then saved it as Comma Separated Values (CSV, comma delimited) file.

Open the CSV file using Excel and see what it contains and what is the format of data presented there.

Close out of excel - if excel is open, you will not be able to import your data into GIS.

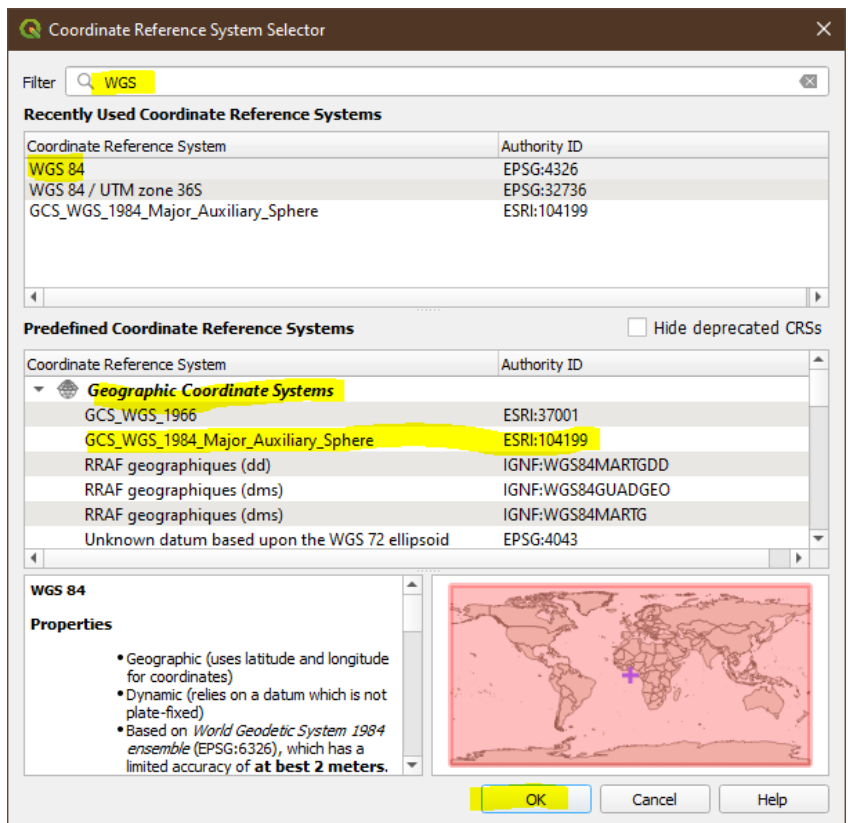
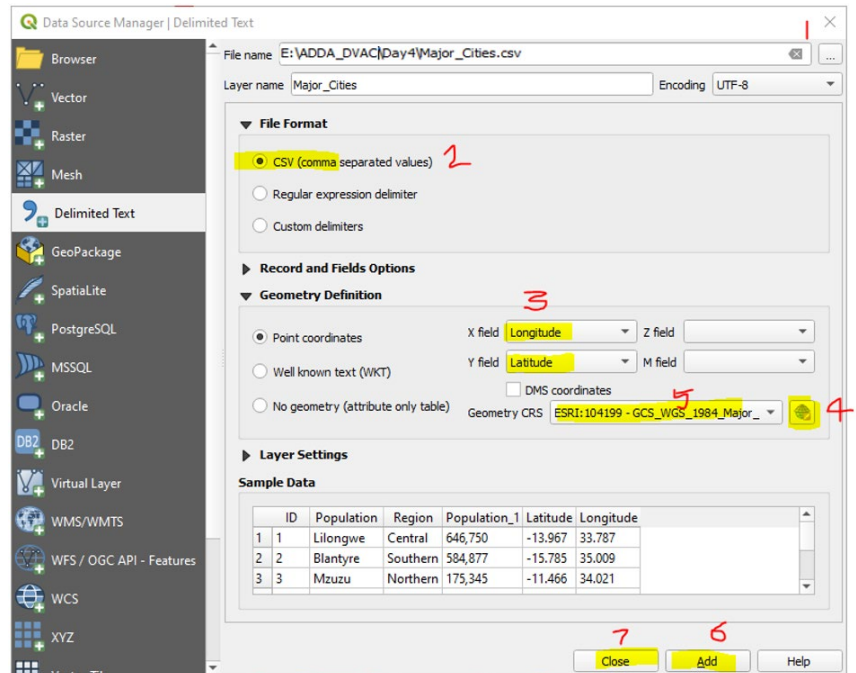
To import this layer to our project, follow the instructions below:

We will now add the CSV (Comma Separated Values) file to our QGIS project.

1. Click **Layer** → **Add Layer** → **Add Delimited Text Layer**
2. When the Data Source Manager window opens, click on Open File button and navigate to where you have saved your **Major_Cities.csv** file on your computer.
3. Make sure to match latitude and longitude values to the right X and Y fields.

We need to assign projection information for the point locations (we will get to the topic of projects little later) Latitude and Longitude values were mostly acquired using handheld GPS units. The GPS projection setting from the unit are required to assign the proper geometry to the file before importing. We know from the source that the GPS was using GCS_WGS_1984 (a type of un-projected, geographic coordinate system with WGS_1984 as the reference datum surface), so we will assign it.

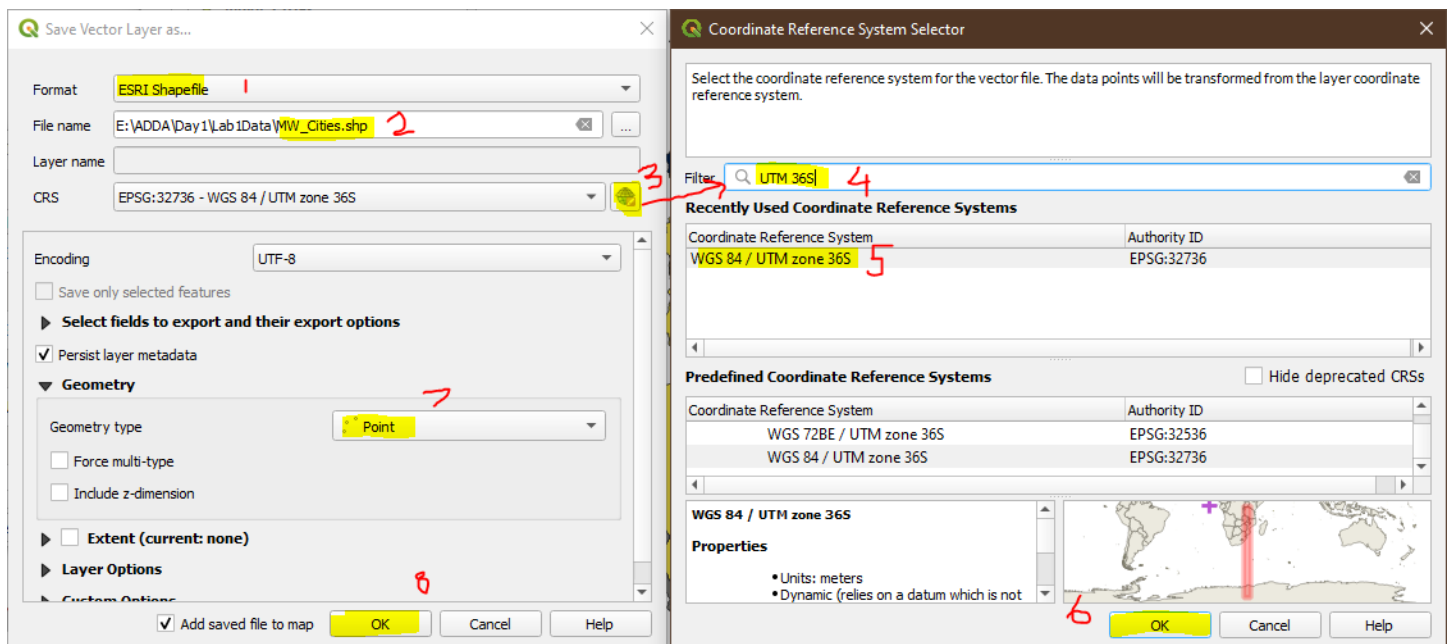
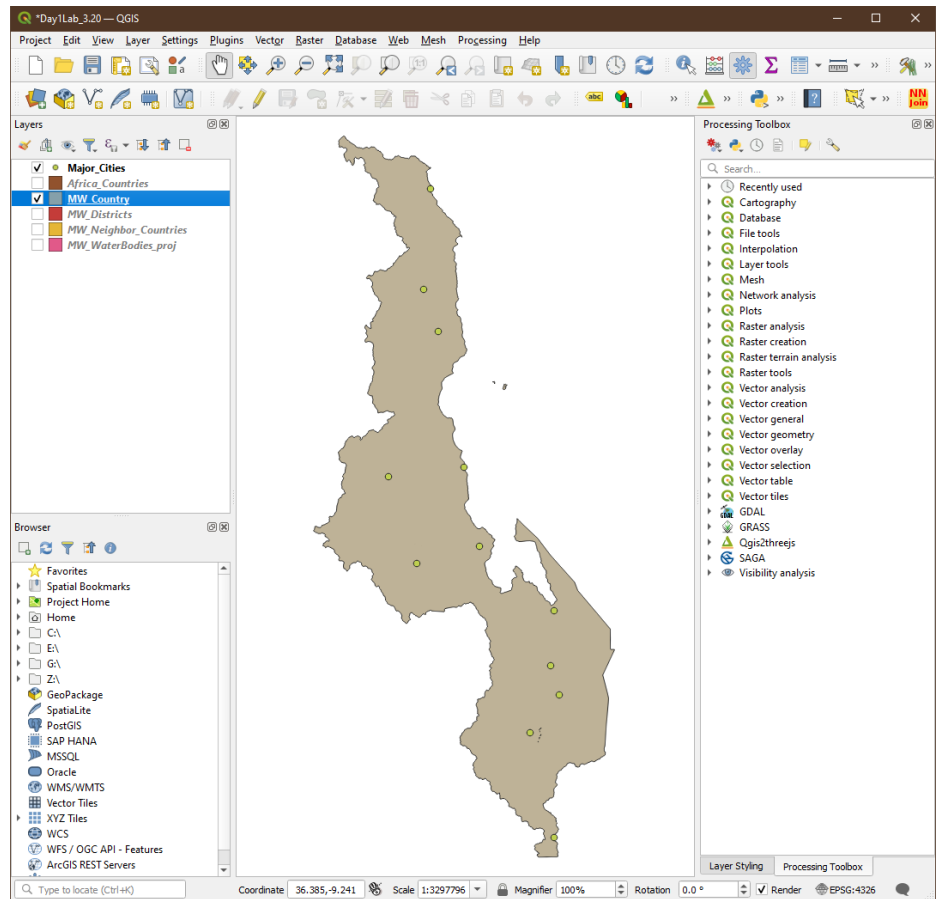
4. Click on the button next to Geometry CRS field (4 on the figure). In the resulting **Coordinate Reference System Selector** window, type WGS to filter all projects with the followed by selecting **GCS_WGS_1984_Major_Auxillary_Sphere (ESRI:104199)** as the coordinate system. Click OK to get out of this window.
5. Click **Add** on the Data Source Manager window.



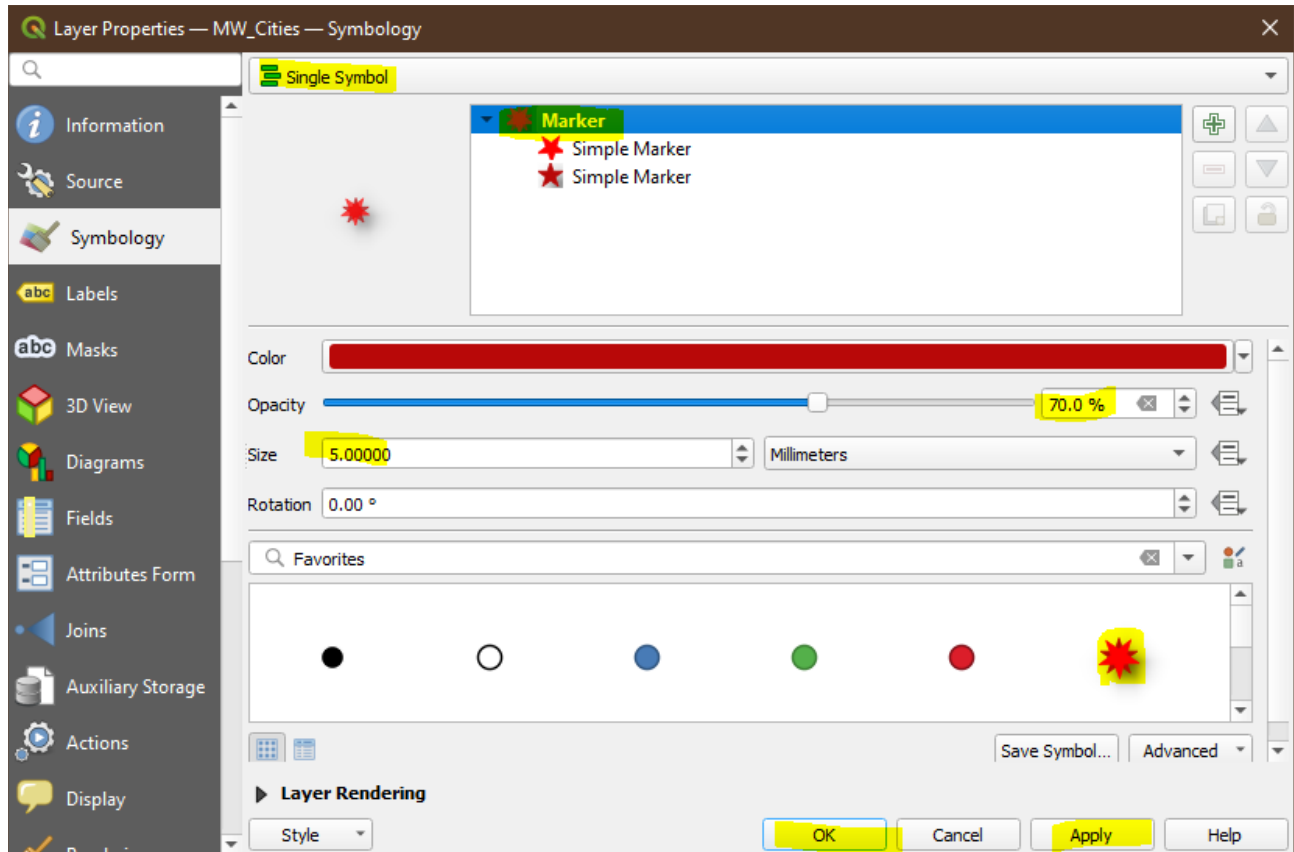
If the projection information was assigned properly, you should see all the cell towers get mapped and identified as points and displayed. Now explore the displayed data. Remember that the points are just being displayed directly from the CSV file. We must export the displayed data to a GIS compatible file format to be able to do further analysis. We will export this to a GIS compatible format after we study and understand the data.

6. To save this point data as a permanent GIS data, we must export the data - **Right-Click** on the Major_Cities layer and select **Export** → **Save Features As...**
7. Now, in the new **Save Vector Layer As** window, make sure to select the output file **Format (ESRI Shapefile)**, **provide a file name** (click on the button with three dots next to it), and finally, you need to select a new **Projected Coordinate System** under **CRS** following the instructions below (see the figure as well).

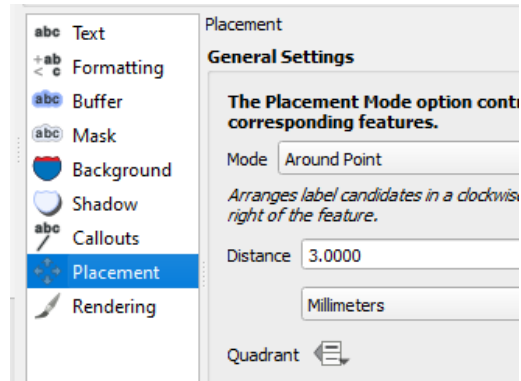
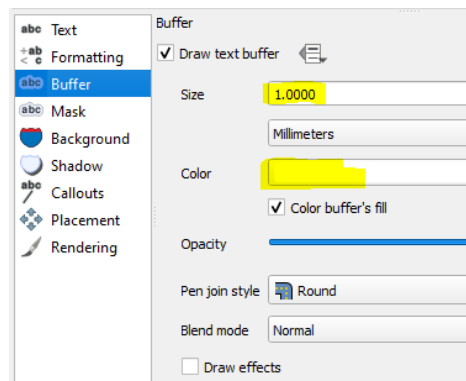
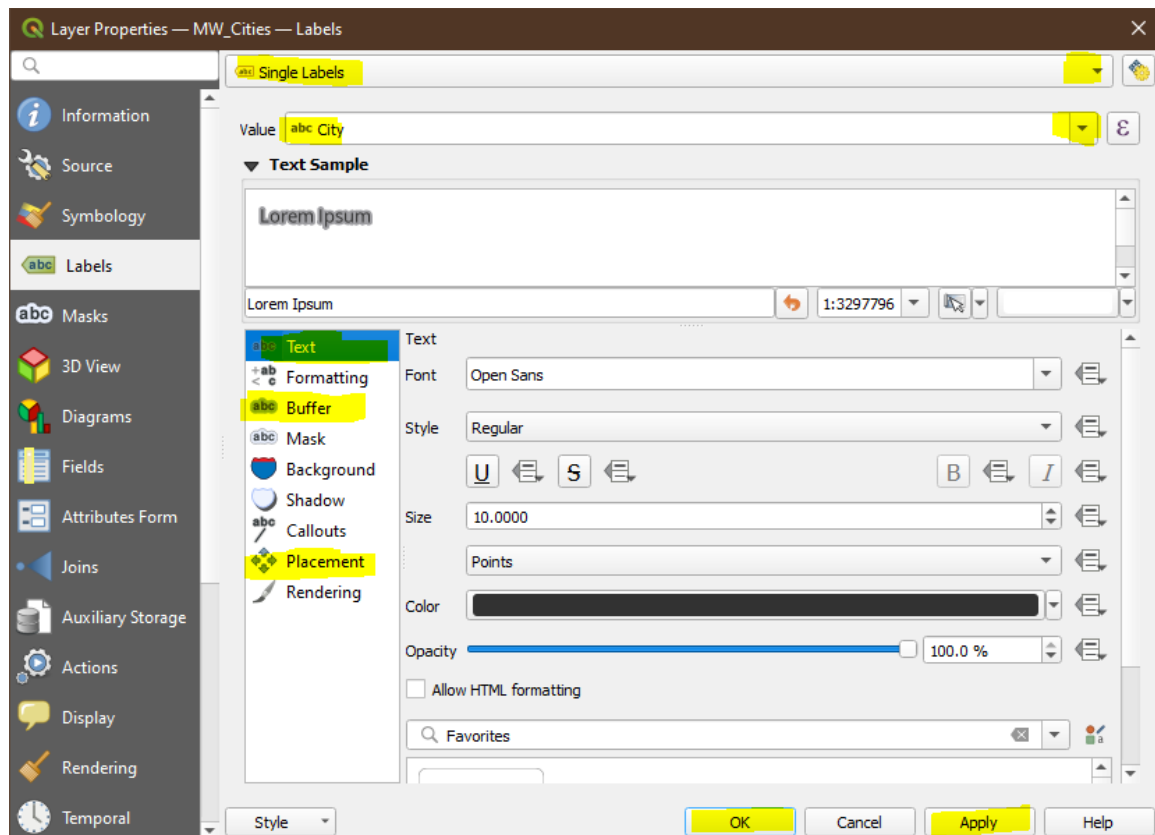
- a. **Selecting new projection for the layer being Exported:** To do any kind of spatial analysis with your data, your data should have a proper projected coordinate system. Since the CSV was displayed using a Geographic coordinate system, we have to now assign a new projected coordinate system. This time, we will pick **Universal Transverse Mercator (UTM)** as the projection. UTM requires you specifying a zone number where your study area falls. For Malawi, it is **Zone 36 South**, so we will pick **WGS 84 / UTM Zone 36S** (you can search for this by typing the number **32736** or **UTM 36S** in the **Filter** box on top). Under **Geometry**, select **Point**. Then Click **Ok**.



8. Click OK to export the layer as new ESRI Shape File. It should add the file to your project in addition to saving the new file on your designated folder.
9. Now, you can get rid of the CSV file displayed in your table of contents by right clicking and selecting **Remove Layer**
9. Next, we will change the symbol and add name of the city as label. Click on layer properties (right click on the layer name and select **Properties** in the menu that appears).
10. Click on **Symbology** tab. We will use **Single Symbol** and select the **star** as the symbol to represent the cities. Change the size to 5.0 mm and click **Apply**. Don't close out of this window yet.



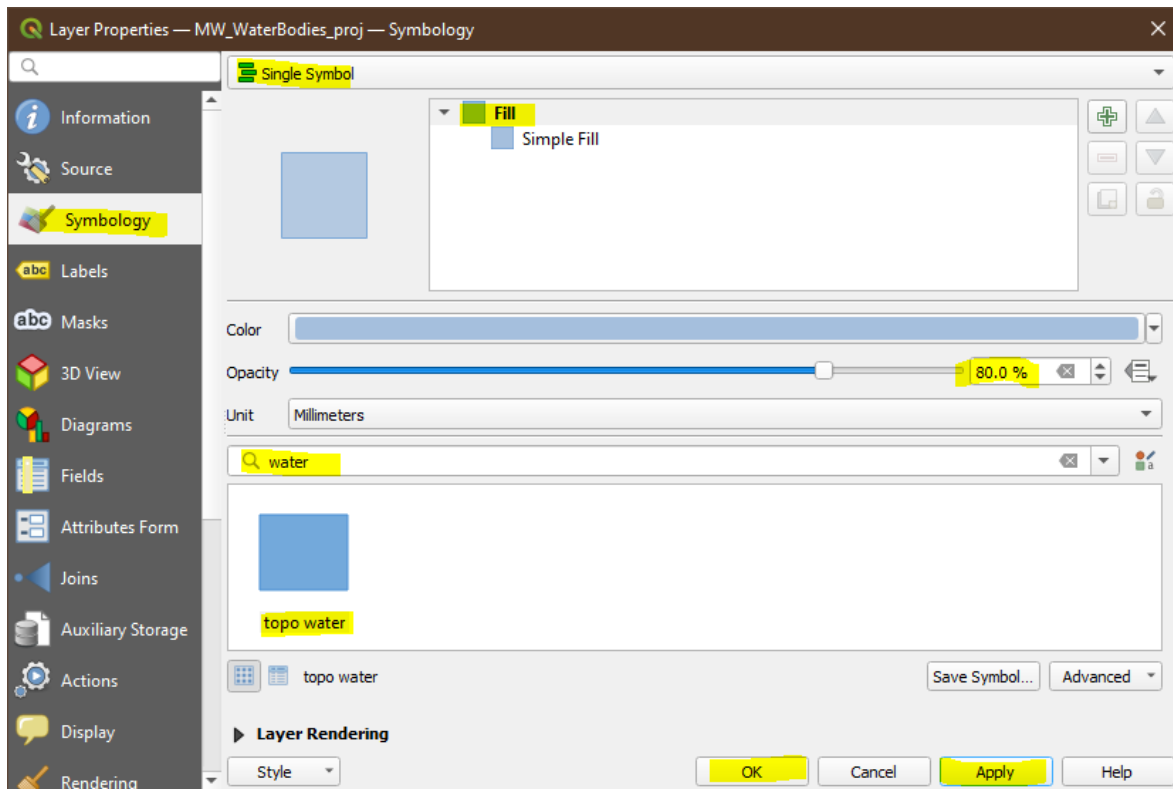
11. To add the names of the cities, click on **Labels** tab on the left under **Layer Properties** window.
12. Click the top box to bring a drop-down menu, and select **Single Labels**
13. Under **Value**, select **City** as the field containing the names of the cities.
14. Under **buffer**, check the box to draw a white **buffer** around the label. This increases label visibility by adding a thin white boundary around the label text.
15. Under **Placement**, select **around point** as the **Mode** and enter 3 mm as the **Distance** where the label will be placed



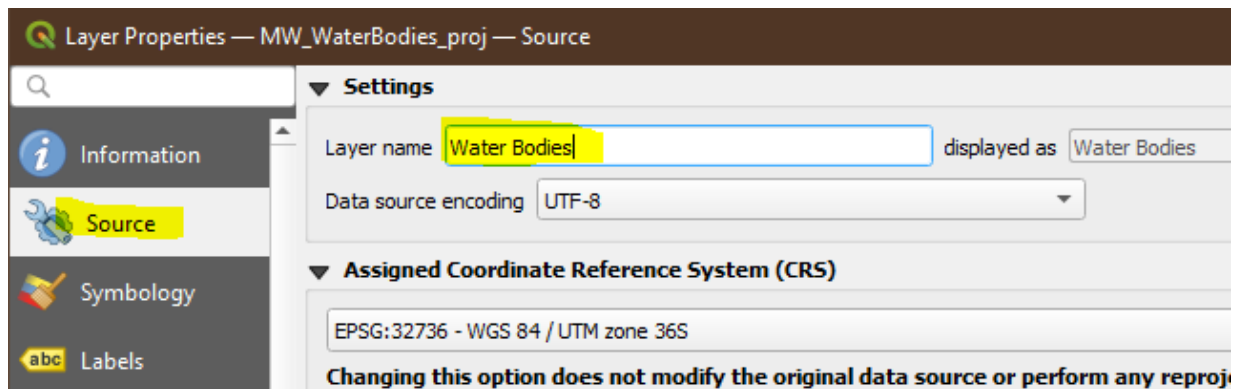
16. Click **Apply** and check the map to ensure it looks good and then click OK and close the window.



17. Now, let's make change to MW_WaterBodies_proj layer to assign **blue** color so they look nice on the map. We will also change the name to make it what it is - "**Water Bodies**"
18. Right click on **MW_WaterBodies_Proj** layer in your table of contents and select **Properties**.
19. In the layer properties window, you can search for **topo water** color by typing water in the search box as shown below



20. Click **Apply** but don't close the **Layer Properties** window.
21. Now, switch to **Source** tab on the **Layer Properties** window and change the layer name to **Water Bodies**.

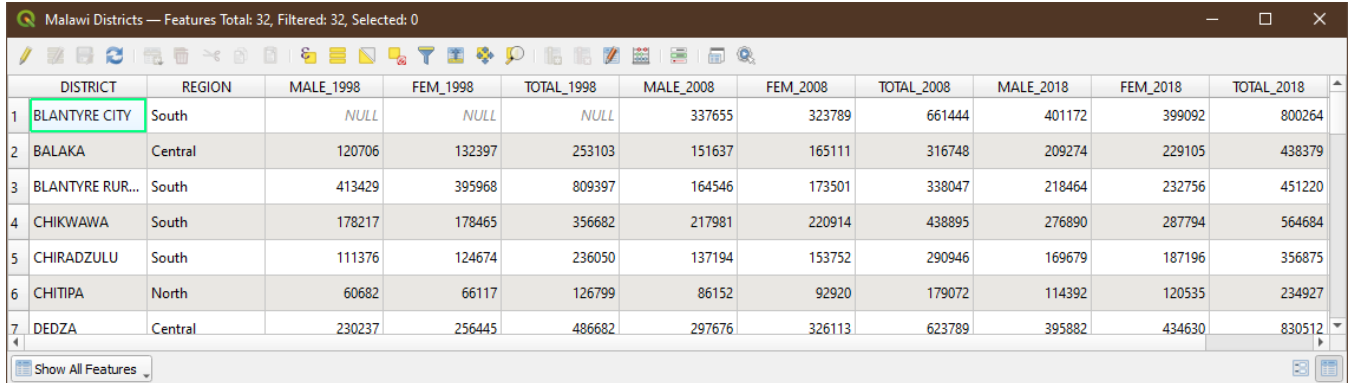


22. By repeating the steps 17 to 20, change the Africa_Countries layer color black outline color without any fill color. So, we should only see the outlines of the countries. Tip: instead of selecting **Fill** color, you should **Simple Fill** under symbology. Then do the same to other appropriate layers.
23. Using step 21 instruction, rename all remaining layers to make them appropriate and professional. Keep them short (1-3 words at the most). Alternately, you can rename a layer by **Right Clicking** → **Rename**. 😊

Map Malawi District Population from Attribute Data

Now, we will look at the Malawi Districts layer and see what kind of information is stored in the attributes for this layer so we can make a map of one of those attributes. Let's open the attribute table (stored in .dbf file)

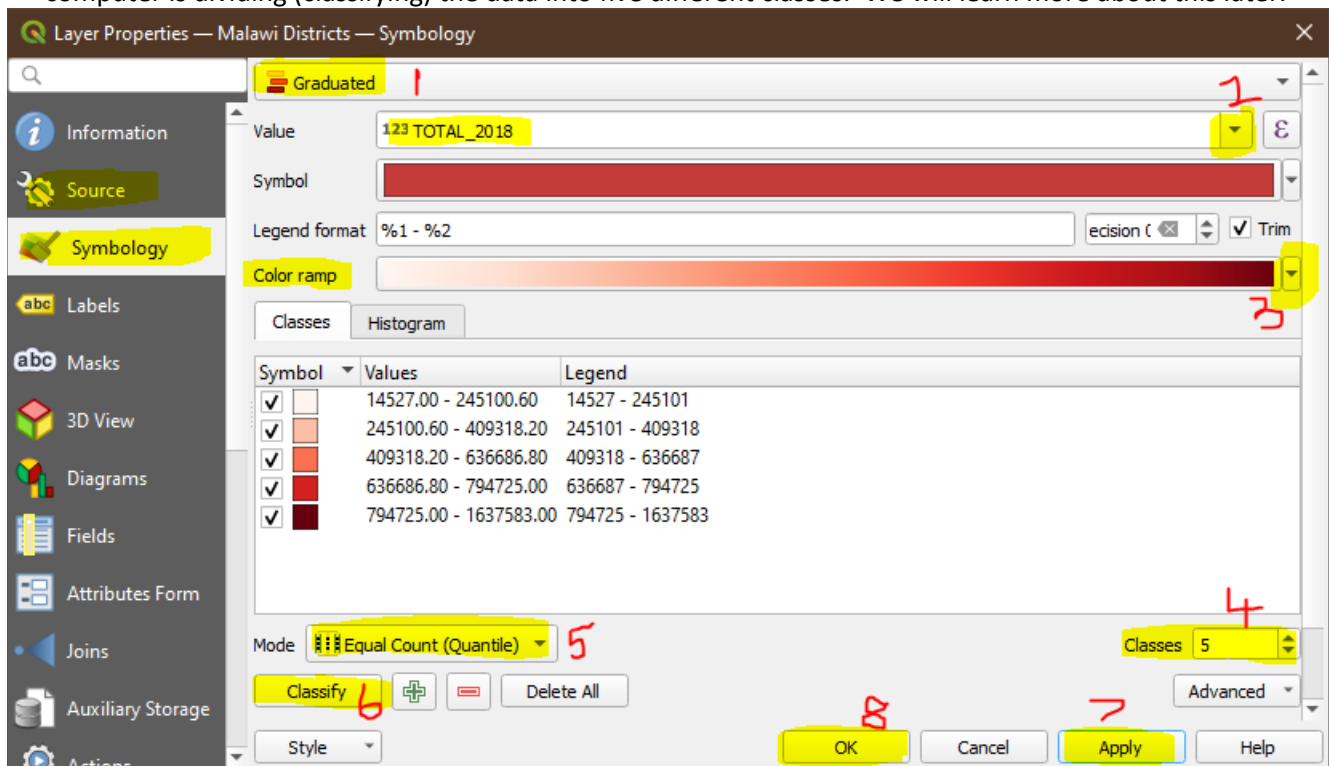
1. Turn MW_Country Country boundary **OFF** and turn **MW_districts** layer **ON**. Remember layers can be dragged and moved up and down in the table of contents if one layer is blocking the view of another underneath.
2. Right Click on **mw_districts** → **open attribute table**



	DISTRICT	REGION	MALE_1998	FEM_1998	TOTAL_1998	MALE_2008	FEM_2008	TOTAL_2008	MALE_2018	FEM_2018	TOTAL_2018
1	BLANTYRE CITY	South	NULL	NULL	NULL	337655	323789	661444	401172	399092	800264
2	BALAKA	Central	120706	132397	253103	151637	165111	316748	209274	229105	438379
3	BLANTYRE RUR...	South	413429	395968	809397	164546	173501	338047	218464	232756	451220
4	CHIKWAWA	South	178217	178465	356682	217981	220914	438895	276890	287794	564684
5	CHIRADZULU	South	111376	124674	236050	137194	153752	290946	169679	187196	356875
6	CHITIPA	North	60682	66117	126799	86152	92920	179072	114392	120535	234927
7	DEDZA	Central	230237	256445	486682	297676	326113	623789	395882	434630	830512

It is clear that there is population, number of male and female population for each district available for 1998 and 2018. Now, let's visualize the total population in 2018 using QGIS.

3. Right Click on **mw_districts** → **Properties**
4. In the Properties window, under **Symbology**, make the changes indicated in the figure by yellow highlights in the order the numbers are arranged.
5. Click **Apply** - Malawi map now represents a thematic map showing the total population by District. Darker shade indicates districts with relatively higher population than lighter shade. **Mode** here refers to how the computer is dividing (classifying) the data into five different classes. We will learn more about this later.



Layer Properties — Malawi Districts — Symbology

Value: TOTAL_2018

Symbol: [Red color bar]

Legend format: %1 - %2

Color ramp: [Red color ramp]

Classes: 5

Mode: Equal Count (Quantile)

Legend:

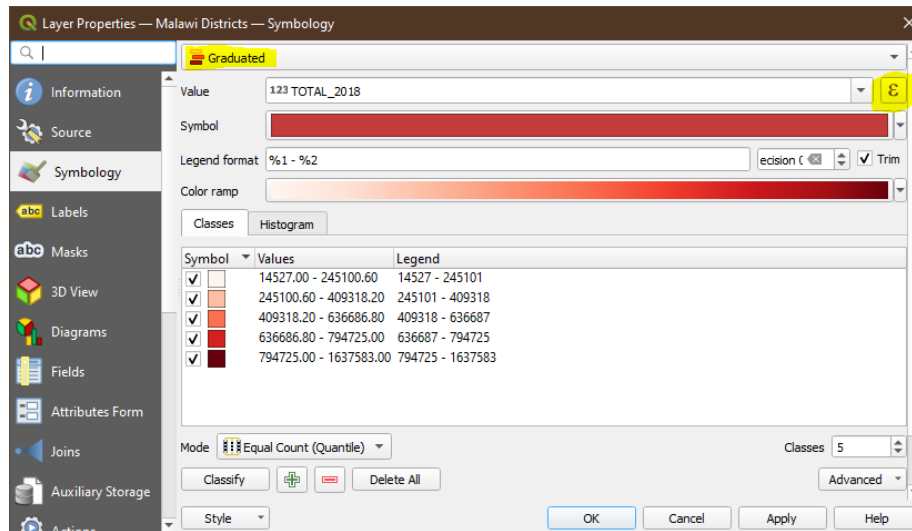
Symbol	Values	Legend
[Lightest red]	14527.00 - 245100.60	14527 - 245101
[Light red]	245100.60 - 409318.20	245101 - 409318
[Medium red]	409318.20 - 636686.80	409318 - 636687
[Dark red]	636686.80 - 794725.00	636687 - 794725
[Darkest red]	794725.00 - 1637583.00	794725 - 1637583


Buttons: OK, Cancel, Apply, Help

- Before we close the properties window switch to **Source** tab on the **Layer Properties** window and change the layer name to **Malawi Districts**.

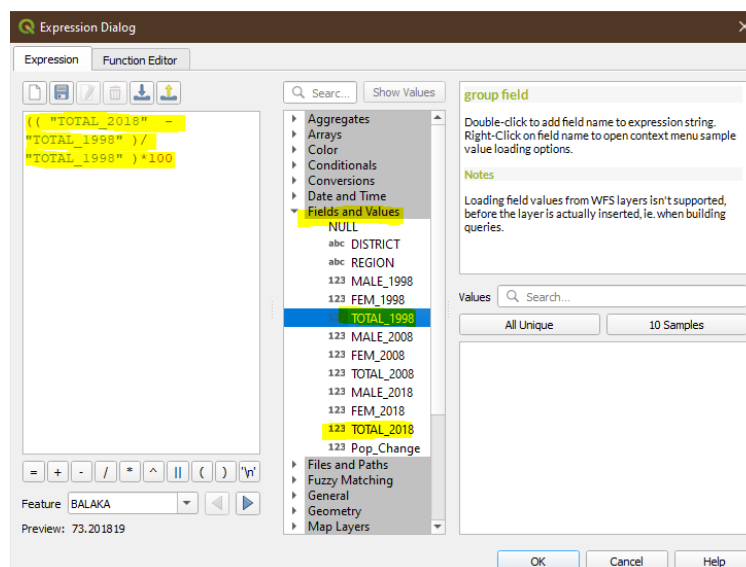
Calculate Map Population Change from 1998 to 2018 in Malawi Districts

- Now that you know how to use one of the fields in the layer attribute table and make a map, we can go one step further to map a map using information from multiple fields. It is possible to map the results of a complex calculation performed within the layer properties using simple SQL query. In this part, we are going to calculate population change in Malawi from 1998 to 2018.
- Right click on Malawi Districts layer and select **Properties**.
- In the top field under properties, select **Graduated**. Instead of picking one of the existing fields to map, we are going to use existing fields, and calculate percentage population change between 1998 and 2018.



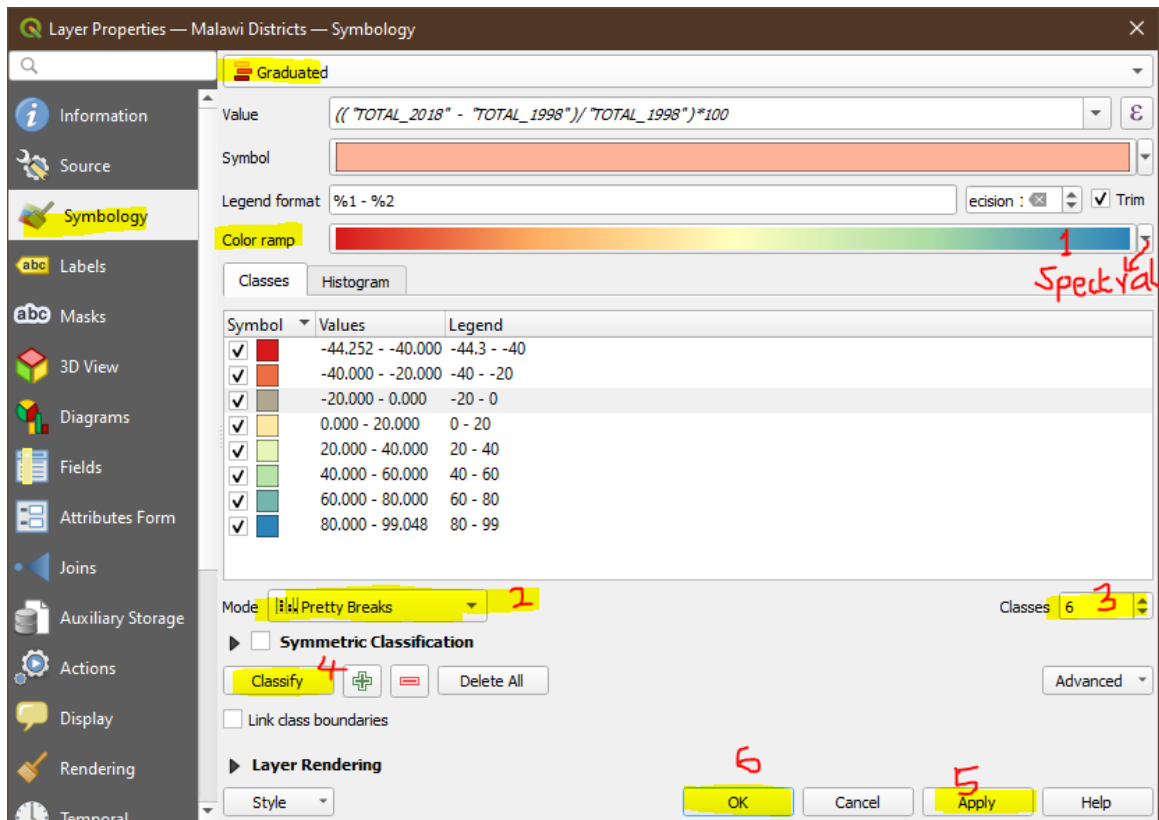
- Still in the symbology pane, click on the **Expression Dialog** button  to the right of the **Value** field.
- In the Expression dialog, clear any information that might already be there and copy and paste the following expression:

$((\text{"TOTAL_2018"} - \text{"TOTAL_1998"}) / \text{"TOTAL_1998"}) * 100$

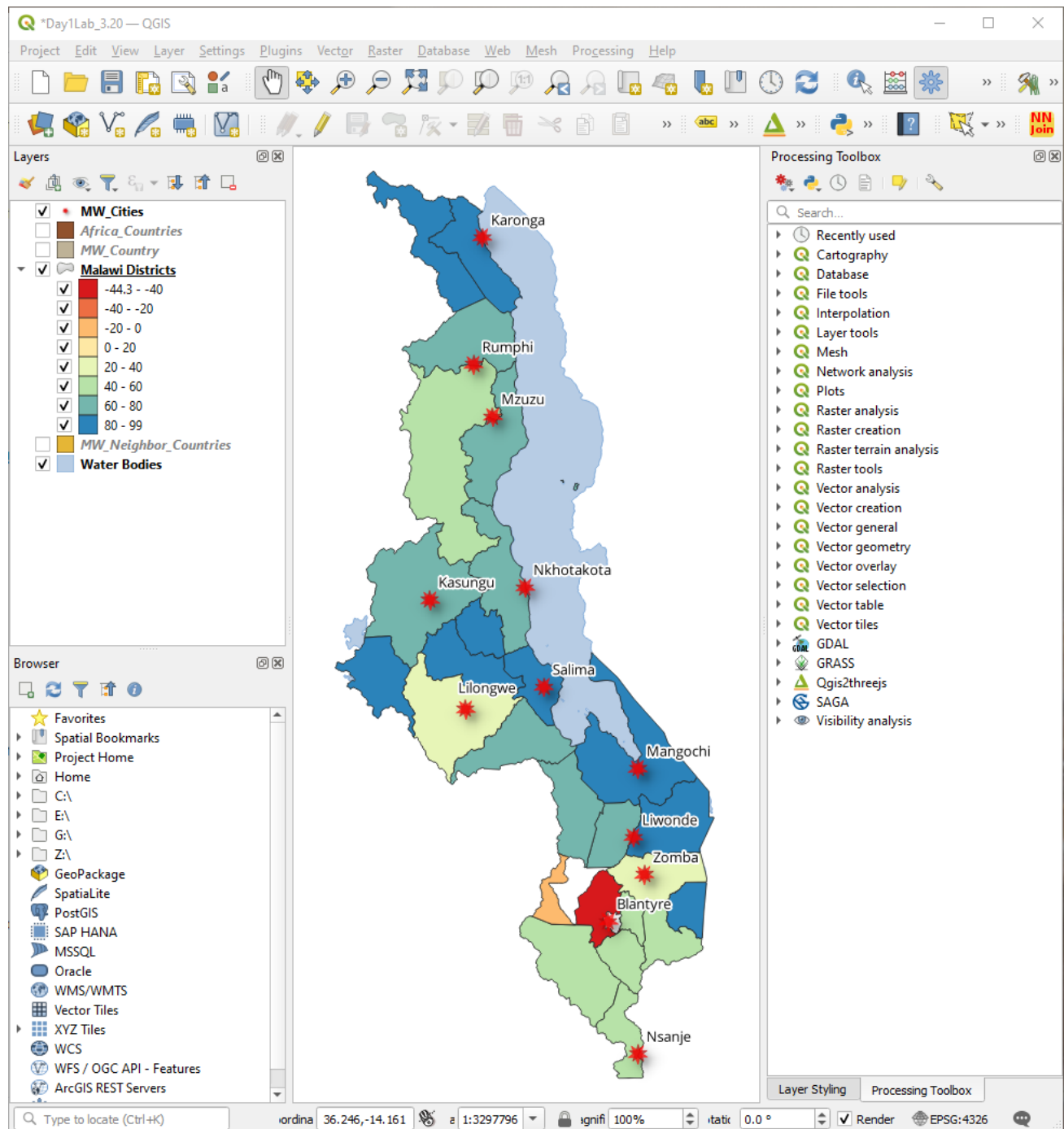


- Click **OK** to close the dialog

8. Back in the **Properties** window, make the changes indicated in the figure below by yellow highlights in the order the numbers are arranged.



6. This should produce a map that looks like the one below:

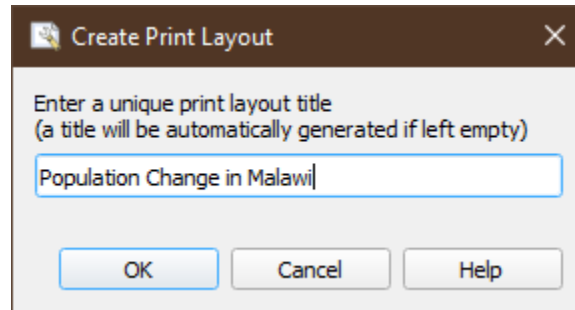


7. Now, since the map shows population change, it is better to change the layer name to represent this. Open **Properties** window, go to **Source** tab and change the layer name to “**% Population Change, Malawi**”.
8. You can see interesting patterns emerging here. Population has declined in some districts whereas majority of the country shows tremendous increase in population. Remember, the default **mode** or **classification** grouped all districts with -44.3 to + 53.3 % change in population in one class. This was not quite useful, so we changed the mode to **pretty breaks**, which happens to be a lot better. However, you should look at the attribute table to get yourself familiar with the data distribution, so you can choose an appropriate classification system that fit the data.
9. Now all layers are ready to be taken to the map shop 😊 – our layout manager!

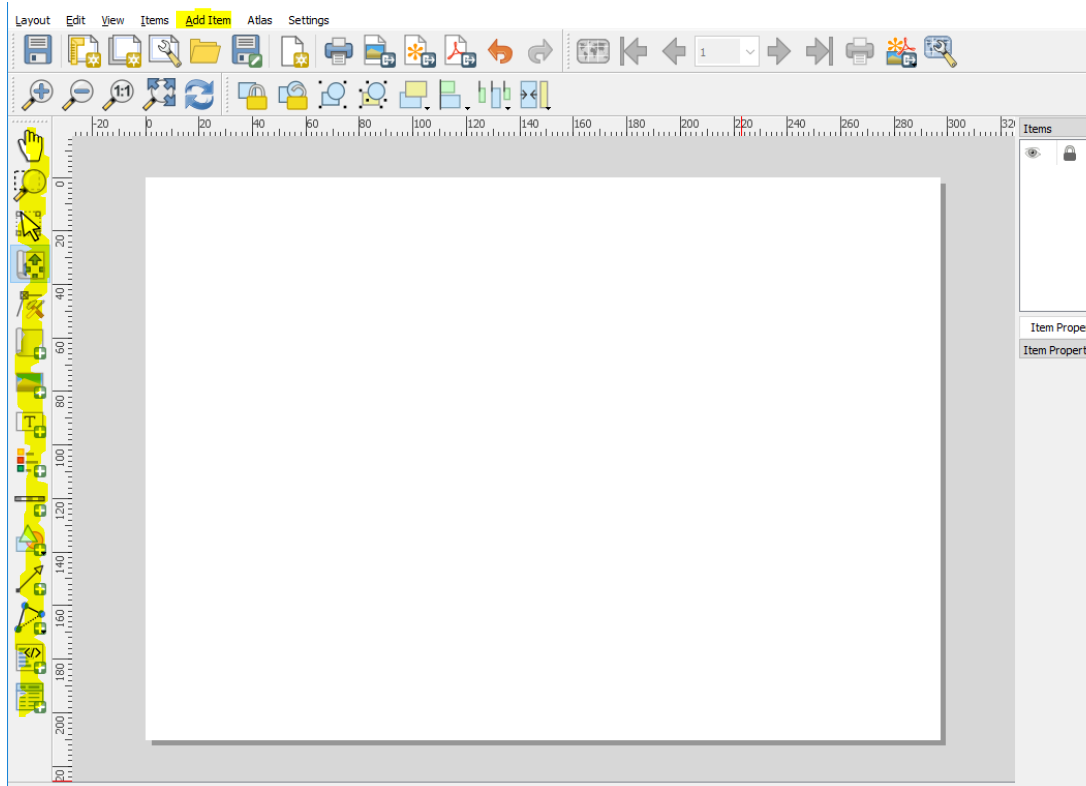
Cartographic Representation and Map Layout:


As a final product for this exercise, you will be making a professional quality map of Malawi with **major cities, districts with names**, and **water bodies**. Your map also should contain title, legend, scale, north arrow, a brief description of what the map is showing and what your observation is regarding the change in percentage population over 20 year period assessed, and finally your name and date.

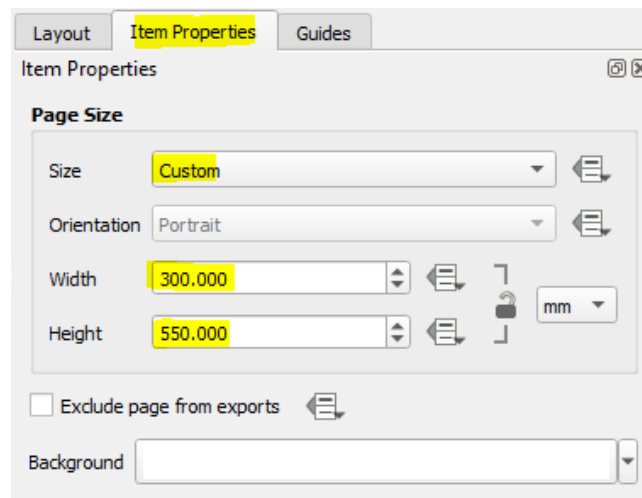
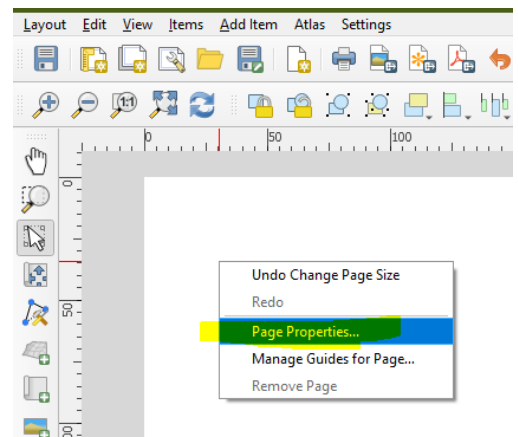
1. Go to Project → New Print Layout. You will be prompted to enter a title for the layout. Enter **Population Change in Malawi** as the title.



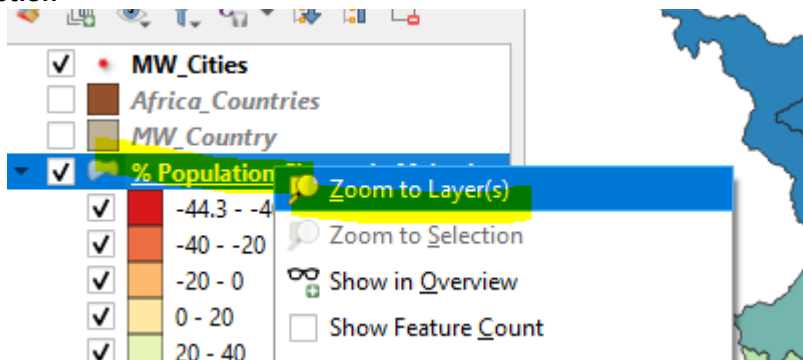
2. An empty map layout composer will open. Explore the highlighted menu and buttons to learn what they do.



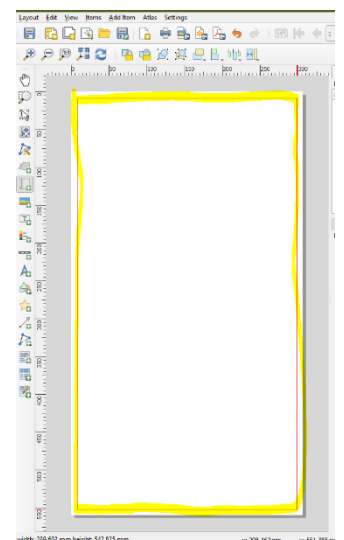
3. In the map layout window, click on Zoom full  to display the full extent of the Layout. We can import the map view from the QGIS project data canvas.
4. We need to change the layout to fit or needs here – to showcase Malawi, which is a country that is tall and narrow. So, a portrait layout will be more appropriate. We will also change the layout size to be much larger than the regular A4 paper size.
5. Anywhere within the canvas (white map area), right click using your mouse to get a submenu. Click on **Page Properties**.
6. On the right side, **Item Properties Panel** will open and show you options for **Page Size**. Enter the following size for the page in mm.



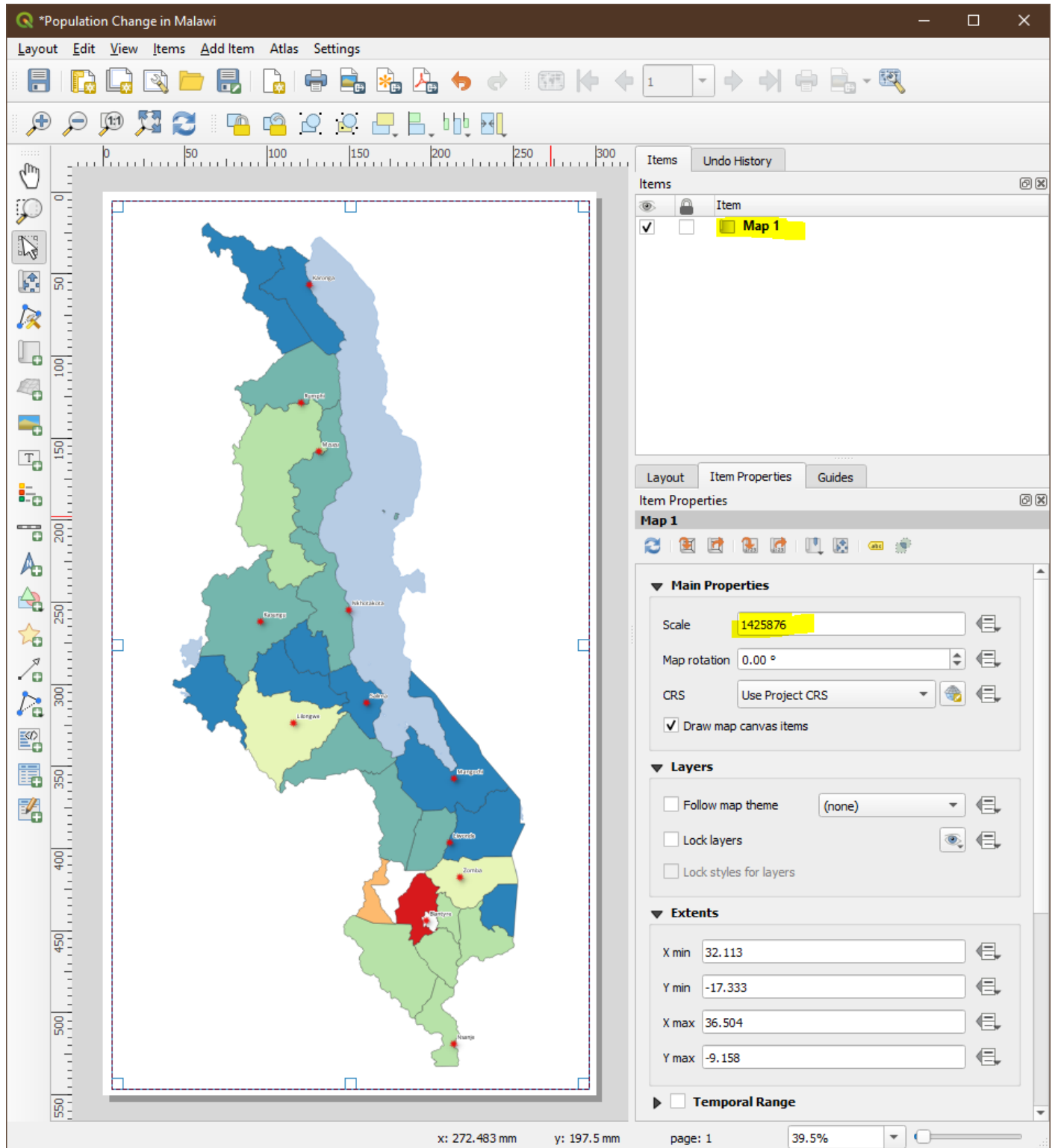
7. Now, go back to your QGIS project window. Right click on Malawi Districts layer, and select **Zoom to Layer** option




8. Now, get back to your On your layout canvas and click **Add Item → Add Map**. Once the Add Map button is active, hold the left mouse button and drag a rectangle where you want to insert the map.



9. If done right, you should have your map view from QGIS project showing up on your Map Canvas. Double Click on the word “**Map 1**” under Items tab. Then change it to **Malawi**. This will be important for what we are going to do next.

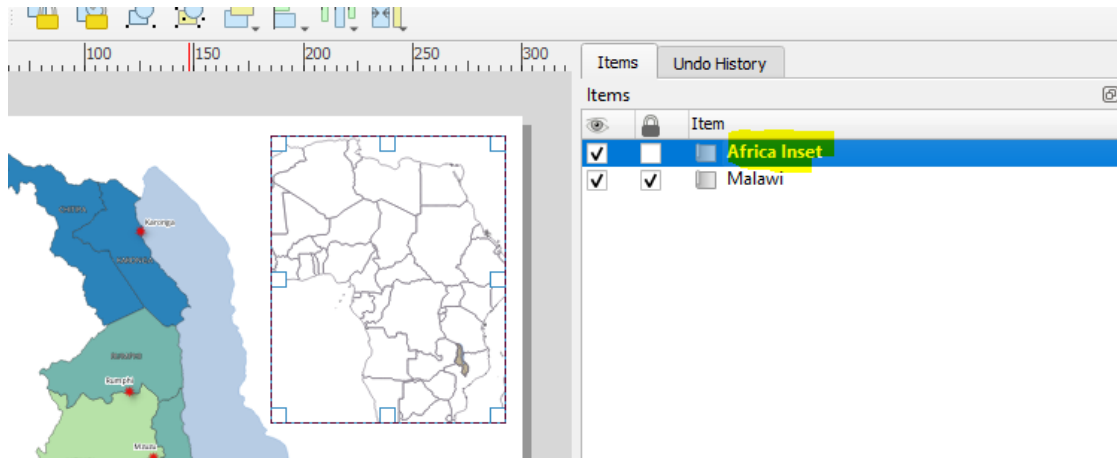


10. You will see that the rectangle that was drawn is filled with the map from QGIS canvas (it may take few seconds for it to refresh and create the data view, so have patience). If the map does not cover the area of interest completely, you can resize the rectangle as well as move the extent of map using  button.

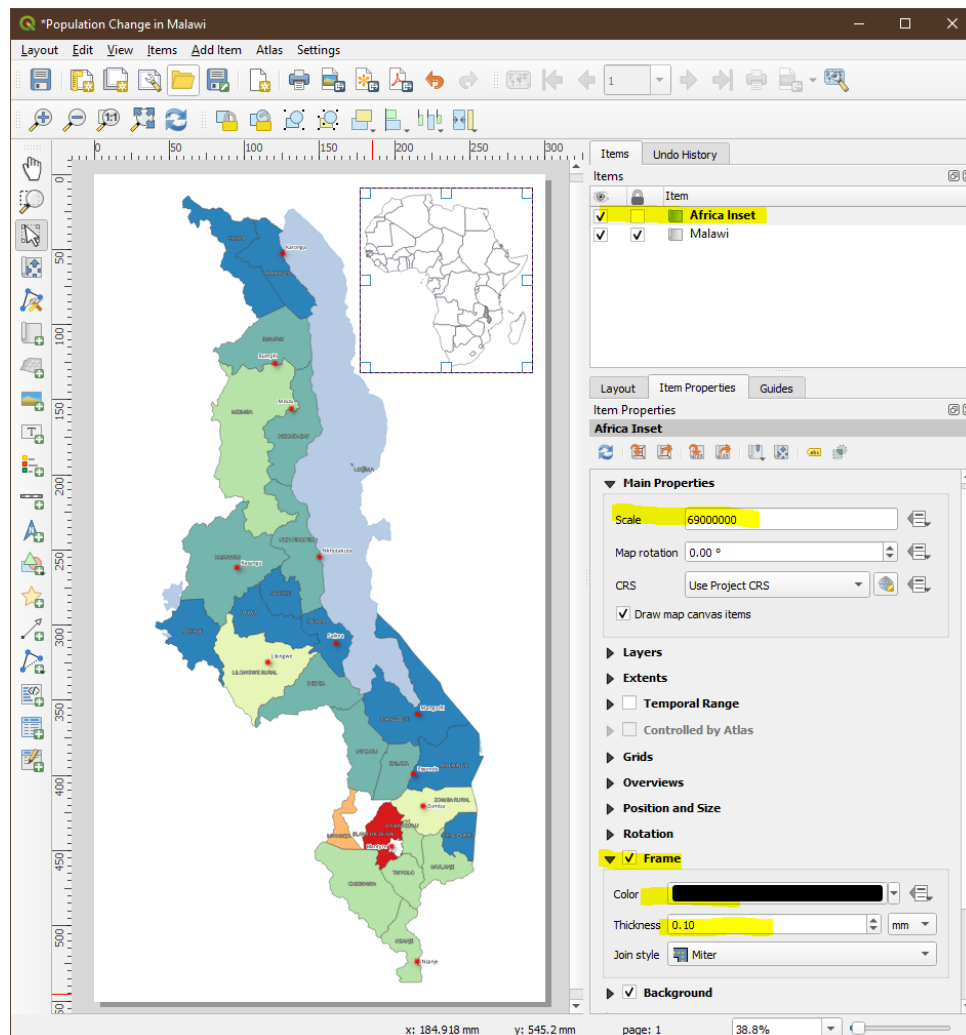
-

- 19

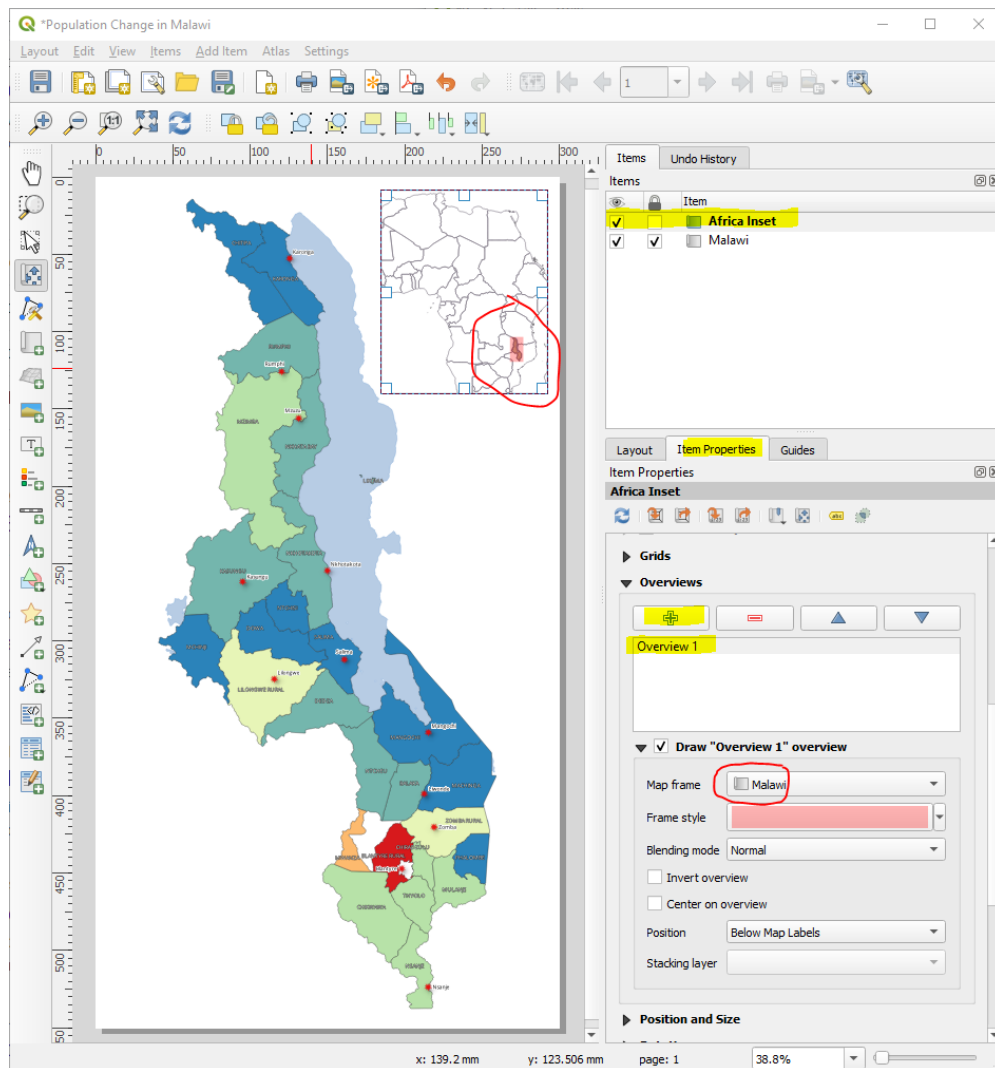
18. Drag a rectangle at the place where you want to add the map inset (in one of the corners is ideal). You will now notice that we have 2 map objects in the layout. We will rename the second Map to **Africa Inset** so when making changes, make sure you have the correct map selected under **Items** panel.



19. Select the **Africa Inset** object that we just added. Select the **Item properties** tab. Under **Main Properties**, change the **scale** to **69000000**. Scroll down to the **Frame** panel and check the box next to it. You can change the color and thickness of the frame border around Africa inset map so it is easy to distinguish against the map background.



20. One neat feature of the Layout Composer is that it can automatically highlight the area from the main map, which is represented in our overview map inset. Select **Africa Inset** map from the list of **Items panel**. In the Item properties tab, scroll down to the Overviews section. Click the Add a new overview (the big + button) button.
21. Below the Overviews window, select **Malawi** as the **Map Frame**. What this is telling the Print Composer is that it must highlight our current main map area with the extent of the map shown in the Africa object.



22. Now that we have the map inset ready, we will add a grid and border to the main map. Select the **Malawi** map object from the **Items panel**. In the Item properties tab, scroll down to the Grids section.

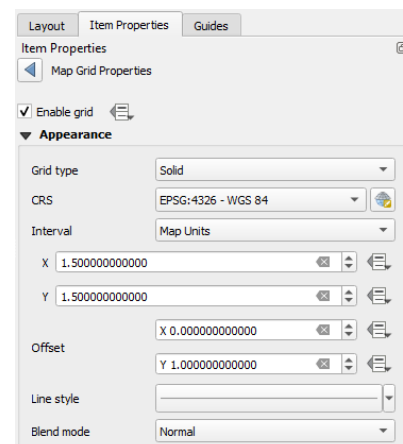
23. Click the + (Add a new grid) button.

By default, the grid lines use the same units and projections as the currently selected map projections. However, it is more common and useful to display grid lines in degrees. We can select a different CRS for the grid.

24. Select **Grid 1** and click on the **Modify Grid** button.

25. Under **Appearance** → **CRS**, click on the **Select CRS button**. In the Coordinate Reference System Selector dialog, enter 4326 in the Filter box. From the results, select the WGS84 EPSG:4326 as the CRS. Click OK.

26. Under **Appearance** → Select the **Interval** values as 1.5 degrees in both X and Y direction. You can adjust the **Offset** to change where the grid lines appear. Adjust the **Offset** to map frame till the coordinates are legible.

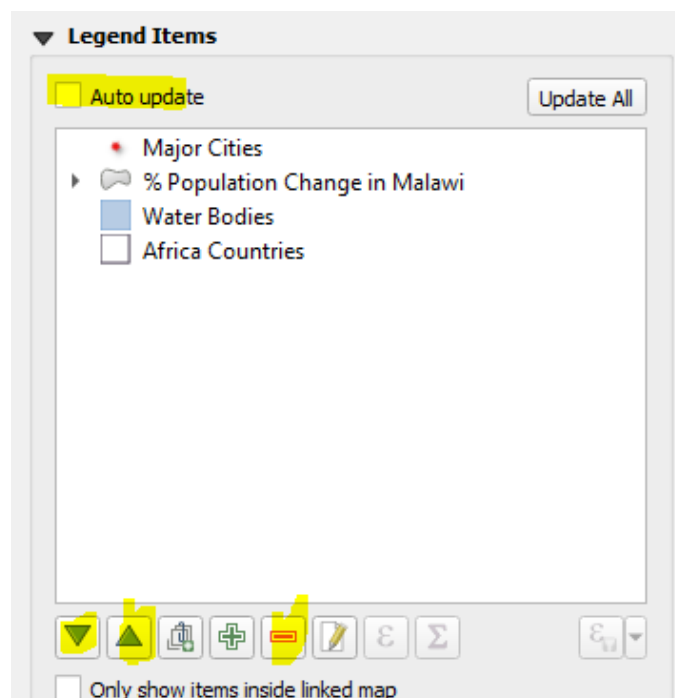
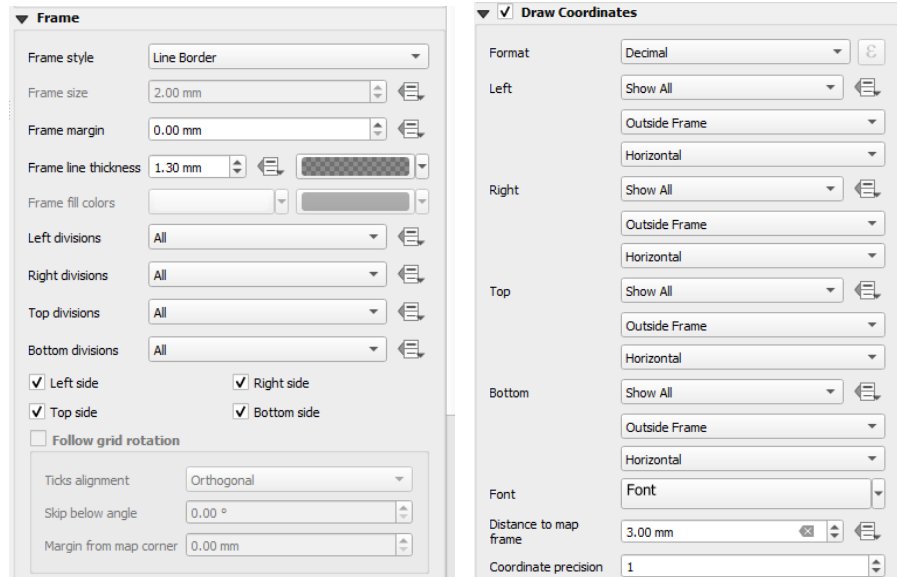


27. Scroll down to the **Grid Frame** section and select a **frame style** that suits your taste.
28. Also check the **Draw coordinates** box.
29. Change the **Coordinate precision** to 1 so the coordinates are displayed only up to the first decimal.

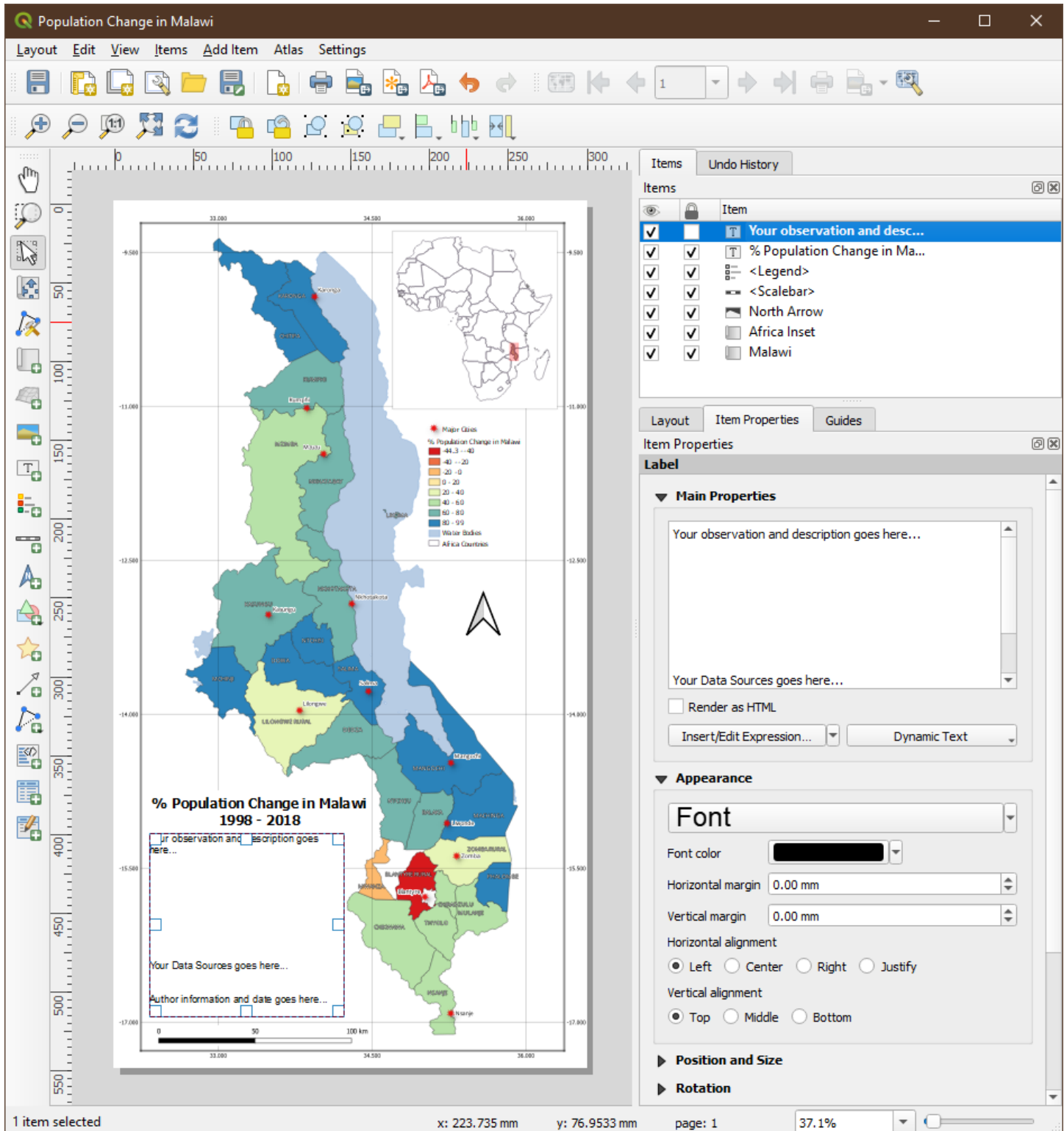
At this point, if the coordinate values or the grid lines are outside the map or touching the edge of the map, you should go back and resize the Malawi Map Frame so that all items are within the map area.

30. Now we will add a North Arrow to the map. The Print Composer comes with a nice collection of map-related images - including many types of North Arrows. Click **Add Item → Add North Arrow**.

31. Holding your left mouse button, draw a rectangle in the empty area on the right side of the map canvas.
32. Now we will add a scale bar. Click on **Add Item → Add Scale Bar**
33. Click on the layout where you want the scale bar to appear. In the **Item Properties** tab, make sure you have chosen the correct map element (**Malawi**) for which to display the scale bar. Choose the **Style** that fit your requirement. In the **Segments** panel, you can adjust the number of segments and their size
34. Now, we will add a legend to the map. First, we want to make sure that the legend displays the elements for the correct map, which in this case is Malawi Map. In your **Map Layout**, on the **Items** panel on the right, click on **Malawi** to indicate that is the main map.
35. Next, click on **Add Item → Add Legend**
36. Draw a rectangle in the empty part of your map.
37. Under **Item Properties**, scroll down to **Legend Items**
38. Disable **Auto Update** by unchecking the box
39. We can delete any of the layers that we don't want to show on the legend.



40. It is time to label our map. Click on **Add Item** → **Add Label**.
41. Click on the map and draw a box where the label should be. In the Item Properties tab, expand the Label section and enter the text as shown here – “% Population Change in Malawi, 1998 to 2018”
42. Add three more labels and place them in appropriate place: 1) data sources and software credits, 2) your name and date, and 3) a brief paragraph below the title that describes the population change patterns that you observe in your data. Look for data sources at the beginning of the exercise.



43. Once you are satisfied with the map, you can export it to one of many formats including Image (many common formats possible) PDF or JPG or SVG and proudly share with your friends and family. For this lab, export it as a JPG or SVG file. Click **Layout** → **Export as**.
44. Save the project.
45. When you are done, post your map to the class forum and get peer-feedback.

That completes your map-making expedition! Congratulations!