USING SPATIAL INFORMATION TO SUPPORT DECISIONS ON SAFEGUARDS AND MULTIPLE BENEFITS FOR REDD+

STEP-BY-STEP TUTORIAL: VERSION 2.1

INTRODUCTION TO QGIS – THE BASICS

GETTING STARTED WITH OPEN SOURCE USING QGIS 2.18

UN-REDD PROGRAMME

Food and Agriculture Organization of the United Nations

UNDP Empowered lives. Resilient nations.

UN environment

The UN-REDD Programme is the United Nations Collaborative initiative on Reducing Emissions from Deforestation and forest Degradation (REDD) in developing countries. The Programme was launched in September 2008 to assist developing countries prepare and implement national REDD+ strategies, and builds on the convening power and expertise of the Food and Agriculture Organization of the United Nations (FAO), the United Nations Development Programme (UNDP) and UN Environment.

The UN Environment World Conservation Monitoring Centre (UNEP-WCMC) is the specialist biodiversity assessment centre of UN Environment, the world's foremost intergovernmental environmental organisation. The Centre has been in operation for over 35 years, combining scientific research with practical policy advice.

Prepared by Corinna Ravilious, Stephen Woroniecki, Tânia Salvaterra and Yara Shennan-Farpón

We welcome comments on any errors or issues. Should readers wish to comment on this document, they are encouraged to get in touch via: ccb@unep-wcmc.org.

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Contents

1. Introduction

REDD+ is a voluntary climate change mitigation approach that has been developed by Parties to the UNFCCC. It aims to incentivize developing countries to reduce emissions from deforestation and forest degradation, conserve forest carbon stocks, sustainably manage forests and enhance forest carbon stocks. This will involve changing the ways in which forests are used and managed, and may require many different actions, such as protecting forests from fire or illegal logging, or rehabilitating degraded forest areas.

REDD+ has the potential to deliver multiple benefits beyond carbon. For example, it can promote biodiversity conservation and secure ecosystem services from forests such as water regulation, erosion control and non-timber forest products (NTFPs). Some of the potential benefits from REDD+, such as biodiversity conservation, can be enhanced through identifying areas where REDD+ actions might have the greatest impact using spatial analysis and other approaches.

Open-source GIS software can be used to undertake spatial analysis of datasets of relevance to multiple benefits and environmental safeguards for REDD+. Open-source software is released under a license that allows software to be freely used, modified, and shared (http://opensource.org/licenses). Therefore, using open-source software has great potential in building sustainable capacity and critical mass of experts with limited financial resources.

The purpose of this tutorial series is to help participants in technical working sessions, who are already skilled in GIS, to undertake analyses that are relevant to REDD+. The tutorials have been used to build capacity in a number of countries to produce datasets and maps relevant to their spatial planning for REDD+, and to develop such map products. Maps developed using these approaches appear in a number of publications whose aim is to support planning of strategy options that enhance biodiversity and ecosystem services as well as delivering climate change mitigation (see http://bit.ly/mbs-redd for country materials). There is of course no requirement for countries to use the approaches described in these tutorials.

Where countries have identified biodiversity conservation as a goal for REDD+, and to be consistent with the Cancun safeguards for REDD+ on protecting biodiversity, it is useful to identify areas where specific REDD+ actions are feasible and can protect threatened species. It may also be useful to identify areas outside forest where threatened species may be vulnerable to the displacement of land-use change pressures or to afforestation.

This tutorial provides a brief introduction to QGIS, a desktop GIS software, and will help users get started with using QGIS (see http://www.opendevelopmentcambodia.net/ for the example datasets used in this tutorial). The purpose of the tutorial is to help bring participants in technical working sessions, who are already skilled in GIS, quickly up to speed on the core functionality of the QGIS software to enable them navigate the system, use the basic functions and provide the essential basics that will enable them to quickly move on to more advanced analyses that are relevant to REDD+.

This tutorial has been used in a number of working sessions with countries to support countries in the transition to open-source software for use in spatial planning for REDD+. A few examples are listed below:

- Training and joint working session on REDD+ economic and spatial GIS tool development. Cambodia, 2015.
  http://bit.ly/2fWNtO5
- 1st joint working session on spatial planning for REDD+. Mongolia, 2015. Spatial analysis to support REDD+ planning in Mongolia: Joint working sessions report.
  http://bit.ly/2fWMRIa
- Nigeria's REDD+ Readiness Programme - Beyond Carbon: Consultation & joint working session on spatial planning for REDD+ in Cross River State, November 2014.
  http://bit.ly/2ffPYY4

2. QGIS – an open-source desktop GIS

2.1. QGIS: Brief introduction to QGIS open-source desktop GIS

QGIS is a free and open-source desktop GIS comparable to proprietary GIS software such as ArcGIS. It has the advantage of being able to run on multiple platforms (Linux, Unix, Mac OSX, Windows and Android operating systems). It supports vector and raster processing and can access and utilize tools available in other open-source GIS packages.

QGIS can:

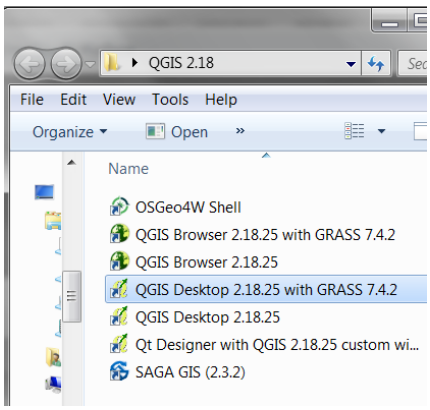
- View geographic information
- Edit geographic information
- Present geographic information (create maps and figures)
- Analyse geographic information
- Be extended in its functionality (through plugins and scripts)

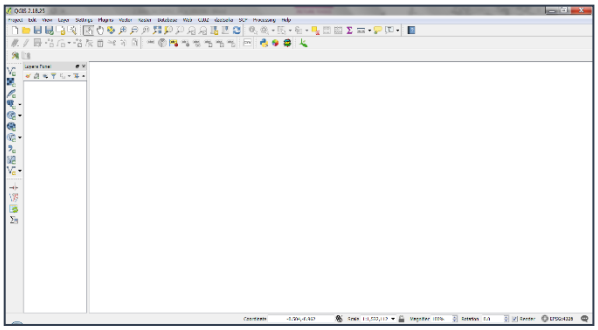
One of the advantages of QGIS is that it provides access to other open-source GIS and remote sensing software through its processing framework. It integrates methods and tools from other open-source software into the QGIS interface, e.g. GRASS, SAGA and GDAL tools and R scripts. It provides a wealth of analysis tools that can be accessed from a single location. Tools can be run individually or through a graphical user interface (GUI) for processing work flows, which is comparable to the ESRI ArcGIS Toolbox. It also has a Graphical Modeller which is similar to the SRI ArcGIS Model builder environment.

When installing QGIS, some packages are automatically installed as part of the QGIS installer e.g. GRASS and SAGA, others you have to install independently and then require configuring in QGIS.

a. Click on the **Start Icon >> All Programs >> 'QGIS Essen'** and click on **QGIS Desktop 2.18 with GRASS 7.4** to open QGIS.

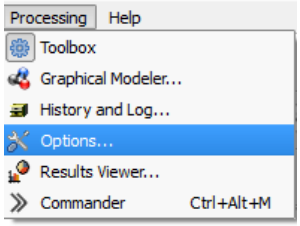
b. Click **OK** to dismiss the QGIS tips.



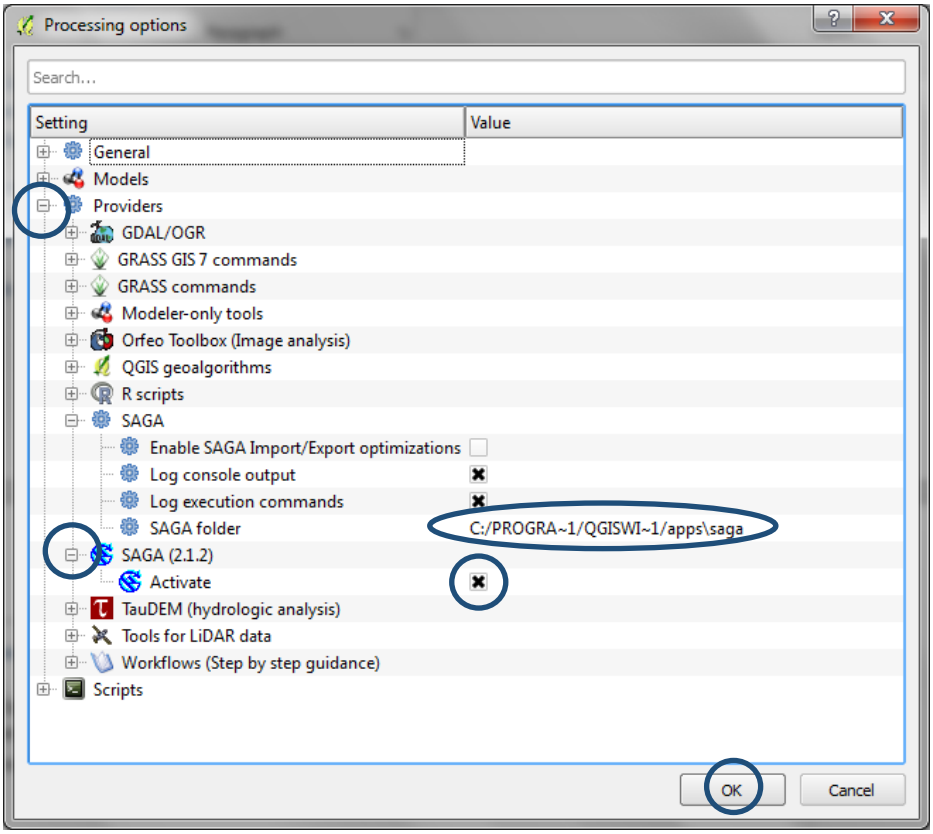


c. From the main menu click on **Processing>>Options**

d. Expand the **providers.** This is where the additional software is configured. E.g. Expand **SAGA** to see that there is a path to the SAGA installation folder.



e. Check that **SAGA** is **activated** by checking the black cross as below. This is necessary to be able to use the SAGA tools within QGIS.



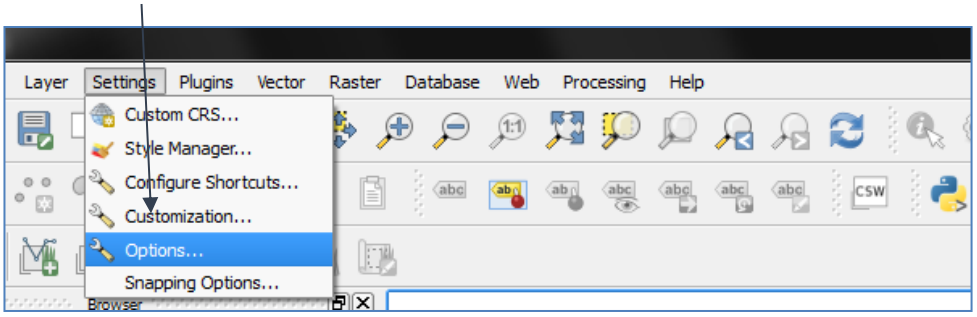
f. Click to close. **OK** the processing options window.

2.2. Understanding Coordinate Reference Systems (CRS) in QGIS

Before adding any data to QGIS it is important to understand how projection systems (coordinate reference systems) work in the software. This is a VERY IMPORTANT section as there are a number of places where projections can be set or altered in QGIS. Knowledge of how projections work in QGIS is needed to avoid errors being introduced.

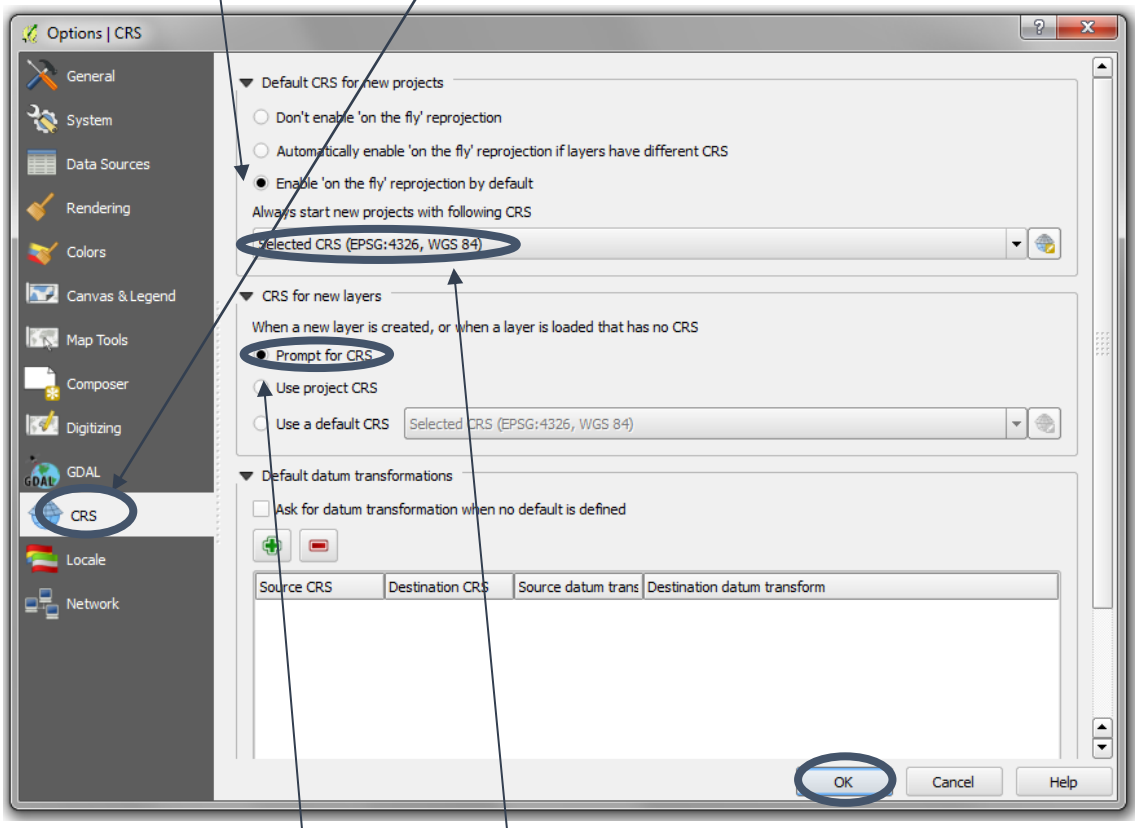
2.2.1. Changing the default CRS (projection) settings

a. Click on **Settings >>Options**



b. In the options window Click on the **CRS** tab to see the Coordinate Reference System options.

c. Click to tick **Enable 'on-the-fly' reprojection by default** so that data layers with different CRSs can be displayed together automatically when added to the QGIS project.



d. Leave the default projection as **EPSG: 4326-WGS84** (this geographic CRS will be the default for new projects).

If you always work in another projection e.g. UTM you may choose to set the default project projection this as the default rather than EPSG: 4326-WGS84.

e. Click to select **Prompt for CRS** so that QGIS will ask for the user for the CRS (projection) of the data when loading layers with no CRS defined.

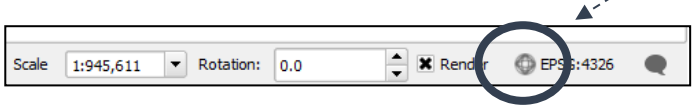
f. Click **OK** to close the window.

*These options will be applied to all new QGIS projects but will not take effect until QGIS is closed and a new project is created. However, **IF** it is inconvenient to exit QGIS the settings for the current project can be set manually (which is illustrated in section 2.2.2).*

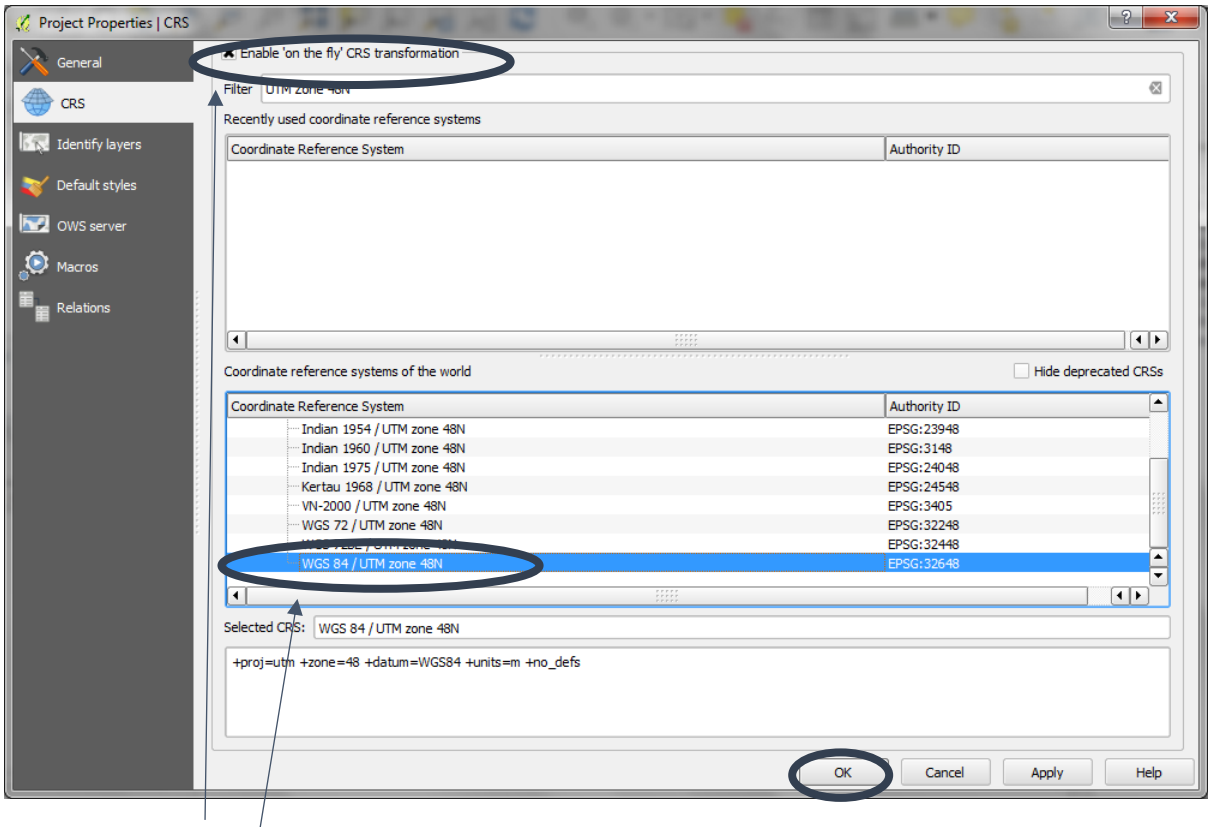
2.2.2. Changing the CRS of the current project

If needed, you can set the current project to a particular CRS without setting it as the default for all other projects.

a. To set the CRS for the current project click on the **CRS icon** next to EPSG in the bottom right hand corner of the QGIS canvas.



The CRS window appears but this time it applies to the **CRS of the current QGIS project ONLY.**



b. Click to tick **Enable 'on-the-fly' CRS transformation** so that any data added to the QGIS project will be transformed on-the-fly from their current projection to the projection selected below.

c. The CRS was set to EPSG: 4326. Changing the CRS here sets the QGIS canvas to the **chosen projection**, in this case **UTM Zone 48N. Select the appropriate CRS from the list below.**

d. **Click OK**

Note: 'on-the-fly transformation' does not physically change the projection of the data; it takes the data in its original projection and makes a temporary transformation as it is drawing it. (Physically projecting the data is illustrated in section 2.2.3).

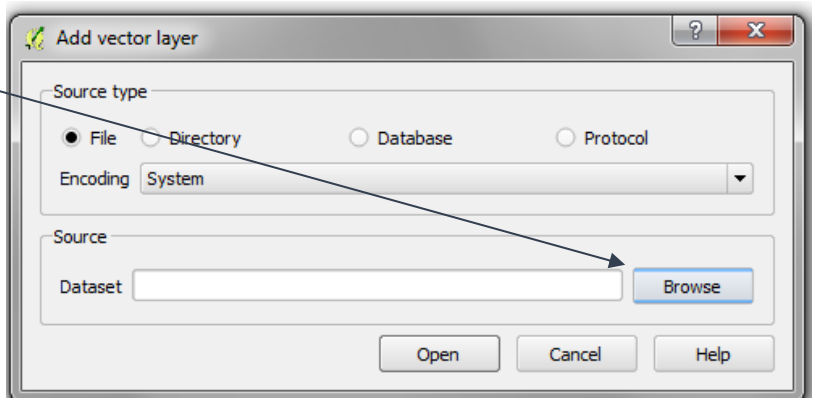
2.2.3. Adding and projecting vector and raster data

If you are undertaking area analysis, data will need to be projected to an equal-area projection (e.g. UTM or Lambert Azimuthal Equal Area) and not just projected on-the-fly. Using an equal-area projection allows the true area to be calculated. Unlike some other GIS software, all the datasets being used in any one analysis must be in exactly the same projection.

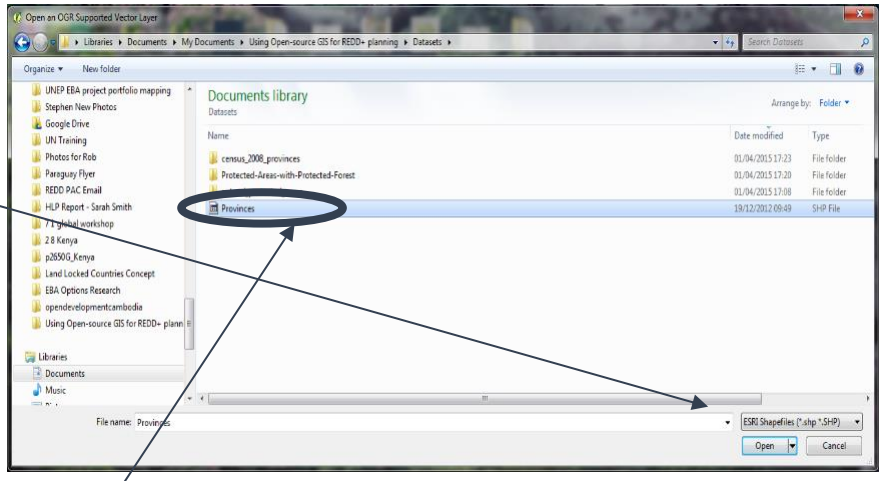
2.2.4. Adding a vector layer

a. Click either **Layer>> Add Layer>> Add Vector Layer** or the **icon**  to add vector layer to the current project.

b. Click **Browse**



c. Change the File type to **ESRI shapefile**



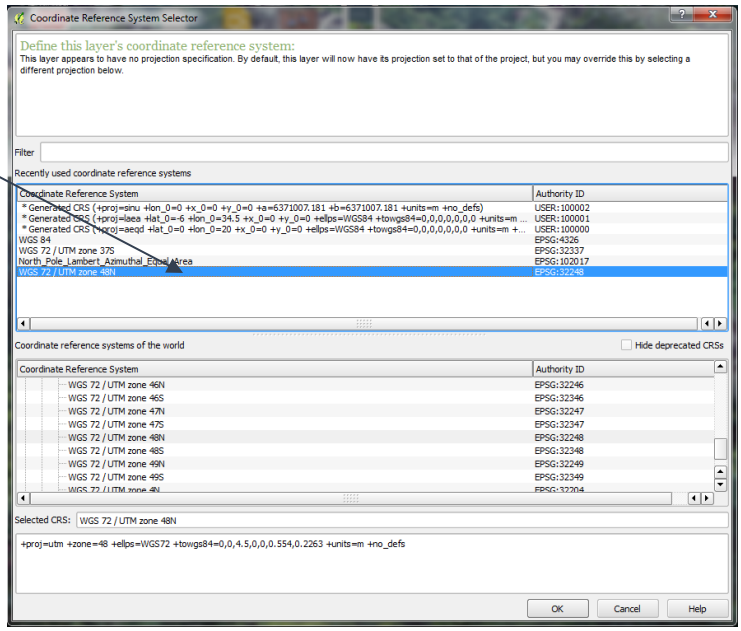
d. Browse to the folder containing the shapefile to add, i.e. in this example a boundary file called **Provinces.shp. Click on the file** to select it.

e. Click **Open**

f. Then Click **Open** again

The dataset is added to the table of contents **BUT** if **the map projection information of the vector dataset is missing**, QGIS will ask the user to specify the CRS of the data.

g. Choose the projection that you want to project the data to (i.e. **NOT** necessarily as shown here).

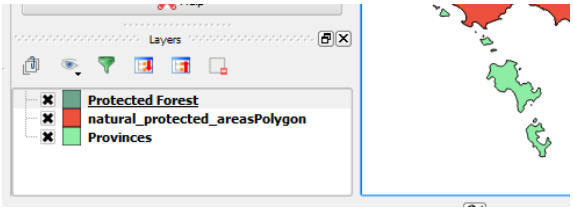


h. If the projection is **unknown,** make a guess. If the data display correctly on top of other datasets for which the CRS is known then it is likely to be OK.

Otherwise **right-click** on the dataset and **Set Layer CRS** and try again.

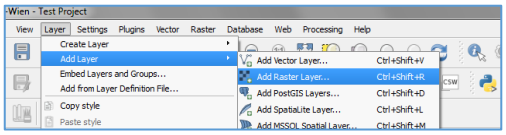
If QGIS is told by the user that the data are in the wrong projection, then the data may appear in the map canvas but in the wrong place. When other datasets are added with correct CRS defined these data will not display in the same location. Remember, make sure 'the on-the-fly' projecting is ticked' or data in different CRSs will not display on top of each other.

i. Layers can be **re-ordered** by clicking the layer in the table of contents (TOC) and **dragging to a new position** up or down the list.



2.2.5. Adding a raster layer

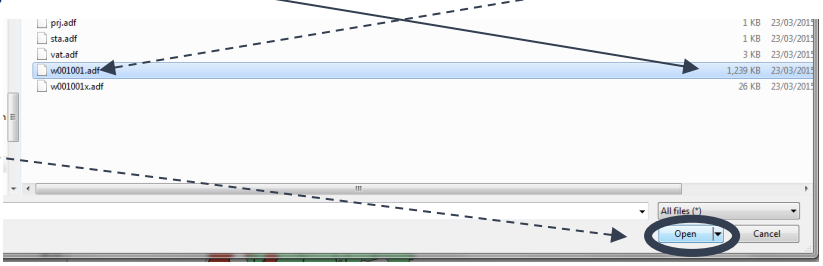
a. Click either **Layer>> Add Layer >> Add Raster Layer** or the **icon** to add a raster layer to the current project.



b. Leave file type as **All files,** rasters of all different types can then be added.

c. For data in ESRI native Grid format, this file format contains a folder with a number of standard files. The file to add is within the dataset name folder, and will always be called **w001001.adf**. It will always be the largest file in the folder.

d. Click **Open.**



2.2.6. Adding a delimited text layer

Tabular data can be added to QGIS using the Add Vector Layer button (and mapped as points if location information is included).

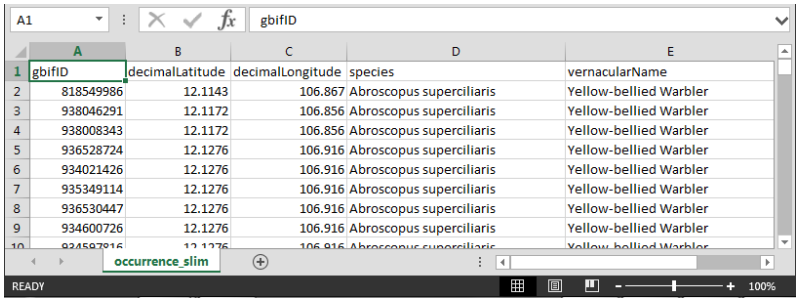
To add a delimited text file to be uploaded as a layer in QGIS:

- The text file must be formatted so that the first line of the text file is a delimited header row of field names;
- The data must contain an X and Y field (formatted as numeric but in any CRS);
- The CRS of the XY coordinates must be known.

IMPORTANT NOTE 'delimited text' data in CSV format means that the data fields are separated by commas. If any of the actual data include commas, this will cause a problem with the import. Spreadsheet software such as Excel can distinguish between the field delimiters and the commas within the text strings as the text strings are enclosed by " ". QGIS however does not see the " " and will read the data incorrectly. This can be resolved by opening the data in Excel and saving the CSV file as tab-delimited rather than comma-delimited.

a. Open the text file in Microsoft Excel (in this example we use GBIFOccurence_slim.csv).

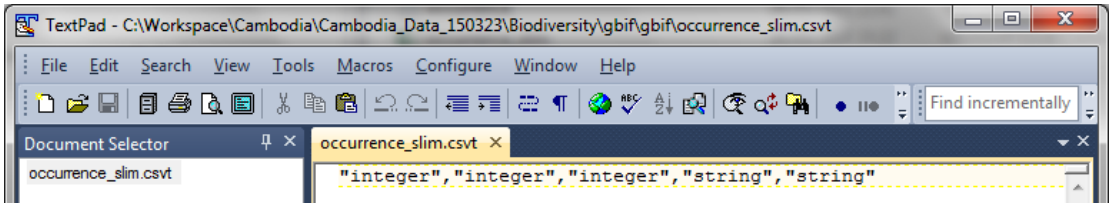
b. Scroll along the column headings, some may have headings that are too long. These need to be changed as GIS software such as QGIS will not accept them, and spaces should be removed.



gbifID	decimalLatitude	decimalLongitude	species	vernacularName
818549986	12.1143	106.867	Abroscopus superciliaris	Yellow-bellied Warbler
938046291	12.1172	106.856	Abroscopus superciliaris	Yellow-bellied Warbler
938008343	12.1172	106.856	Abroscopus superciliaris	Yellow-bellied Warbler
936528724	12.1276	106.916	Abroscopus superciliaris	Yellow-bellied Warbler
934021426	12.1276	106.916	Abroscopus superciliaris	Yellow-bellied Warbler
935349114	12.1276	106.916	Abroscopus superciliaris	Yellow-bellied Warbler
936530447	12.1276	106.916	Abroscopus superciliaris	Yellow-bellied Warbler
934600726	12.1276	106.916	Abroscopus superciliaris	Yellow-bellied Warbler

c. Click **File>>Save** to save the file (keeping the file format as csv). If it asks if you want to keep the file in this format click **yes.**

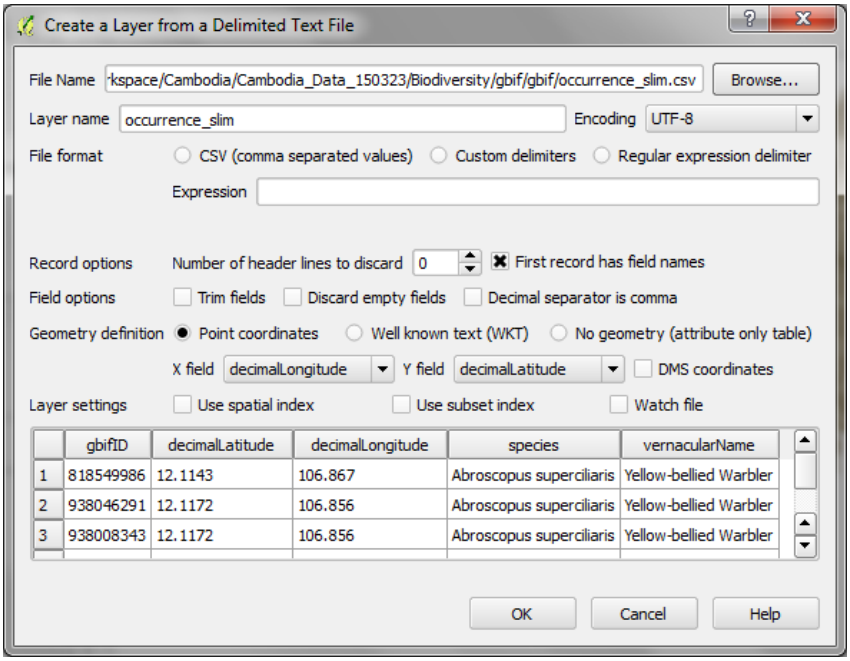
d. Open a **text editor** and **create a new file** and **add** the following text to correspond to the data types of each of the columns in the .csv file**,** e.g. for a file containing 3 numeric columns and two text columns this file should contain:
"integer","integer","integer","string","string".



e. **Save the file** with **the same name** and in the **same folder** as the csv file but with the **.csvt** ending.

This will ensure that when the file is opened later in QGIS that the numeric (Integer) fields are read with the correct data type, otherwise QGIS will default to making all the fields text (string).

f. In QGIS click the **add delimited text button** QGIS will try to guess which fields to use for the **X field** and **Y field** (i.e. which of the data file's fields contain location information)



g. Ensure the correct columns containing the longitude **(X field)** and latitude **(Y field)** have been selected.

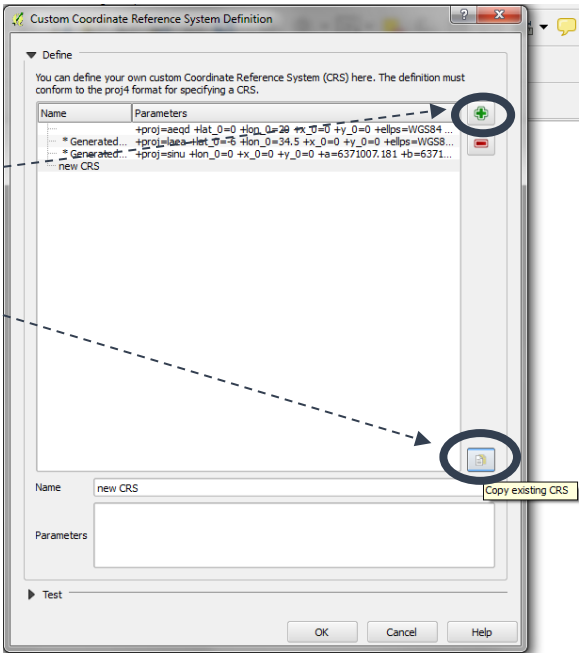
h. Click **OK.**

2.2.7. Creating a custom CRS

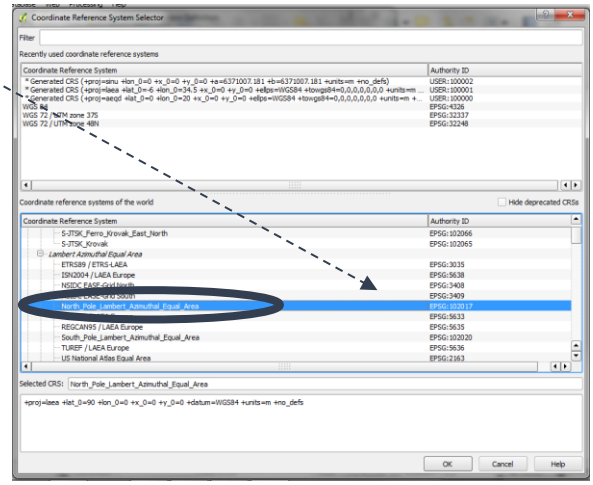
Sometimes it may be useful to create a **custom projection**, for example if your area of interest/country/region crosses more than one UTM Zone, UTM may not be the best CRS option - it would require analysis to be done by splitting the data and carrying out the analysis separately for each zone. The Lambert Azimuthal Equal Area projection is one option for creating a custom projection.

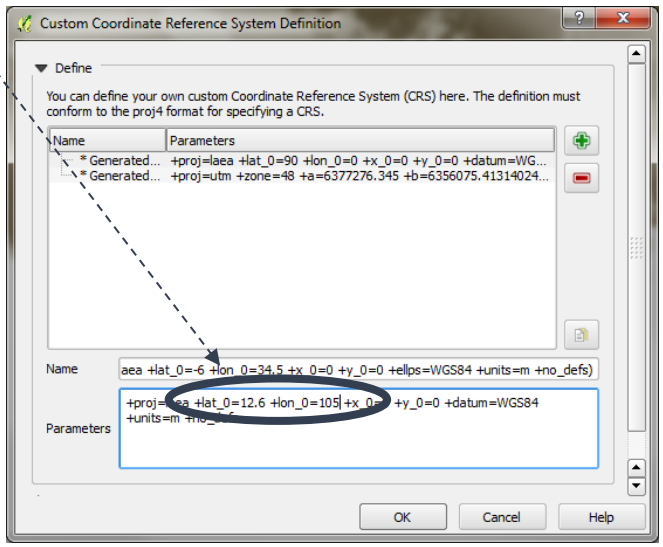
a. From the main menu click **Settings >> Custom CRS**.

b. Click **Add new CRS**, and give your projection a name (change it from newCRS).
Next, we will choose the parameters for a Lambert Azimuthal Equal Area projection, click on **Copy existing CRS**



c. Click to select **North_Pole_Lambert_Azimuthal_Equal_Area**.
d. Click OK
e. Then edit the information in the parameters box to change the central meridian and latitude of origin to centre the projection on a particular country or region of the world. For example, for Cambodia this means setting **lat_0=12.6** and **lon_0=105**
f. Click **OK**.





Note: Although we can choose to use a custom projection, Cambodia falls within a single UTM zone so it is not necessary to use a custom Lambert Azimuthal equal area projection for this country.

IMPORTANT/ USEFUL
Projection tips:

- ***IMPORTANT*** DO NOT **Right-click>>Set Layer CRS** on a dataset. This will NOT project the data to another projection. It will RE-DEFINE the projection only i.e. it will incorrectly tell QGIS that the dataset is in a different projection without making the change. So ONLY use this to fix a dataset that has the WRONG projection defined.
- Unlike ArcGIS, **on-the-fly (i.e. not permanent) area calculations CANNOT be done in QGIS**, the data have to be actually saved in the projected coordinate system.
- If the required CRS cannot be found in the list, a custom CRS can be defined manually - under **setting>>custom CRS.**
- **Right-click on a map layer>>Set Project CRS from Layer** to set the Project CRS (Map Canvas projection) to be the same as a particular layer.
- If the Map View is in a projected coordinate system (i.e. not EPSG: 4326) the scale of the canvas can be set at the bottom of the screen.
- Some of the projections in QGIS 2.8 appear to be faulty, so if a layer does not display, check the projection details to check whether this is the source of the problem. Bugs can be reported here http://hub.qgis.org/projects/quantum-gis

- Note: **There is a bug in version 2.8** – when a new dataset is created by running some analysis, the projection information is not maintained. The new dataset is added to the QGIS project with the default projection (see section 2.2.1). You then have to re-define the projection manually (or change your default projection as appropriate before running the analysis).

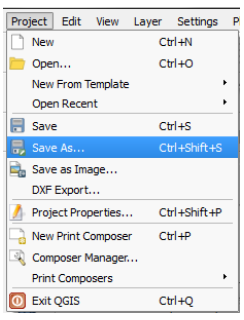
2.2.8. Projecting data / saving data to a new CRS

a. **Right-click** on the dataset to project (in this example PF.shp). Click **Save as**.
b. Select the **format** to be saved to and give the file an appropriate name. It helps to include the projection in the filename – in the example, we append _UTM_Zone48N
c. Leave the encoding system as default.
d. Tick **Add saved file to map** to add the projected data to the current project.
e. Change the CRS method. Either to **Project CRS** to save the data in the same CRS as the Map Canvas (or **Selected CRS)**, and then select the  to pick the output CRS from the CRS Selector window.

f. Click **OK** then **OK** again

2.3. Saving a QGIS project

a. Click **Project >> Save As** or **Save Project from the main menu**
b. Navigate to a folder to save the project and give it a name 
c. Click **Save**

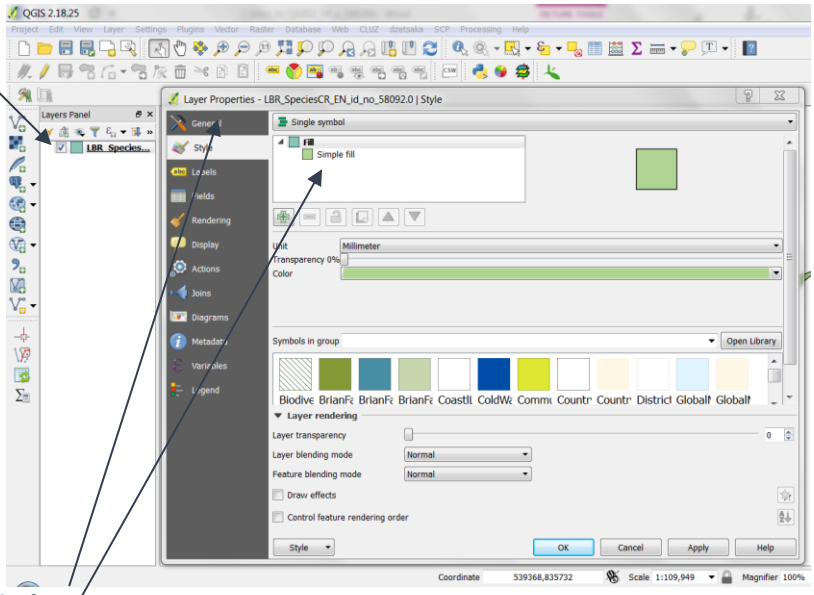


Note: The QGIS project is saved as a .qgs file. This is a text file containing all the information QGIS needs and is great for expert users who may wish to make edits in the text document. It also means that broken QGIS files have a good chance of being repaired as they can be opened in a text editor.

2.4. Symbology

2.4.1 Vector Symbology

a. When a dataset is added to QGIS it is added with a simple solid fill, random coloured symbology. **Double-click** on the data layer in the Table of Contents to change this.

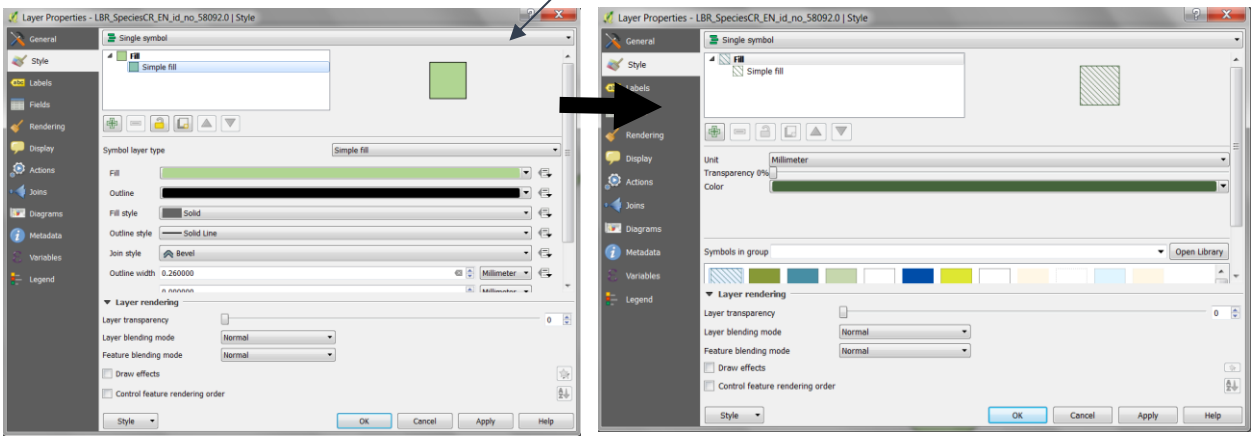


The **layer properties window** opens

b. Click the **Simple fill** box to change both the fill and outline symbology

d. The fields change to those of the **Symbol layer type** on the right hand side

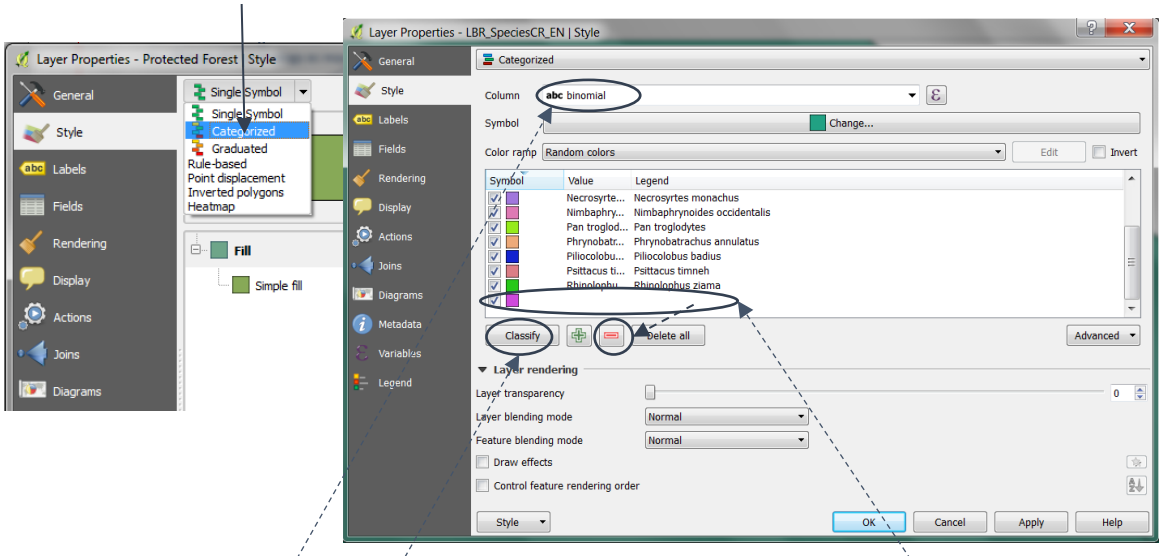
e. Change the symbology as required:



g. Click **OK** to close the **Layer properties** window.

h. For categorical data e.g. to shade a layer based on a set of thematic values in the attribute table of a layer, Click the **Single Symbol** to drop down the options.

Click **categorized**



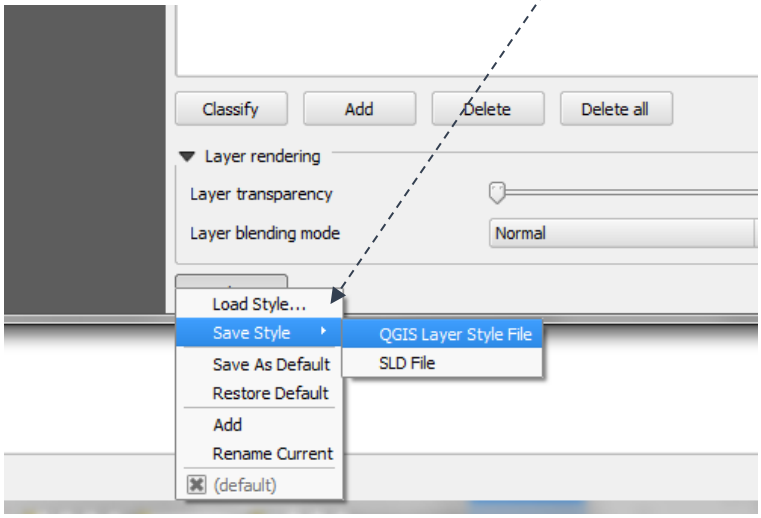
i. Choose the attribute of the layer upon which to base the shading. E.g. in this example **'category'**

j. Click the **Classify** button to add the unique combinations to the symbol window.

k. To remove any symbols (e.g. the empty one that is always added at the end), click the symbol row, then Click **Delete**

l. **Double-click** on each symbol to bring up the **Symbol Selector Window** and change the symbology for each individual symbol, in the same way as for the **Single Symbol**

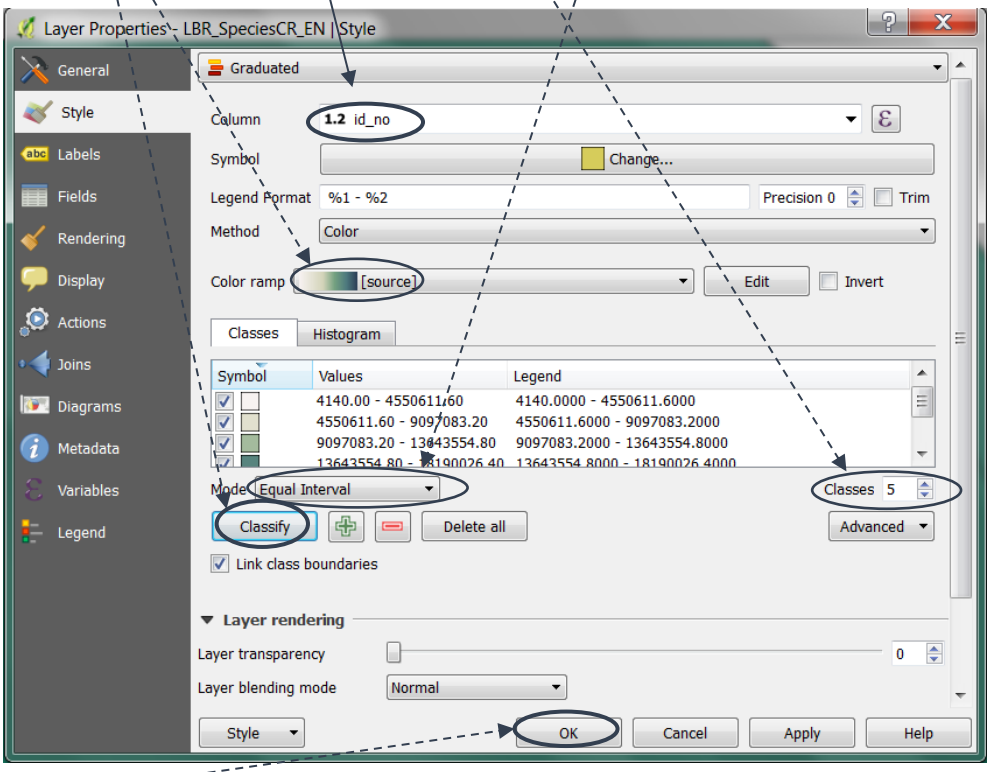
m. In the bottom left-hand corner of the box, click **Style >> Save Style >> QGIS Layer Style File** once a set of symbols have been created. This will save the styles to a **QML** style file.



*The next time this layer is added to a QGIS project these styles can be loaded clicking the **Load Style** button.*

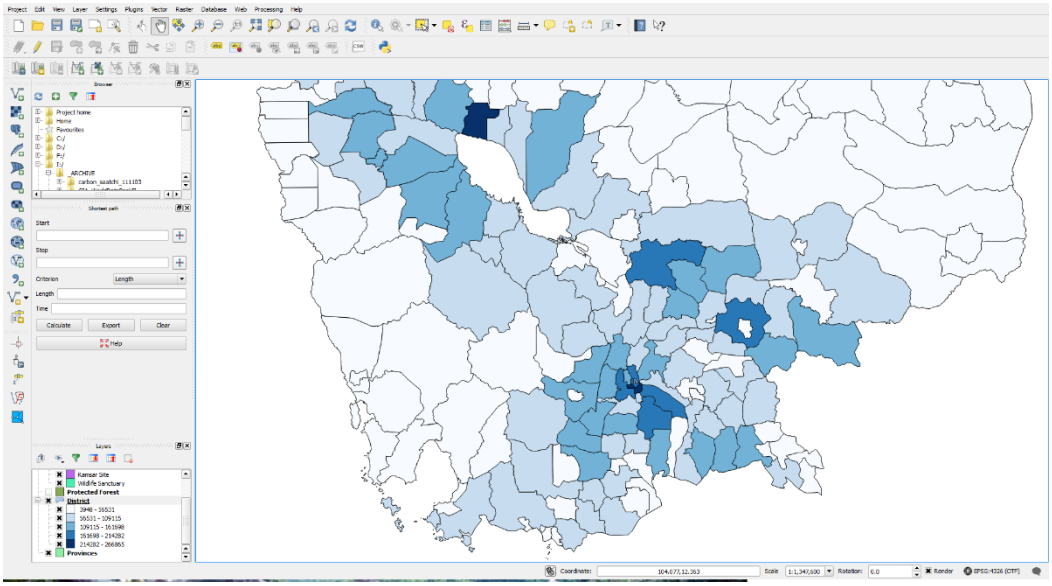
Some data are best presented using a **graduated** symbology, e.g. for population density data.

n. Select the attribute from which to shade the data
o. Choose the number of class breaks
p. Select how the classes should be defined. E.g. **Equal Interval**
q. Click **Classify**
r. Chose a colour ramp to shade the data

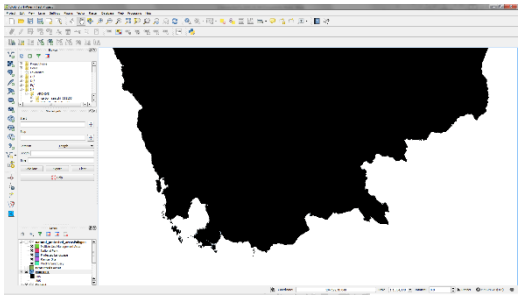


s. Click **OK**

Example map below



2.4.2 Raster Symbology

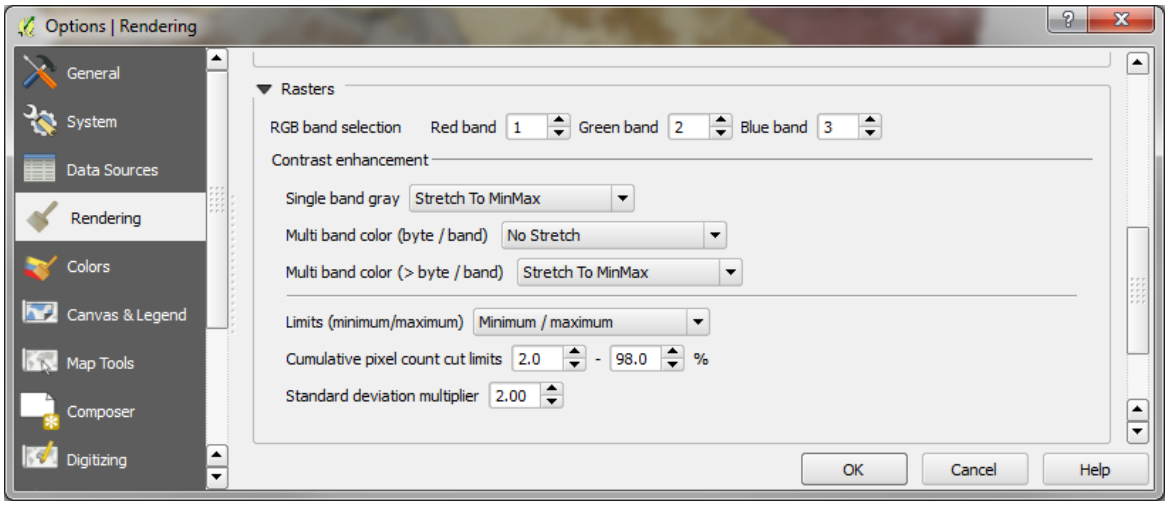


Raster symbology can seem a little more complicated than vector symbology. The notes below should help users understand raster symbology a little better.

When a raster dataset is added to a QGIS project it often appears all in one colour or the values displaying on the colour ramp are incorrect. There may not be a problem with the data. It is more likely that the method of shading this dataset, or the default QGIS settings, need changing.

First, **check** to ensure rasters are displaying the full range of values by default:

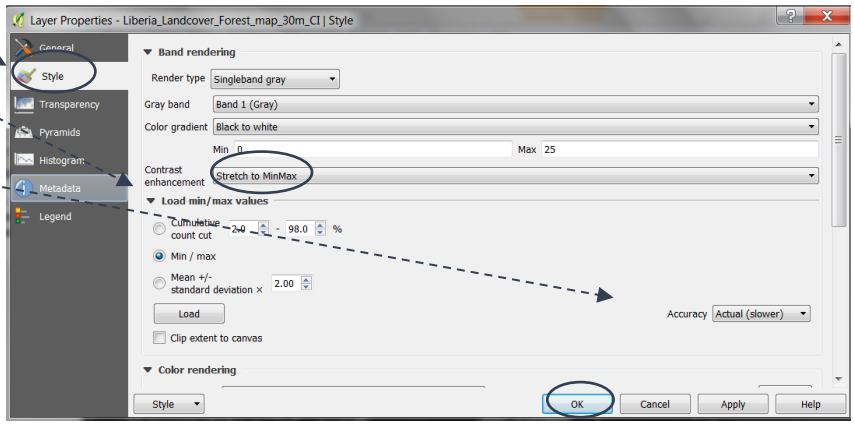
- **a.** From the main menu, click **Settings>>options**
- **b.** Click on the **Rendering** Tab
- **c.** Scroll down to **Rasters**
- **d.** Change **Single band grey** to **Stretch to MinMax**
- **e.** Change **Limits (Minimum Maximum)** to **Minimum Maximum**



- **f.** Click **OK**

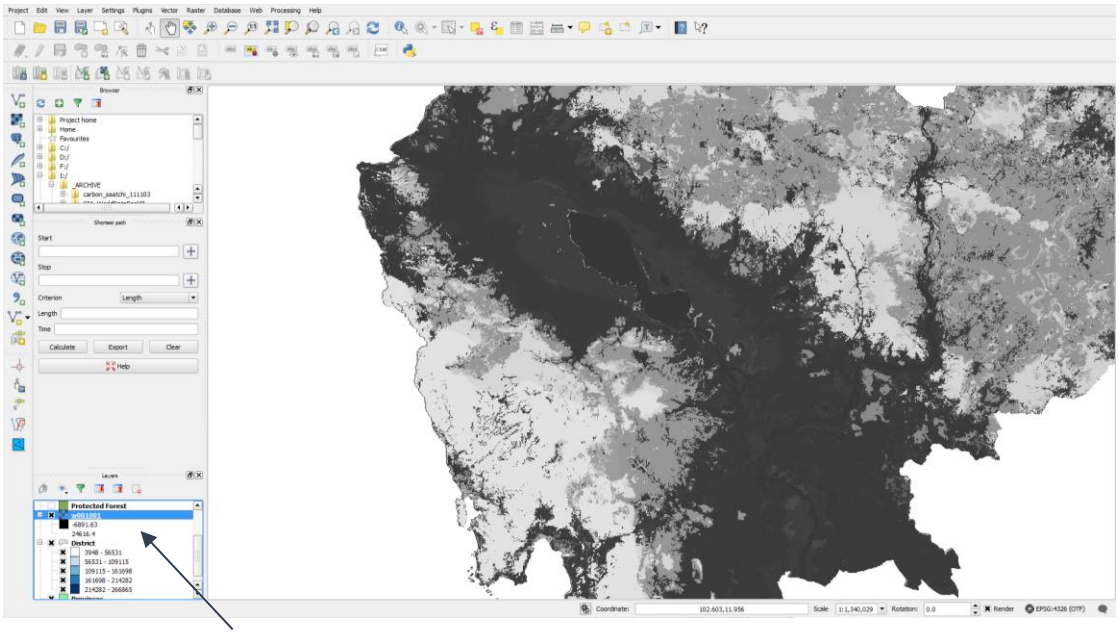
To change the same settings on a single raster layer:

- **a.** Double-click on the raster dataset to bring up the **Layer Properties** window
- **b.** Click on the **Style** tab
- **c.** Click to **Use Min/Max**
- **d.** Click on the **Actual (slower)** option in Load min/max values from band



e. Click **Contrast enhancement** to **Stretch to MinMax**
f. Click **OK**

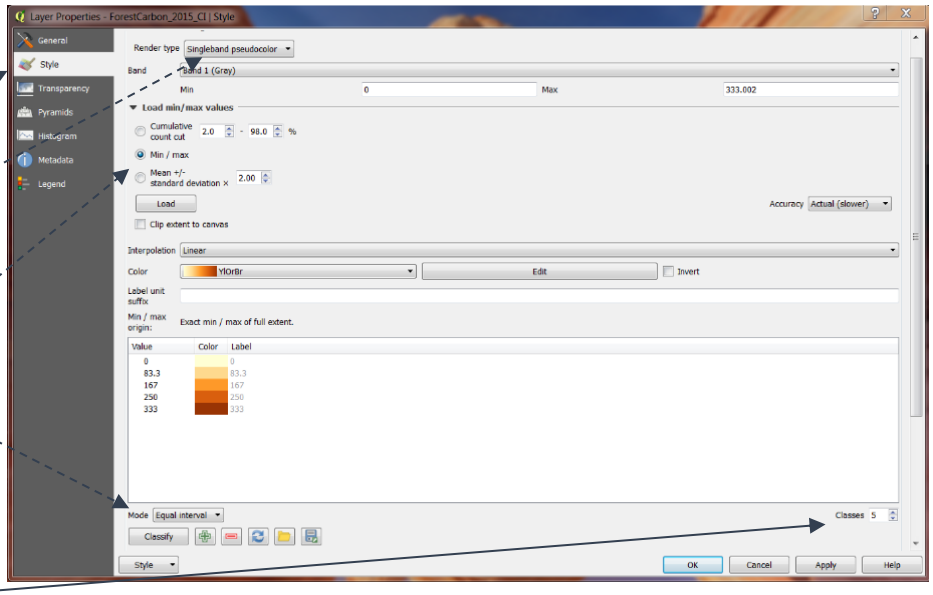
The variation in the data can now be seen



Note: that in the Table of Contents the data are stretched from a low to a high value, using the above method of shading it is not possible to see class breaks.

Alternatively you can choose to display the raster dataset in class breaks:

a. **Double-click** on the raster dataset to bring up the **Layer Properties** window
b. Click on the **Style** tab
c. Change the Render Type to **Singleband pseudocolor**
d. **Change the colour ramp**
e. Change the **Mode** to **Equal interval**
f. Click **Min/max**
g. Click **Actual (slower)**
h. Click **Load**
i. Change the number of **classes** in this example we will leave it at **5**
j. Click **Classify**
k. Change the **Color interpolation** to **Discrete** *(choosing discrete means that the colour is discrete for each class rather than Linear which ramps the colour within the classes)*



l. **Manually change the labels**, e.g. in this example the first class represents values <= 0, class 2 represents 0 – 5271, class 3 = 5271 – 10542 etc.). *You can also manually change the class breaks if you are not happy with the equal interval classes*

m. Click **OK**

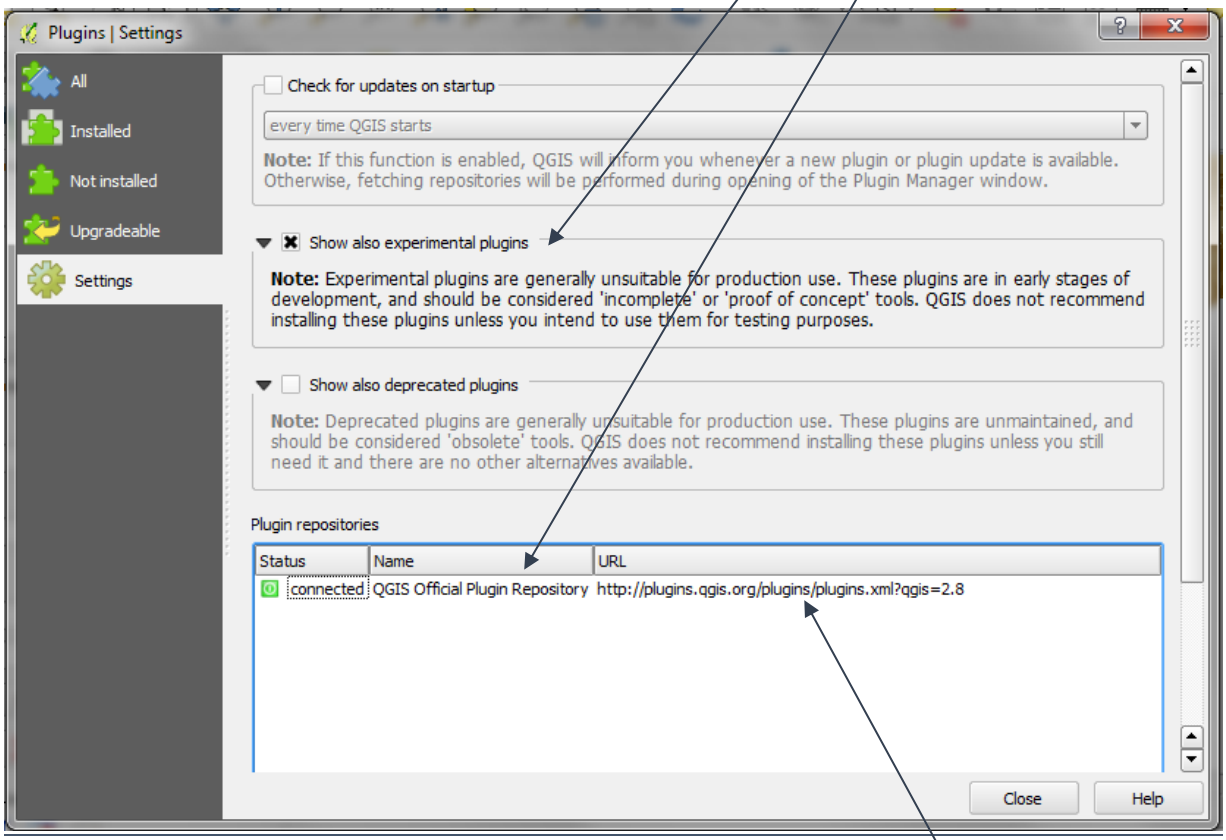
2.5. Installing plugins

QGIS comes with an additional functionality in the form of 'plugins'. They are very easy to install, provided there is an internet connection to initially install them. Once installed, they remain in the QGIS installation and an internet connection is not required. Some plugins are part of the core QGIS system and are written in C++ or python. These are part of the QGIS installation and are maintained by the QGIS development team, others are external and maintained by individuals and can be very easily installed manually. This plugin architecture allows many new features and functions to be easily added to the application as they are developed, rather relying on the core development team to add the functionality.

a. From the main menu click **Plugins>>Manage and Install Plugins**

b. Click on the **Settings tab** and tick **Show also experimental plugins** (as there are some useful plugins or updates to plugins that are still experimental)

c. Check in the field below that the **Official Plugin Repository** is showing in your list of plugins



d. Click on the '**All' tab**

e. Select the desired plugin from the list and click **Install**

f. The plugin repository can also be explored from a web browser (see the url above)

2.5.1. Useful plugins for spatial analysis to inform REDD+ planning and safeguards policies

Here are a few plugins that have been particularly useful so far in carrying out spatial analysis work for REDD+ planning:

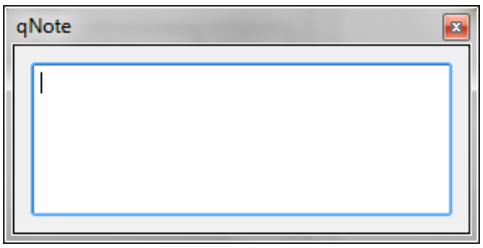
2.5.1.1. qNote

"qNote" is a great way of storing documentation about a QGIS project. The plugin adds an additional free-text window to the project in which notes can be typed. This provides a method to attach metadata within the project so that it does not get lost. Information on the following could be stored:

- Content of the project
- Purpose
- Analytical methodologies
- Area of interest
- Where the data came from
- Who created the project
- What the project was created for e.g. a report or publication
- Version of the project / date last edited
- Restrictions on sharing the project

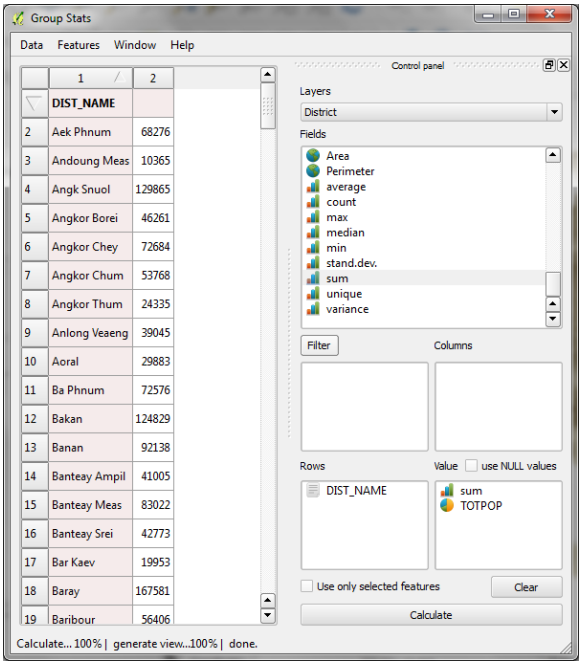
This information stored within a project is extremely valuable when sharing projects as well as providing an aide-memoire when revisiting a project at a later date.

a. Click on **Plugins>>Manage and Install Plugins**
b. Scroll down and **tick qNote**
c. The **qNote** window appears at the bottom of the QGIS project. The window can be turned on and off by clicking **View>>Panels** and selecting **qNote** on or off.



2.5.1.2. Group stats

Simple statistics can be calculated from vector layers using the standard QGIS tools from the **Vector>>Analysis Tools>>Basic statistics** or **Vector>>Analysis Tools>>List Unique Values** menus. However, these are not sophisticated enough for summarizing the results of overlay analyses.



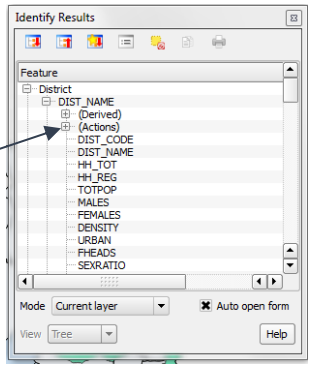
The Group Stats plugin is useful for creating summary statistics about a dataset based on groups of features. It is similar to a pivot table in Excel.

a. Click on **Plugins>>Manage and install plugins**
b. In the **All** section, search for Group Stats and install the plugin.
c. One installed, Group Stats can be accessed from the **Vector>>Group Stats** menu
d. Drag a summary field into **Rows**
e. Drag a function into **Value**
f. Drag the value to summarise into **Value**
g. Click **Filter** to filter the data before summarizing
h. Click **Calculate** to calculate the summary statistics

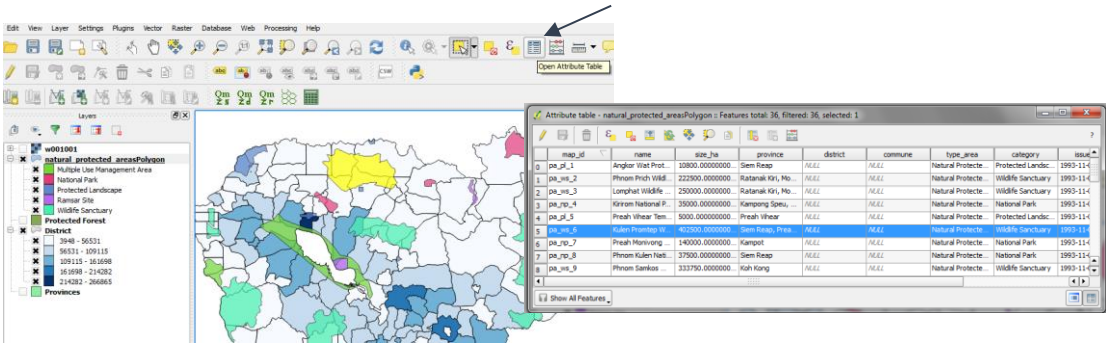
2.6. Querying data

Data can be simply queried in the following 3 steps:

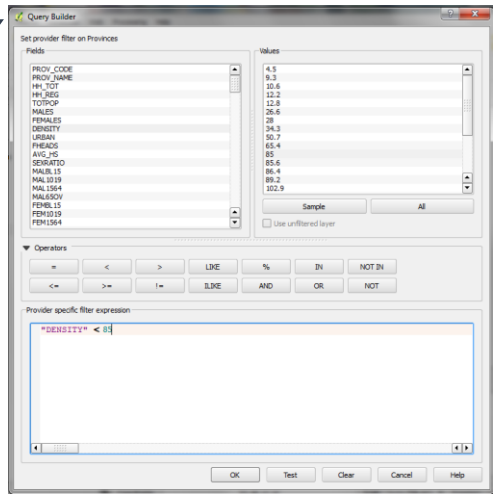
a. First click on the **data layer** in the **Layer Panel** to select the layer to query.
b. Click the  **identify button.**
c. Then click on any **feature of interest** in the **map canvas** to identify the feature within the selected layer.
d. Select **Actions** from the **Identify Results** menu that appears, and then double-click on the attribute table icon  to view the available attribute data in the area of interest.
e. Alternatively a feature can be selected by clicking on the **map canvas** with the **select features by area or single click** tool  and the feature(s) is highlighted.

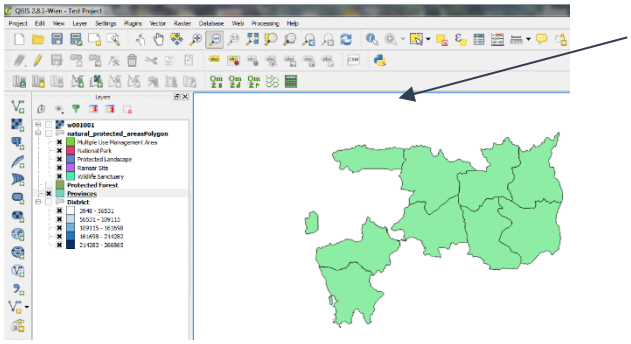


f. The **attribute table** can then be opened to see the **highlighted selected feature(s)**

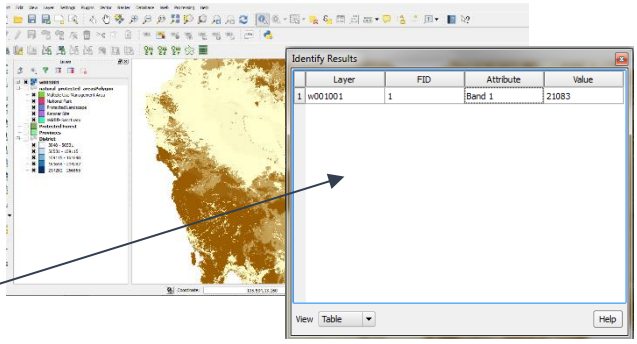


g. If only certain polygons are required in the map display, a **Right-click>>Filter** on the layer will bring up the **Query builder** window to allow the user to select features for display. In this example, only Cambodian provinces with a population density of less than 85 are shown in the map display.





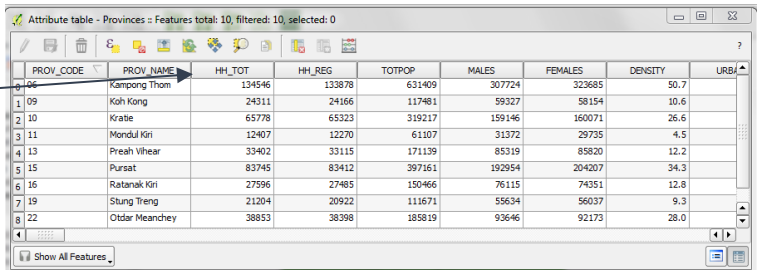
h. For Raster data there is **NO option to open an attribute table**, as QGIS does not recognise them. The only option for rasters is to click on the **raster data layer** in the **TOC** to select the layer to query, and then **click on the map** with the **identify button**  to bring up the **Identify Results window** and select **View >> Table** to view the values for the location of interest



2.7. Joining Tables

a. Joining of Tables is simple in QGIS. First **identify the datasets/tables to join**. Check there is a **common field** that can be used to join the tables together. The names of the join fields do not have to be the same – just have the same content (for example here we join a table VulnIndex.dbf to Provinces.shp).

b. Open the attribute tables of the dataset to be joined to explore the fields e.g. in this example a table containing census data by province will be joined to a shapefile of a vulnerability index.



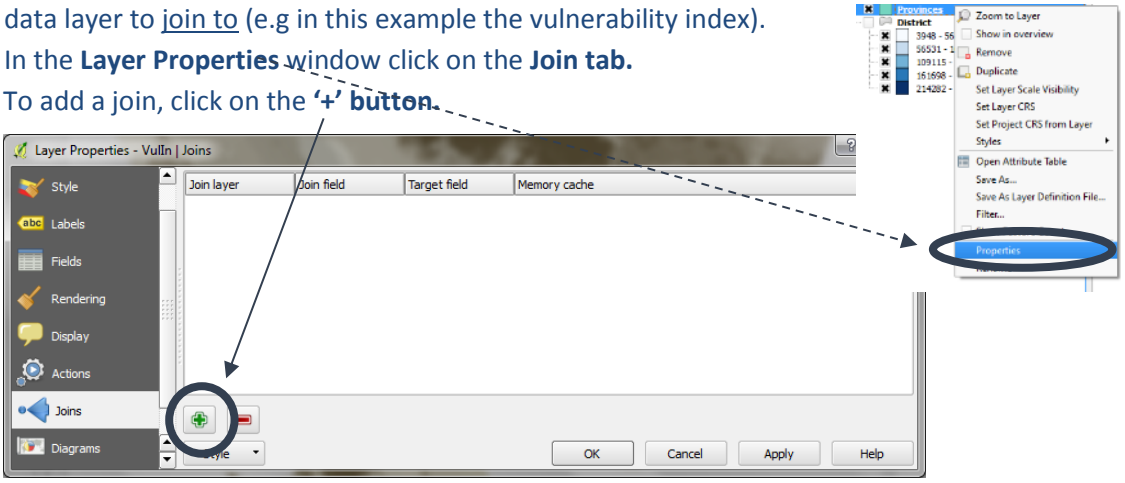
c. Note the names of the field to be used in the join, in this example, the name of the province is called 'PROV_NAME'.

d. Close the Attribute table.

e. **Right-click>>Properties** on the data layer to join to (e.g in this example the vulnerability index).

f. In the **Layer Properties** window click on the **Join tab.**

g. To add a join, click on the **'+' button.**



h. Select the **table to join** e.g. 2012_pop table

i. Click **OK**.

j. The table has been **temporarily joined** onto the shapefile. To make the join permanent, **Right-click** on the shapefile and click **Save As…**

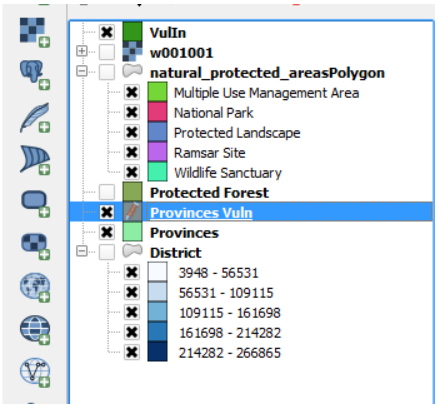
k. Click **Browse** to save the shapefile with a new name

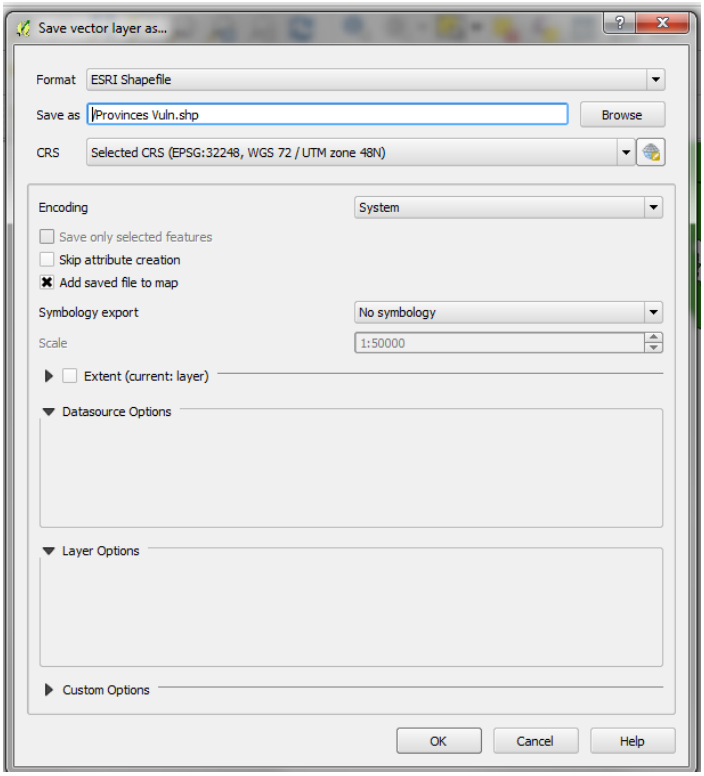
l. Keep the **CRS** the **same as the existing layer**

m. Tick to **Add saved file to map**

n. Click **OK**

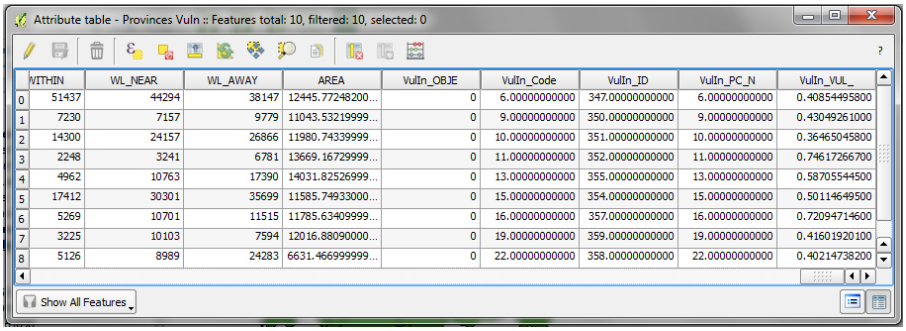
o. The new dataset is added to the map





p. Open the **Attribute table**

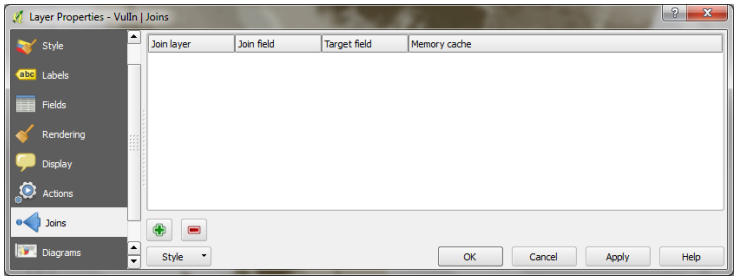
q. See the fields from the vulnerability index table at the end of the table:



r. Double-click on the **saved dataset** to open the **layer properties**

s. Click on the **Joins tab** to see that there are no longer any joins present and therefore the population fields have been made permanent.

t. Click on the **Fields tab**



Note: that all the fields joined from a CSV file will be of type 'string' unless a .csvt file is created (refer to section 2.2.3.3 Adding delimited text layer). Some may need to be numeric but unfortunately the field types cannot be changed. The solution is to add a new field and calculate the information across from the string field to the numeric field, as follows:

a. Click the  **toggle editing** button to start editing

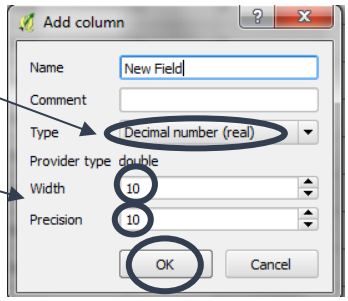
b. Click the **Add Field** Button

c. **Add a new field** of type **Decimal number (real)**

d. Give the field a name, e.g. 'Vulnerab'

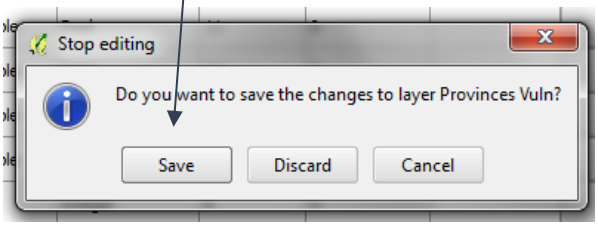
e. Set Width and Precision to **10**

f. Click **OK**

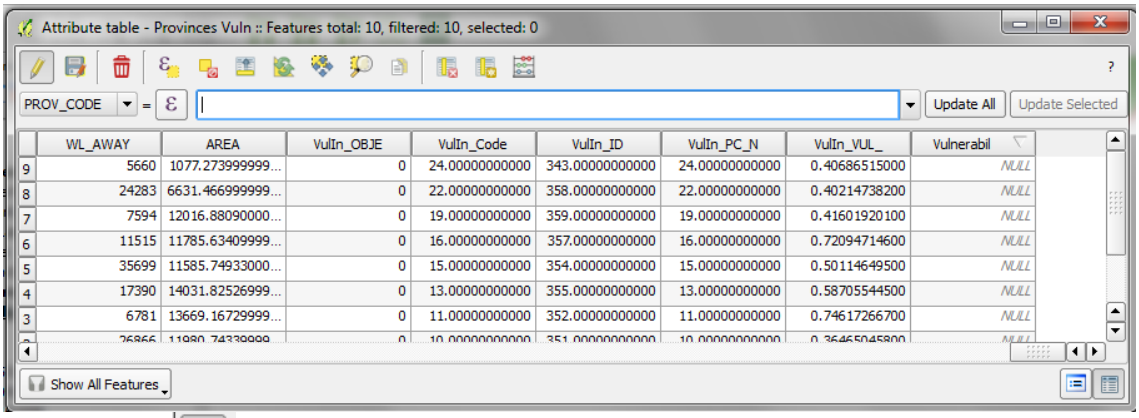


g. Click the  **toggle editing** button to stop editing

h. Click **Save**

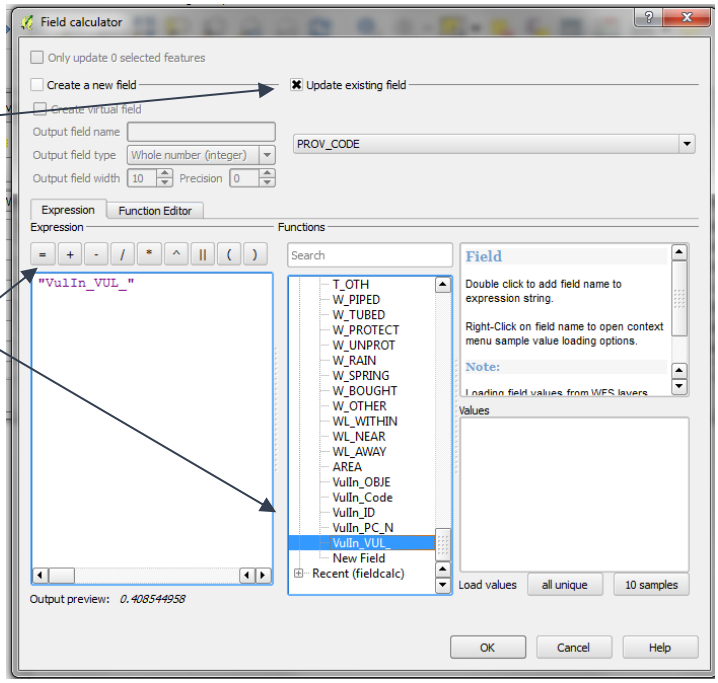


i. **Right-click** on the data layer and **open the attribute table**
The new 'empty' field is located at the end of the table.

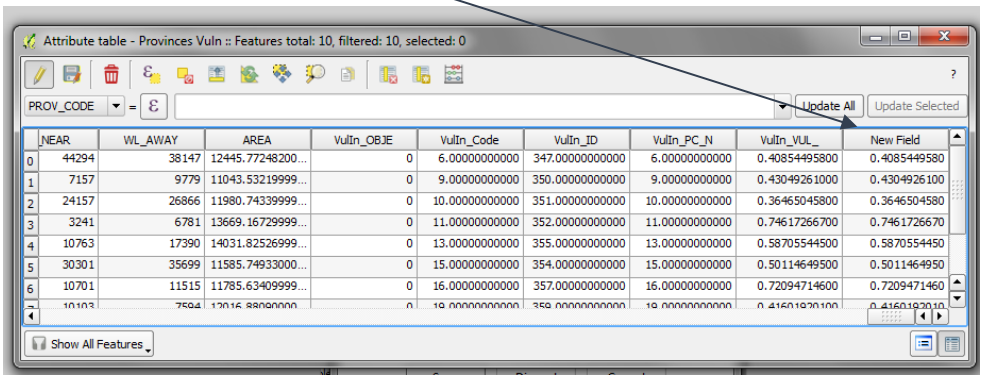


j. Click the  **toggle editing** button to start editing.

k. Click the **calculator** button
l. In the **Field calculator** tick the **Update existing field**
m. Choose to update the new empty field created
n. Double-click on the **(string) field** which contains the **data to transfer** to the decimal field
o. This will bring it into the **expression** window
p. Click **OK**



r. Click the **toggle editing** button to stop editing
s. Check that the attribute has been updated. It is sometimes necessary to close and reopen the attribute table.



	NEAR	WL_AWAY	AREA	VulIn_OBJE	VulIn_Code	VulIn_ID	VulIn_PC_N	VulIn_VUL_	New Field
0	44294	38147	12445.77248200...	0	6.00000000000	347.00000000000	6.00000000000	0.40854495800	0.4085449580
1	7157	9779	11043.53219999...	0	9.00000000000	350.00000000000	9.00000000000	0.43049261000	0.4304926100
2	24157	26866	11980.74339999...	0	10.00000000000	351.00000000000	10.00000000000	0.36465045800	0.3646504580
3	3241	6781	13669.16729999...	0	11.00000000000	352.00000000000	11.00000000000	0.74617266700	0.7461726670
4	10763	17390	14031.82526999...	0	13.00000000000	355.00000000000	13.00000000000	0.58705544500	0.5870554450
5	30301	35699	11585.74933000...	0	15.00000000000	354.00000000000	15.00000000000	0.50114649500	0.5011464950
6	10701	11515	11785.63409999...	0	16.00000000000	357.00000000000	16.00000000000	0.72094714600	0.7209471460

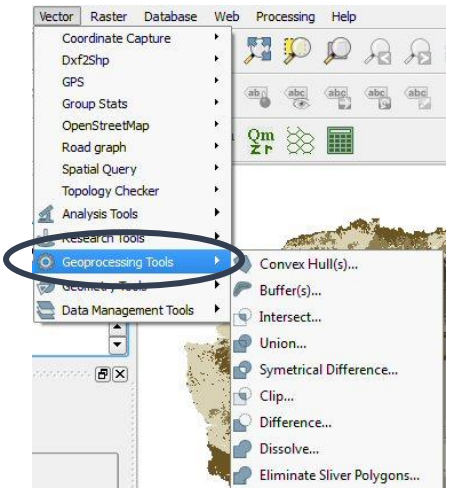
2.8. The Processing Toolbox

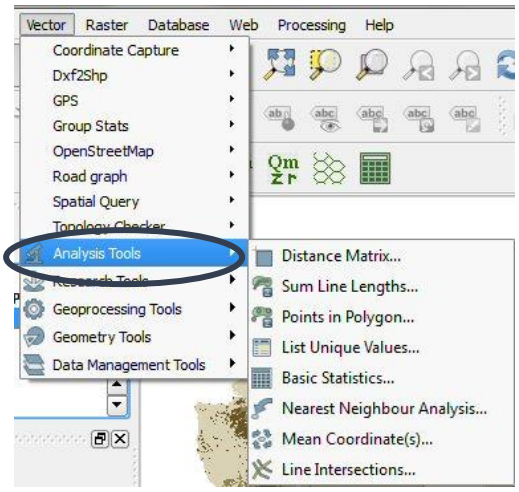
This part of the tutorial makes a brief introduction to the processing toolbox and explains how to access the various analysis tools. It does not go into detail about running the wealth of individual tools available, but provides a few examples.

There are four core elements of the processing environment that you should be aware of:

1. The toolbox – the main element where you can access the algorithms and scripts (including ones you have generated yourself).
2. The graphical modeller – where you can generate your own workflows by stringing together a series of algorithms.
3. The history manager – which provides a record of the processes that you have run.
4. The batch processing interface – which allows any of the algorithms to be run in batch mode to process multiple files.

Some of the vector and raster analysis functions can be accessed from the main menu bar, by clicking on **Vector >> Geoprocessing Tools** or by clicking on **Vector >> Analysis Tools.**





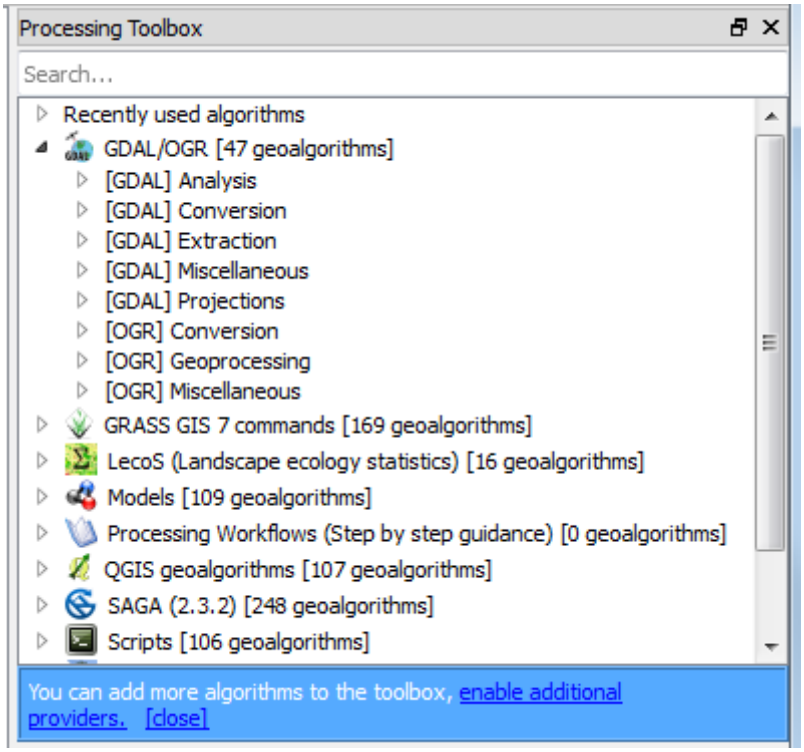
NOTE: If the Processing Toolbox doesn't appear on the right hand side of the QGIS window, right-click on the grey bars at the top of the window to activate the Processing Toolbox and make it appear.

There are also further functions in the processing toolbox (access in the right hand panel in the QGIS window) which are **grouped by 'algorithm provider'**. You can search for functions in the **Search** box at the top of the toolbox.

The **Models and Scripts** section is where user-created algorithms and python scripts are stored.

There are two ways to execute an algorithm:

1) Double-click on its name in the toolbox.
2) For batch processing right-click on its name and click **Execute as batch process.**



2.8.1. Example 1 – Running a vector clip in batch mode

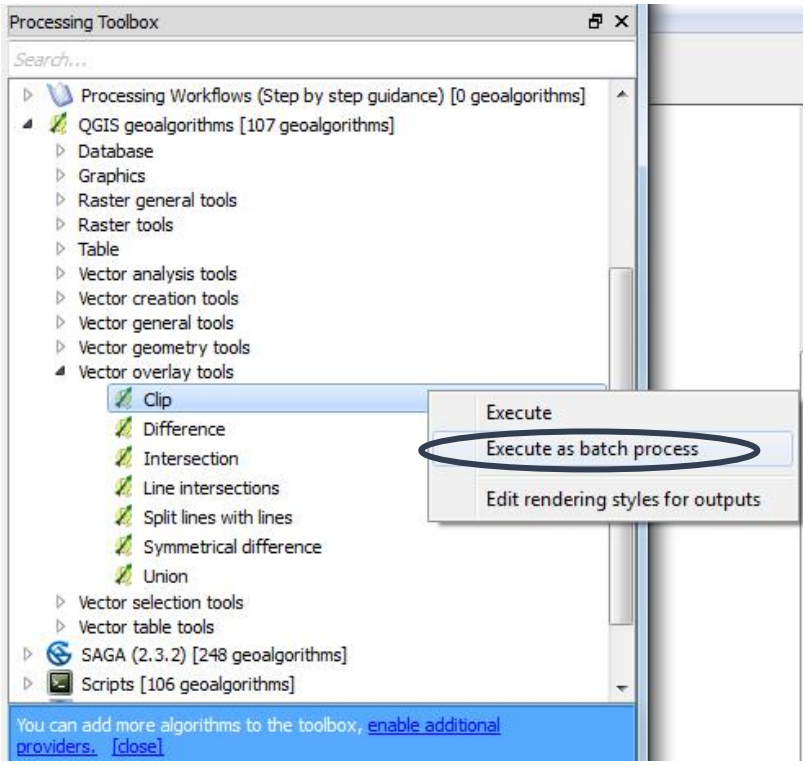
The **Vector Clip** tool allows you to cut datasets to a desired area of study. Running in batch mode allows you to clip multiple datasets at once.

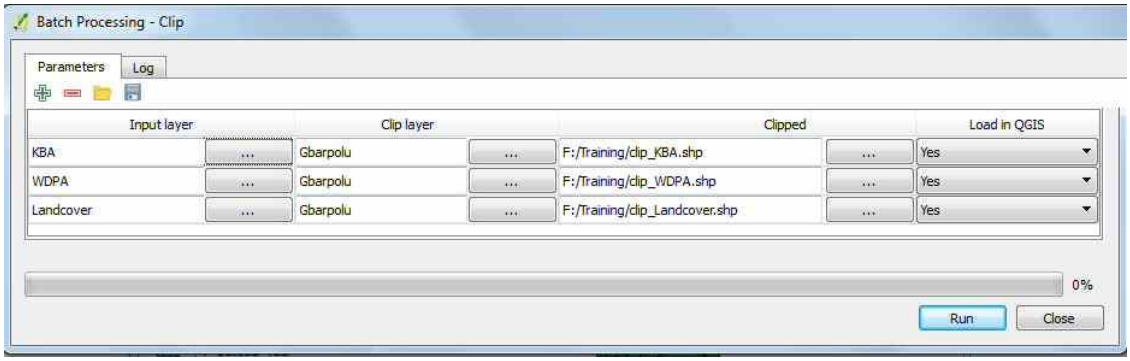
a. In the Processing Toolbox, expand QGIS geoalgorithms

b. Expand Vector overlay tools

c. Right-click on **Clip** and then select **Execute as batch process**.

d. In the **Input layer** column, click on the **'...'** box and select all of the files that you want to clip (use the **Shift key** to select multiple files).

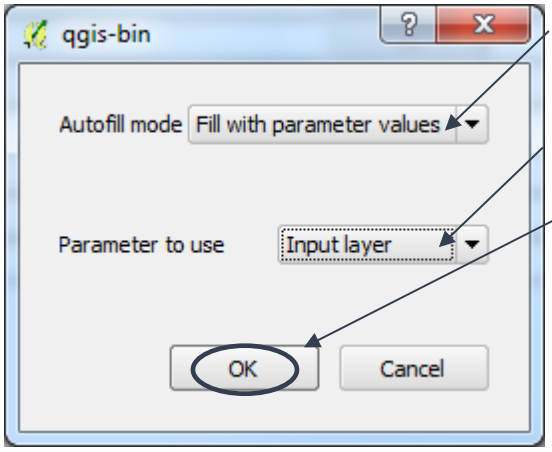




e. In the **Clip layer** column, click on the **'...' box** and select **the vector boundary file containing a single province**.

f. Double-click the top of the **Clip layer** column, to fill every cell.

g. In the **Clipped column**, click on the **'...'** box and select the location to store your clipped files and type a new name e.g. **clip_.shp** (this will be the name preceding the filename of the clipped files).



h. In the pop-up box, under **Autofill Mode** select **Fill with parameter values**.

i. These parameter values should be **set from the input layer**.

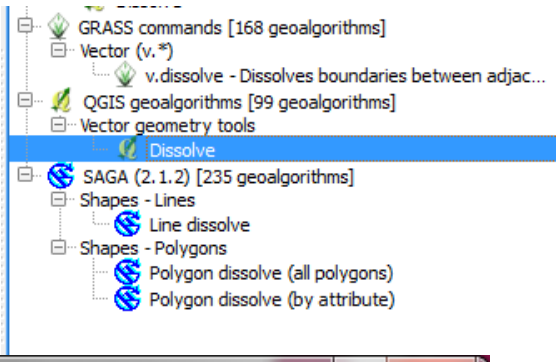
j. Click **OK**

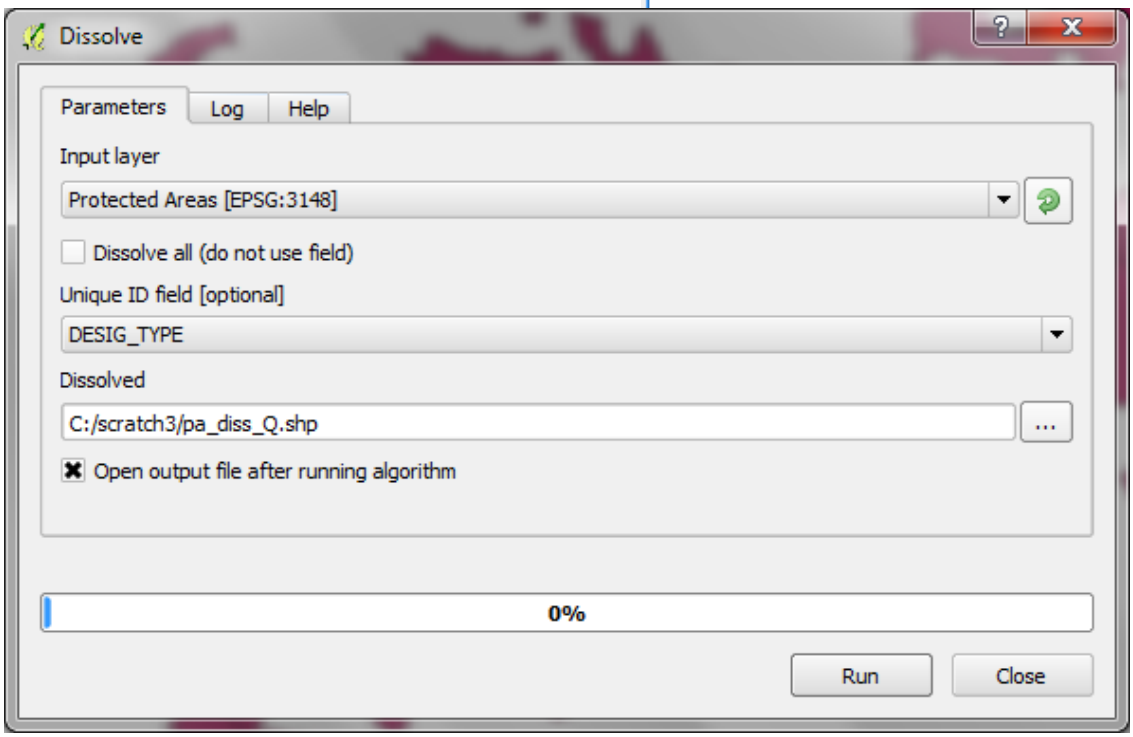
k. Click **Run**

2.8.2. Example 2 – Dissolve

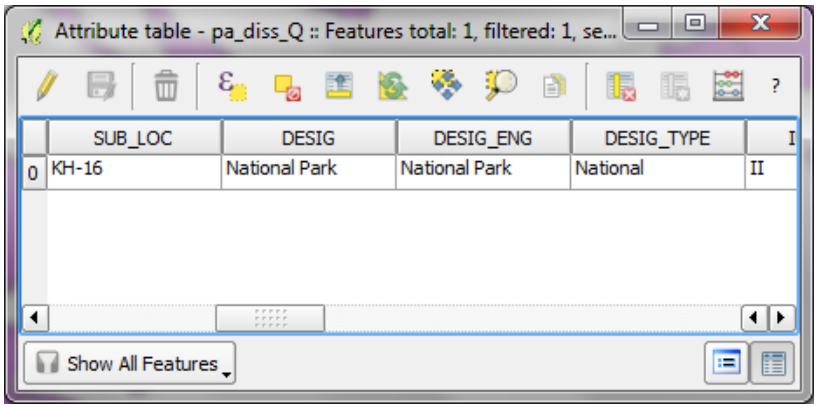
There are various tools that can be accessed from the Advanced Interface which allow you to conduct a 'dissolve' analysis. This provides a good example to show that there are often many tools in QGIS that can run the same or similar analysis. In this example we will run the dissolve 3 times using 3 different tools as there are some slight differences in the results which is worth noting.

a. First run the **standard QGIS dissolve**. Double-Click on the QGIS dissolve tool.
b. Select an **input** file e.g. **Protected Areas** vector layer
c. Uncheck **Dissolve all (no not use field)**
d. Chose a field to dissolve by e.g. **DESIG_TYPE**
e. Navigate to an output folder and give the output file a name.
f. Click **Run**





g. On the new dissolved dataset **Right-click>> Open attribute table.** Notice that there is only one row in the attribute table.

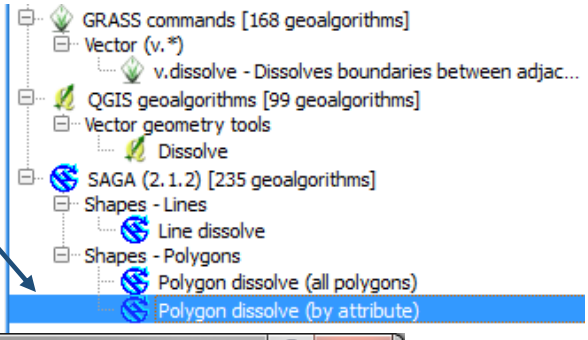


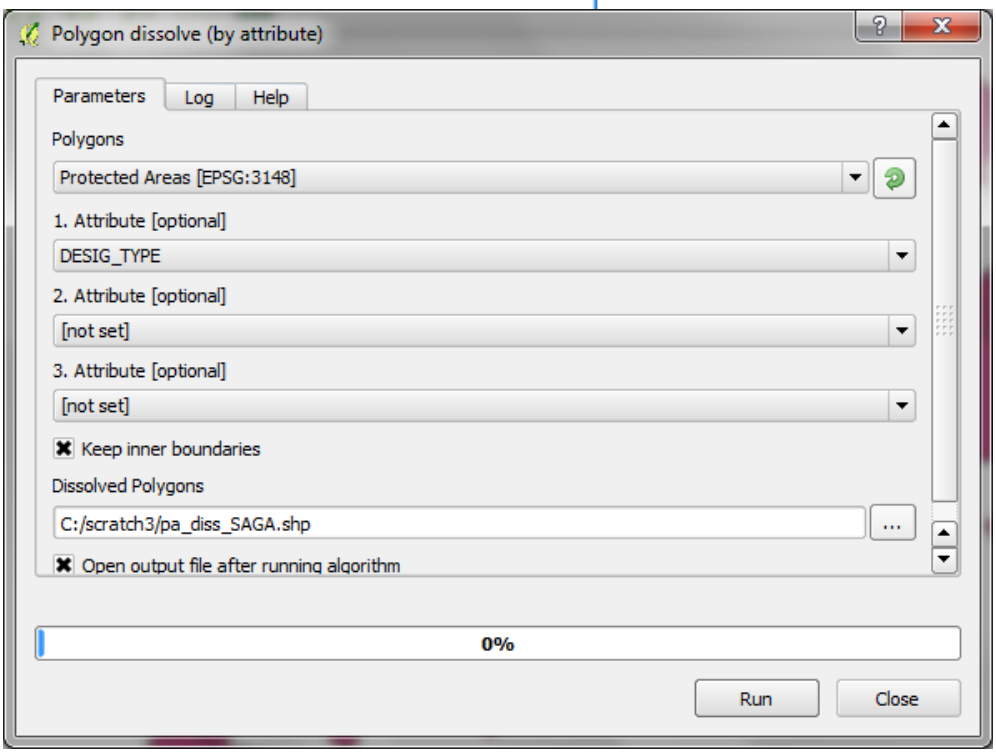
*It has created a **multipart polygon** layer (one attribute to many polygons). Also notice that even though we did a dissolve it has not dropped the attributes fields beyond DESIG_TYPE therefore the rest of the attributes are incorrect, it has just randomly kept the attributes from one of the original polygons.*

h. Next try the **SAGA** tool **Dissolve by attribute**. Use the same files used for the QGIS dissolve tool.

i. Set the **Polygons** (to be dissolved) e.g. Protected Areas.

j. Set the **attribute** (to dissolve on) e.g. DESIG_TYPE.





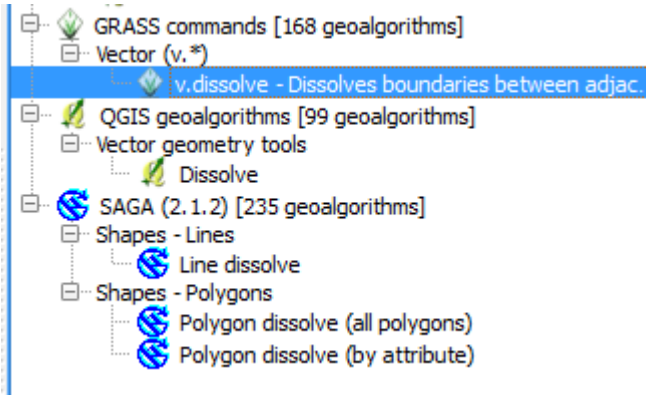
k. Navigate to an output folder and give the output file a name.

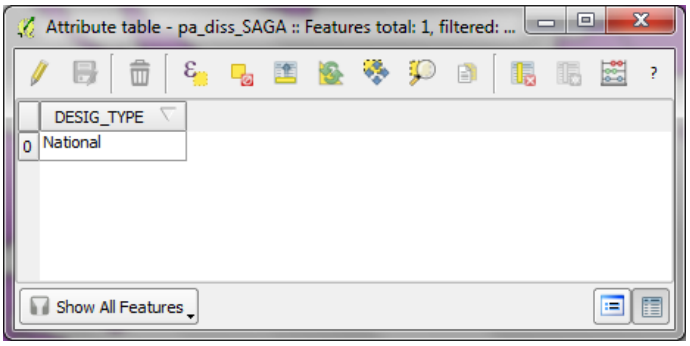
l. Click **Run**

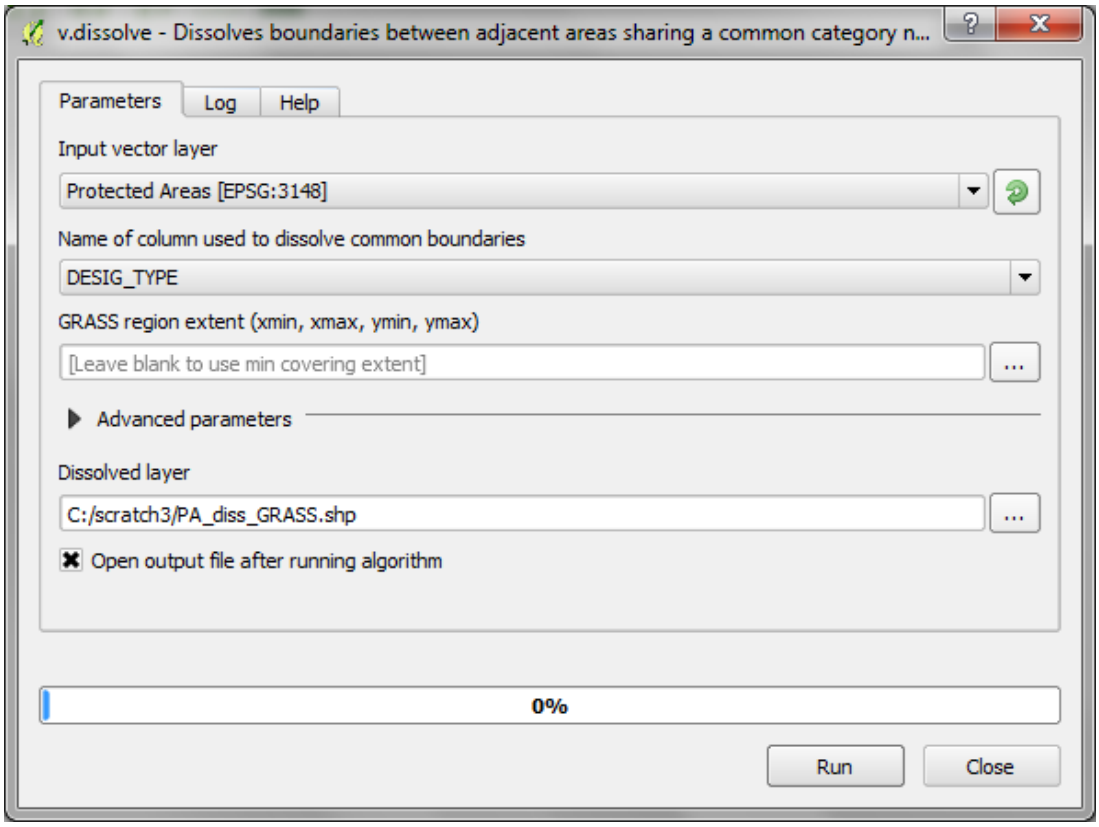
m. On the new dissolved dataset **Right-click>> Open attribute table.** There is again only one row in the attribute table.

It has created a multipart polygon (one attribute to many polygons). Also notice that it has correctly dropped the other attributes fields beyond field that was used for the dissolve i.e. DESIG_TYPE.

n. Next try the GRASS tool **v.dissolve.** Use the same files used for the QGIS and SAGA dissolves.
o. Set the **Input Vector layer,** e.g. Protected Areas.
p. Set the **Name of column used to dissolve common boundaries** e.g. DESIG_TYPE.
q. For **Dissolved Polygons,** navigate to an output folder and give the output file a name.

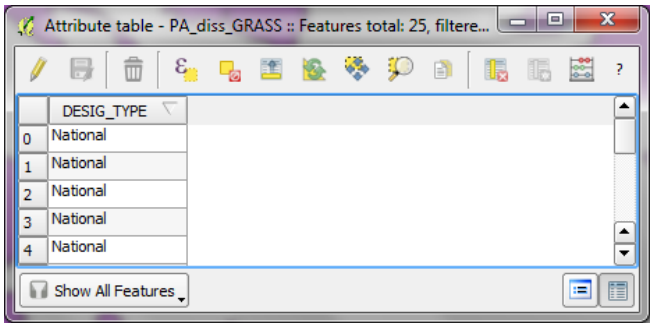






r. Click **Run**

s. On the new dissolved dataset **Right-click>> Open attribute table.**



*Notice it has many rows. It has create a **singlepart polygon** (one attribute to one polygon). Also notice that it has correctly dropped the other attributes fields beyond DESIG_TYPE.*

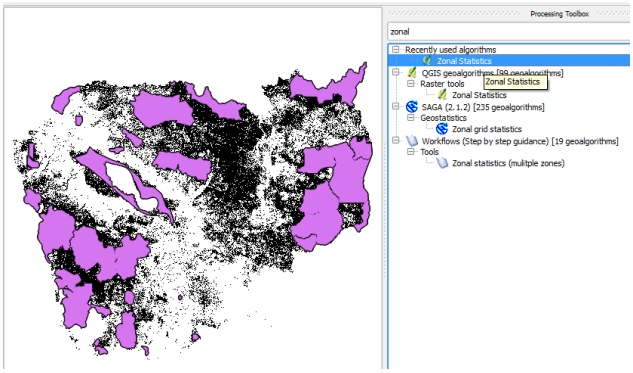
This highlights that the SAGA and GRASS dissolve tools work better than the core QGIS one. Both are correct but just use different ways of storing the attributes. There is a tool in the QGIS toolbox to convert from multipart to singlepart and vice versa.

Note: If you are running a spatial analysis where one or more of the datasets have multipart features it can sometimes slow down the processing and sometimes cause the process to fail if the multipart features are complex.

2.8.3. Example 2 – Zonal statistics for Raster data

The Zonal statistics algorithm produces statistics for raster layers based on a zonal polygon layer. For example, you can generate statistics of forest cover (raster layer) within protected areas (vector polygon zones layer).

a. Search for and double-click on the **Zonal Statistics** tool in the processing Toolbox.



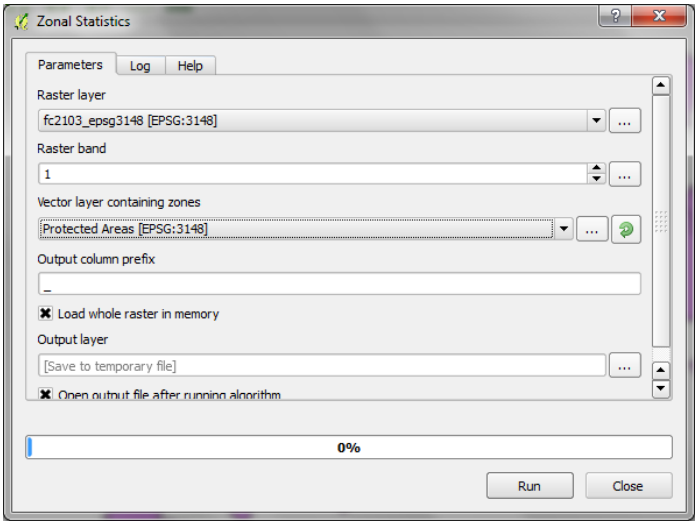
b. Choose a **raster layer** for which to generate statistics e.g. **Forest cover**

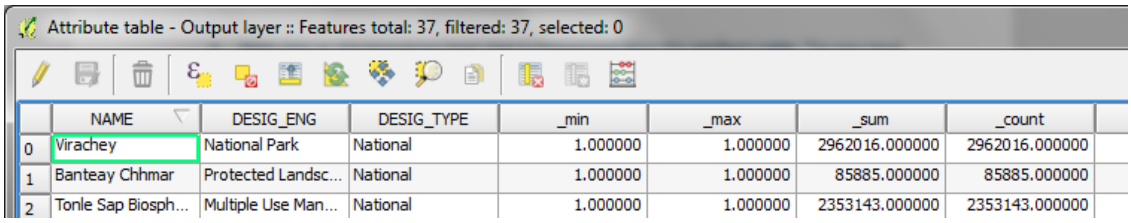
c. Choose a **vector polygon** layer to use as the zones to generate the statistics by. E.g. **protected areas**

d. Chose an output folder and name for the **new output dataset**

e. Click **Run**

f. Right-click on the new vector layer and **open the attribute table**



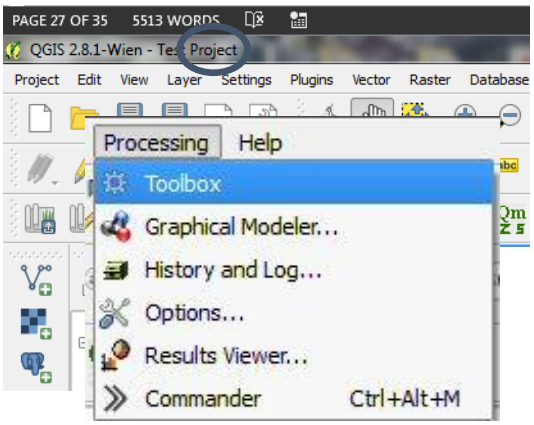


	NAME	DESIG_ENG	DESIG_TYPE	_min	_max	_sum	_count
0	Virachey	National Park	National	1.000000	1.000000	2962016.000000	2962016.000000
1	Banteay Chhmar	Protected Landsc...	National	1.000000	1.000000	85885.000000	85885.000000
2	Tonle Sap Biosph...	Multiple Use Man...	National	1.000000	1.000000	2353143.000000	2353143.000000

The new layer is a copy of the protected areas layer with additional fields **(_min, _max, _sum, _count, _mean, _std, _unique, _range, _var)** containing statistical summaries relating to the raster layer within each protected area polygon .e.g. count = the number of forest pixels in the protected area.

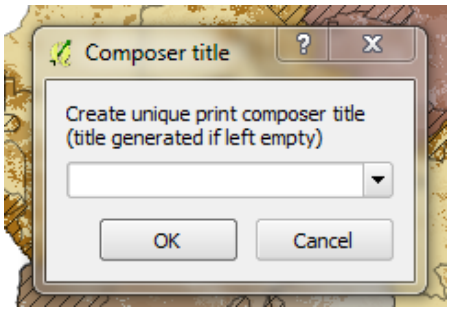
2.9. Map Layouts

Once all the layers have been symbolised, a map composition can be created. The layers will appear in the map layout as they do in the map view, so this is where we choose effective colours and symbols. The Layers can either be renamed in the Table of Contents or later when adding the legend to the map composition.



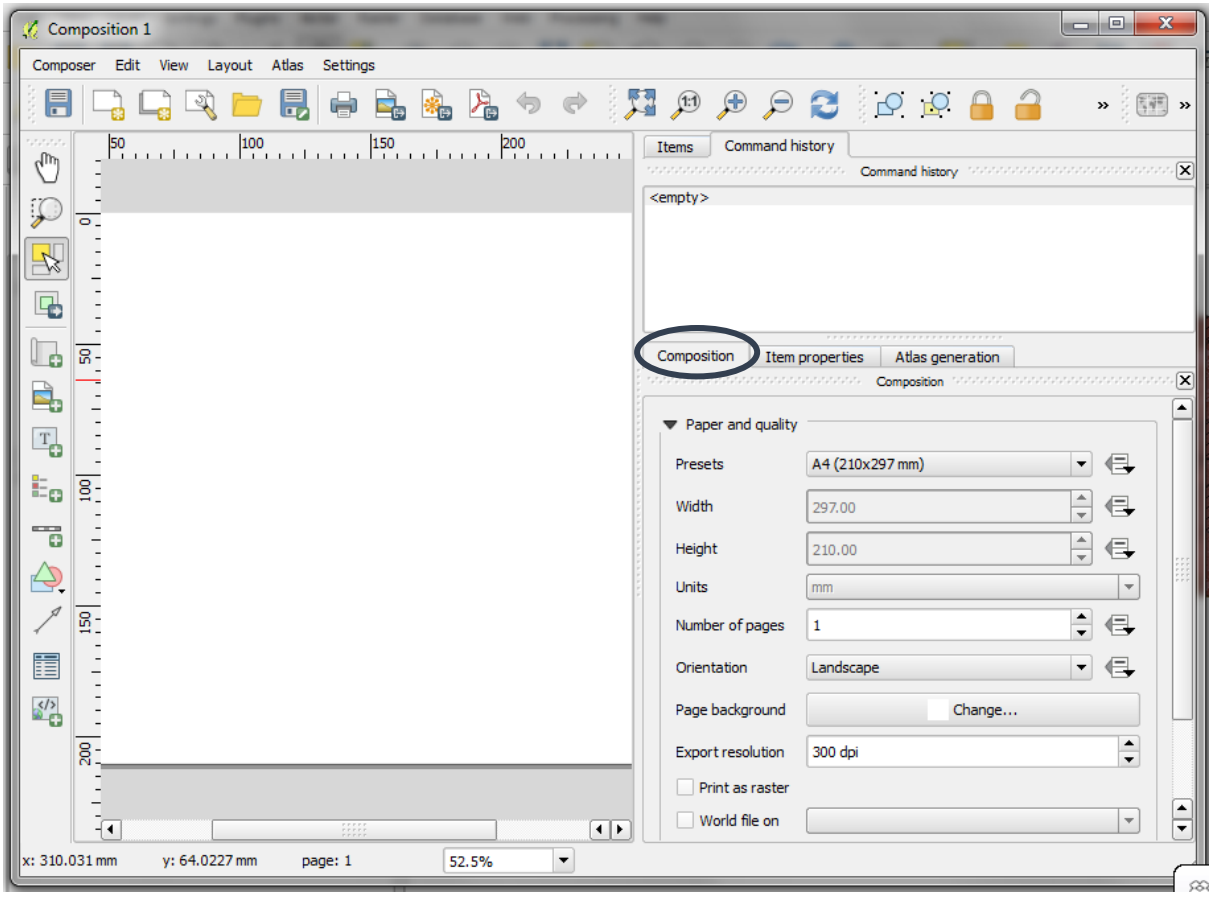
a. Click on the **New Print Composer** button.

b. Enter a title for the composition.

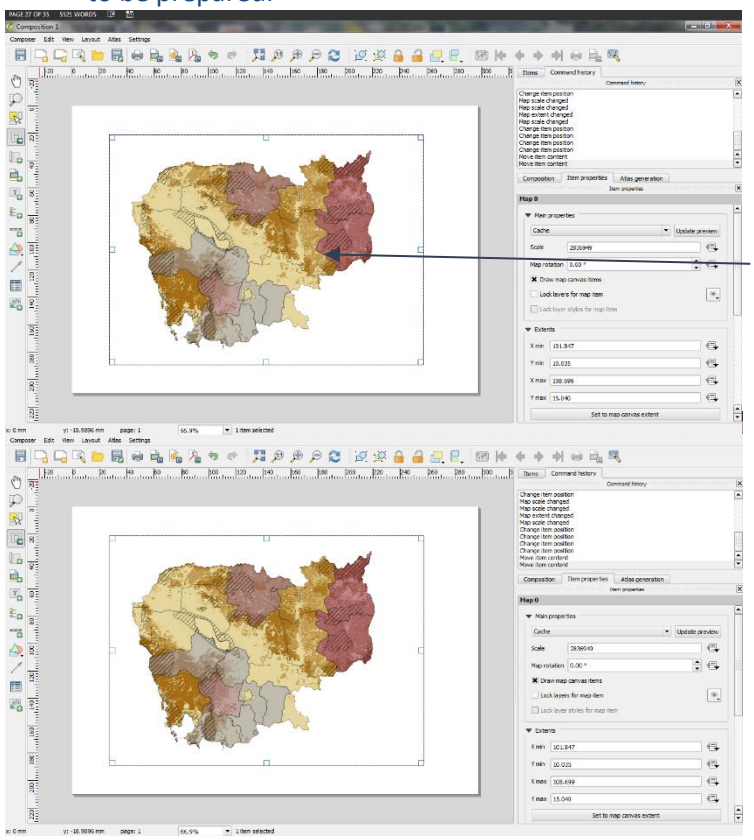


An empty composer window opens with a white canvas.

a. Click on the **Composition tab.**



b. Choose a **page size** and **orientation** for the map layout. The page is now set for the map layout to be prepared.



Next **add a map** to the canvas

a. Click the **Add new map** button on the left of the screen.

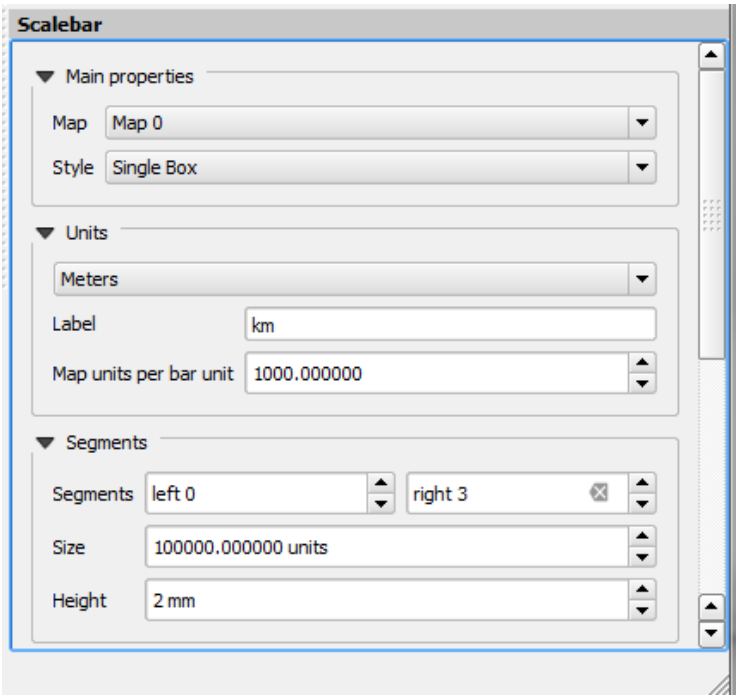
b. **Draw a box** onto the map canvas using the mouse. The map will appear in this box.

c. Change the **Map scale** to a more appropriate scale for the composition.

(A higher number will zoom out and a lower number will zoom in)

d. Click the **Move item content** button to pan the map to the desired extent.

Next **add a Scalebar** to the map.



a. Click the **Scalebar** button

b. **Click on the map layout** to position the scalebar

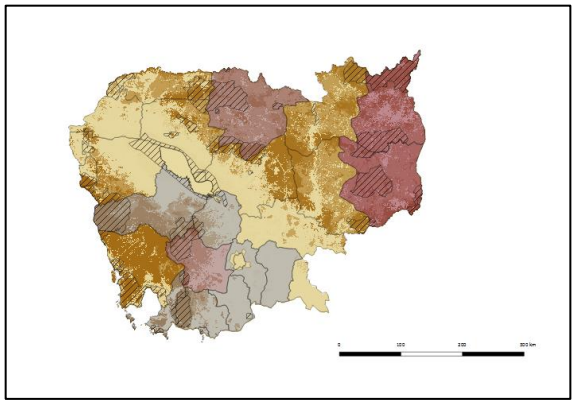
c. Change the **scalebar segment size** (the data units are in meters so the size is set in meters)

d. Change the **map units per bar** to be **1000** (to convert from metres to kilometres)

e. Change segments to **3** or 5 (so the scalebar starts and ends with a black segment)

f. Change Height to **2** and Line width to **0.2**

g. **Add a label** to show the units of the scalebar in **km**

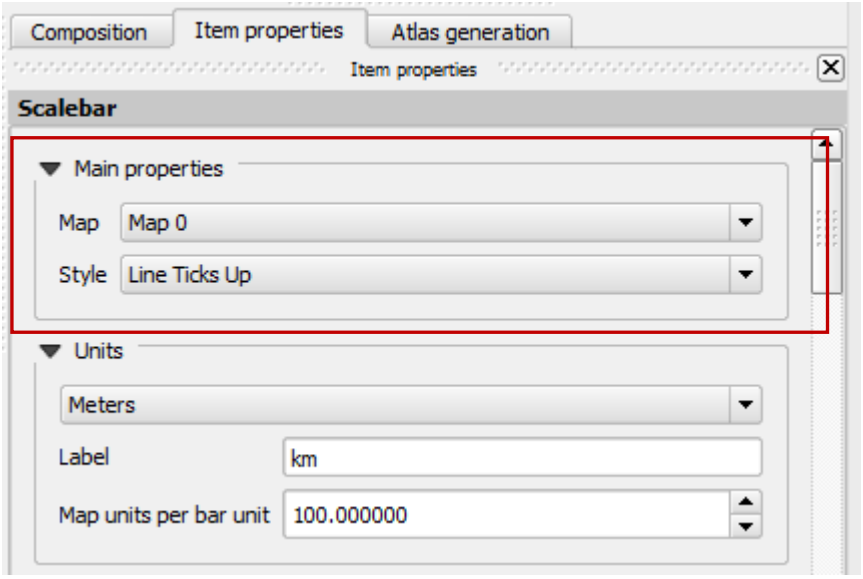


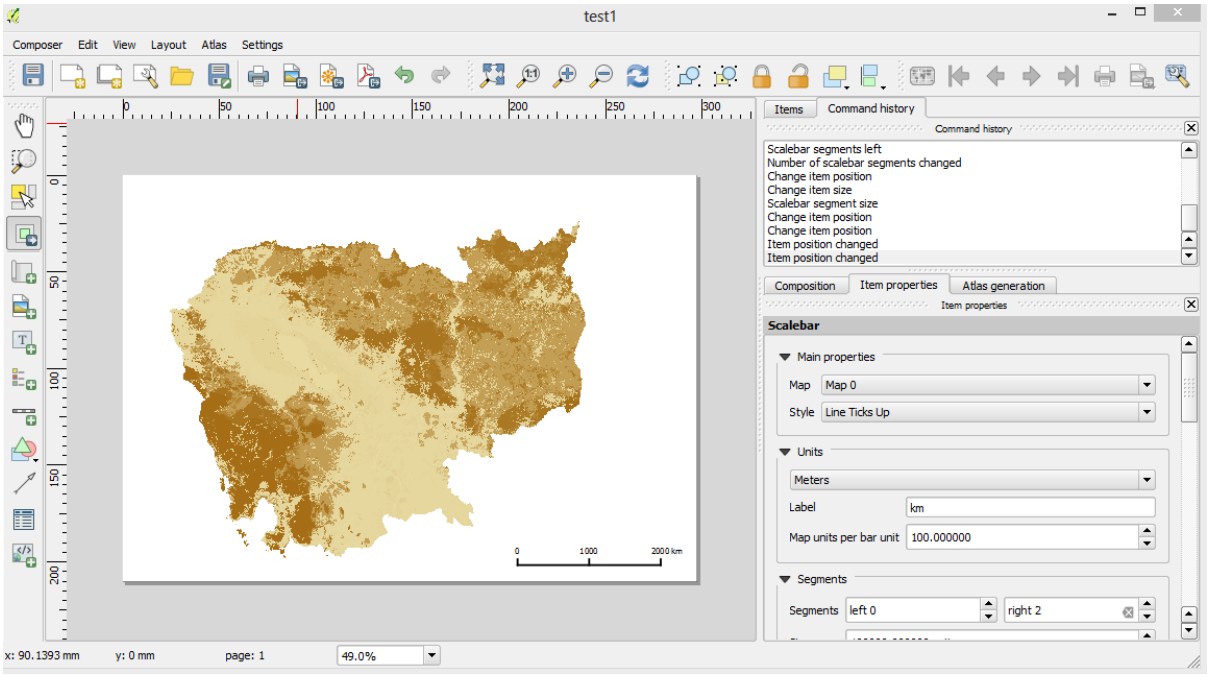
h. Scroll down to the **Fonts and colors** section. Set the **font and size** of the **scalebar text**. (For an A4
map an appropriate font size would be 6 or 7)

i. Untick **Show Frame**

The scalebar should look small and neat, change the size if you want to make a shorter scalebar.

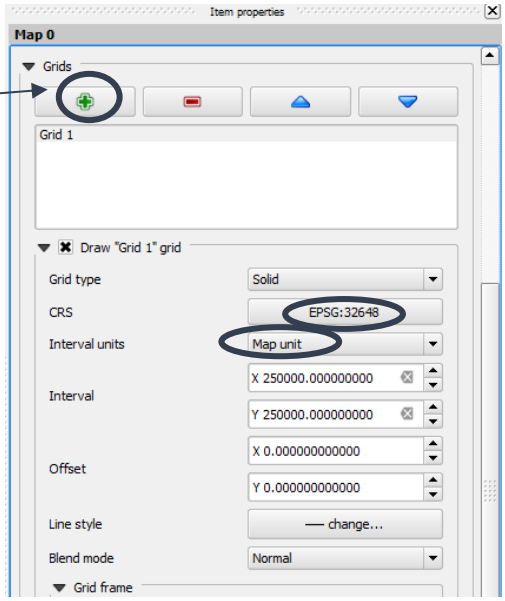
You can also use the Scalebar Main properties to change the format of the scalebar, for example, to Line Ticks Up:

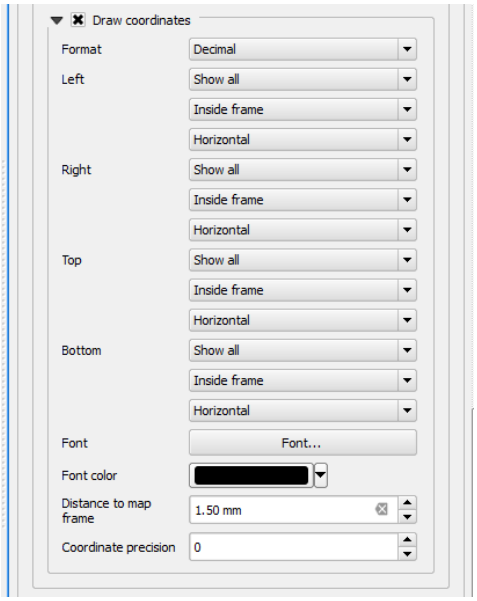




Next **add a graticule** to the map.

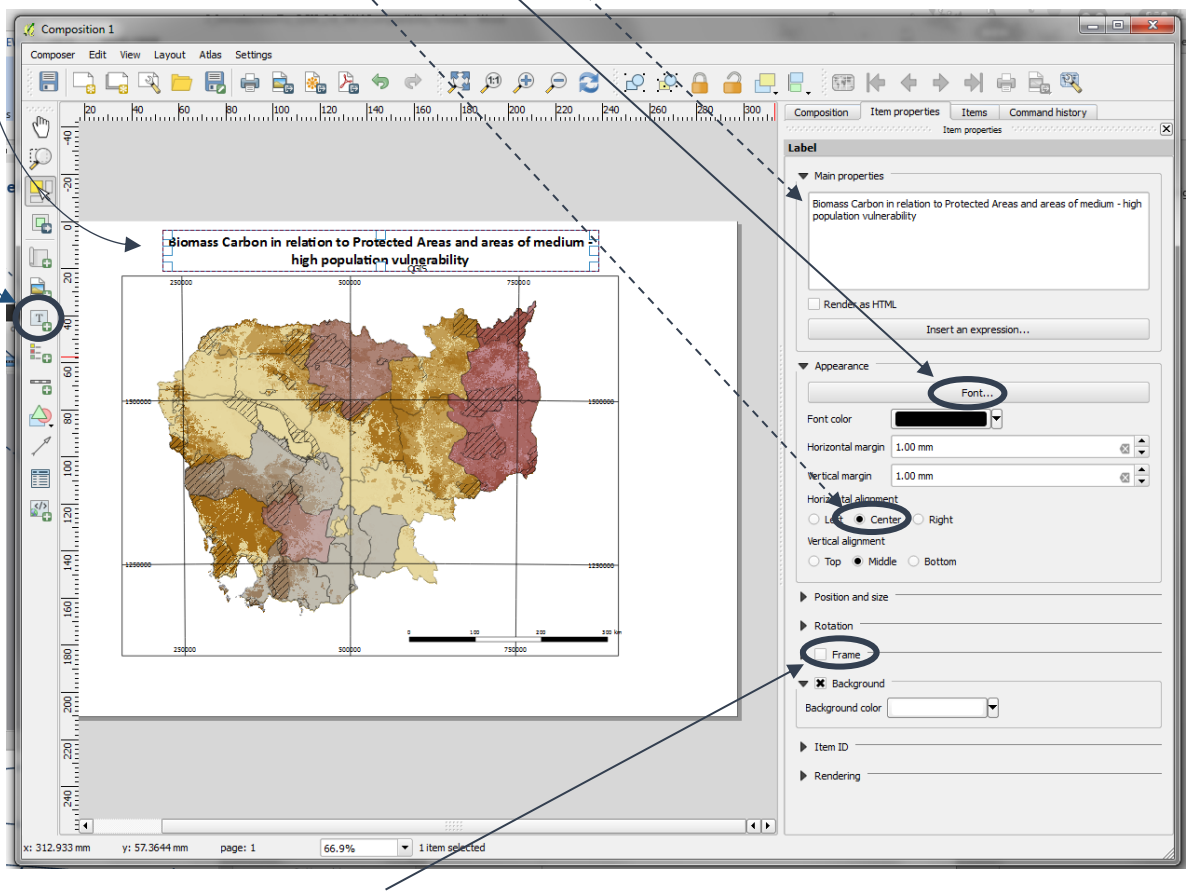
a. Click on the **Select/Move map items** button 
b. Click on **the map** that was dragged into the layout
c. Click on the **Grid arrow** to expand the options
d. Click the **green '+' sign** to create a new grid
e. Set the **CRS to the same projection as the map in question**, in this case UTM zone 48N
f. Choose the **interval for the grid lines** (this will be a grid in the same units as the map projection)
g. Set the **Interval X** and **Interval Y**
h. Tick **Draw annotation**
i. Choose **Annotation position** (inside or outside depending on preference





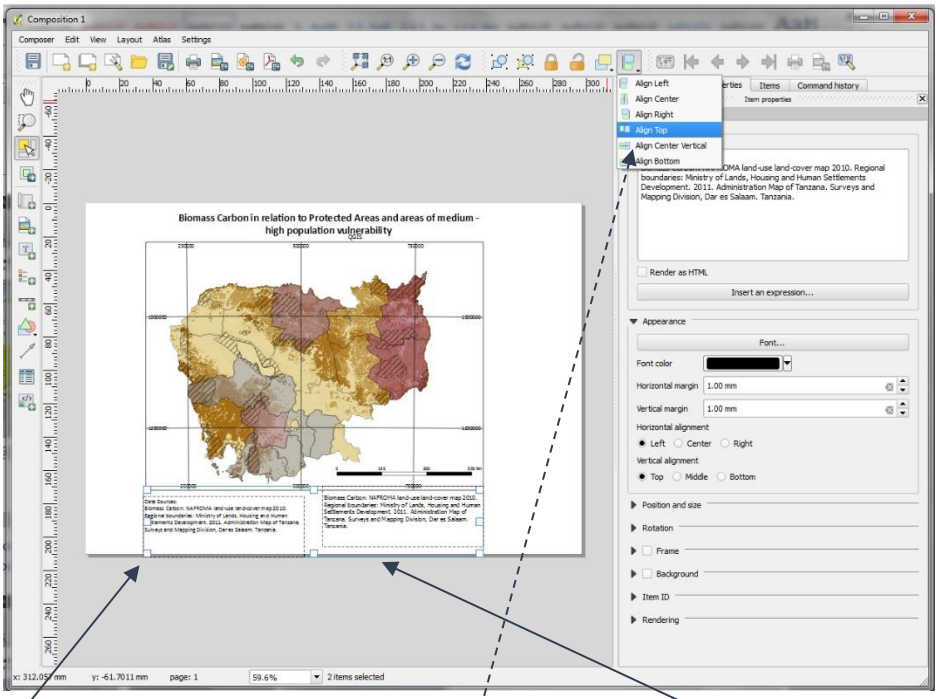
Next add a **Title** to the map:

a. Click the **Add new label** button.
b. Click above the map to **position the label.**
c. Change the **label text for a Title.**
d. Change the font of the text.
e. Change the alignment to **Center.**



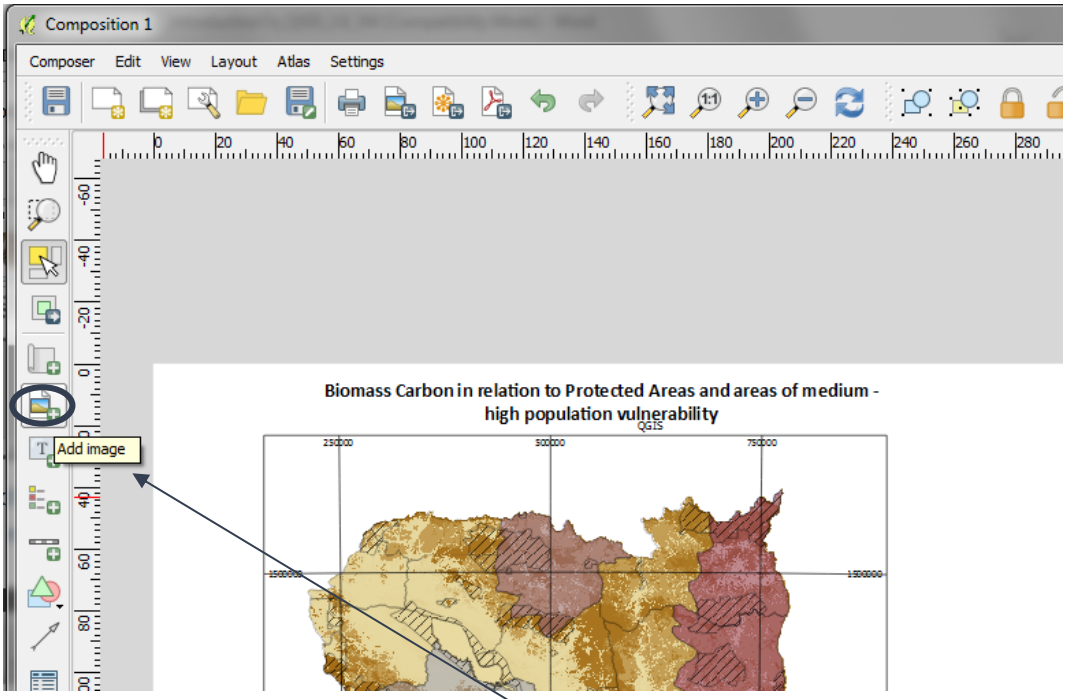
f. Ensure that **Frame** is **unticked.**
g. Repeat the above to add a **subtitle / map caption** with a smaller font size.
h. Add smaller text for **data sources used** on the map and **map projection, creator date** etc.

Remember to choose appropriate fonts and sizes.



i. Click on one of the text boxes and **hold down Shift** whilst selecting the second one.

j. From the menu the text boxes can then be **aligned.**



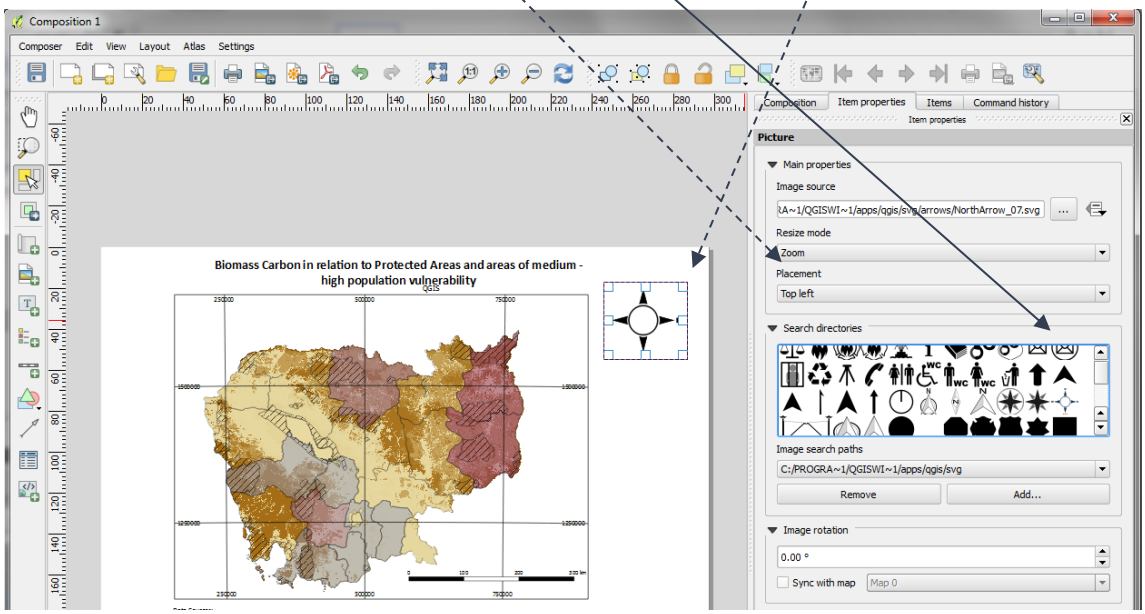
Next Add a **North Arrow** to the map:

a. A North Arrow is added as an image. Click on the **Add image button.**

b. **Drag a box** onto the map canvas using the mouse of roughly the size and shape desired.

c. Click on **Search Directories** in the Picture window and scroll down to find the arrow options. Click to add a North Arrow of your choice.

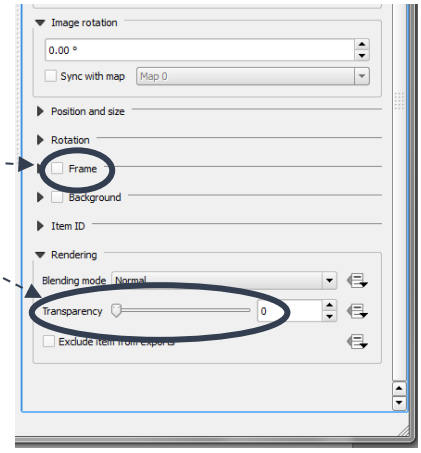
d. The symbol will appear in the box that you created. **Adjust the box size** to change the dimensions of the arrow.



e. Scroll down to **Frame** and **Rendering.**

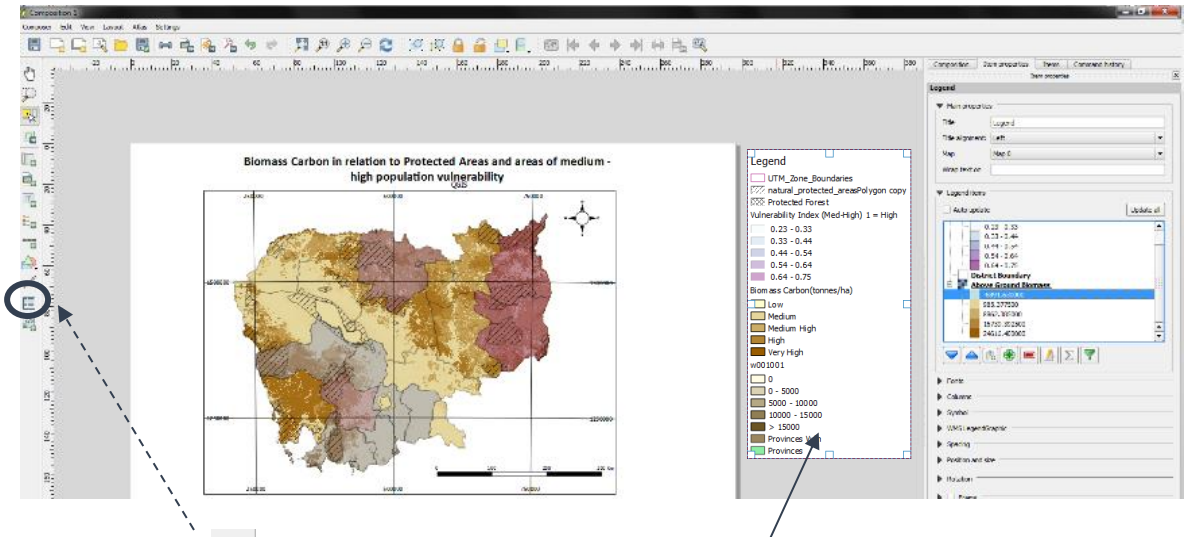
f. Ensure **Transparency** is set to **0** (i.e. far left) .

g. Ensure **Frame** is un-ticked.



The North arrow should look small and neat as on the example below.

Next add a **Legend** to the map.



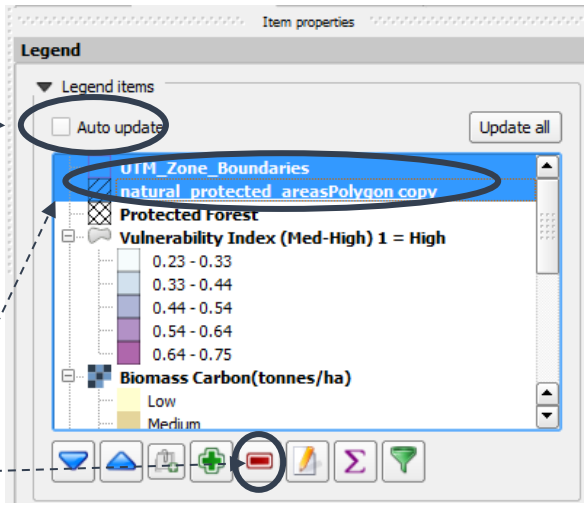
a. Click on the  **legend** button and click on the **grey area** to the right of the map composition. The legend will appear.

The initial legend includes every item present in the table of contents in the data view.

b. The **Legend items** tab will appear on the right.

c. **Untick** Auto Update.

You may not want all the layers in your QGIS project to be displayed in the legend, depending on what is included in this particular map layout.



d. **Click on any layers to be removed from legend**

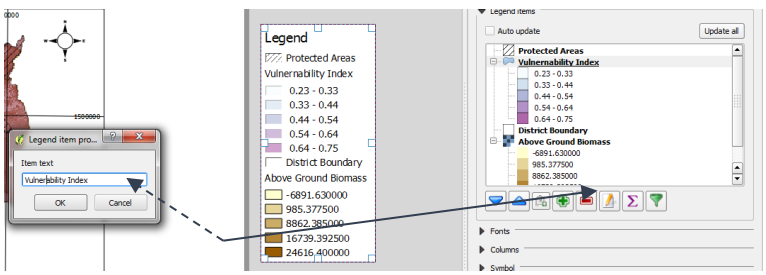
e. Click the **'-'** button to remove them.

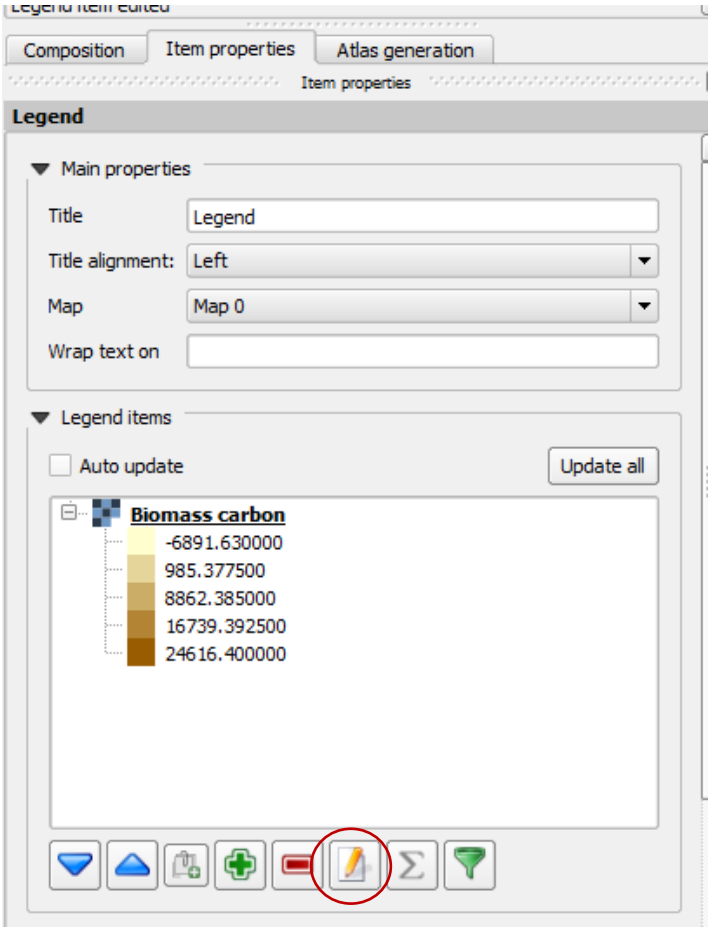
f. For each legend, **highlight values to remove**.

The legend should now look smaller and with fewer layers, showing only the legend for layers that appear on the map (depending on what you have removed).

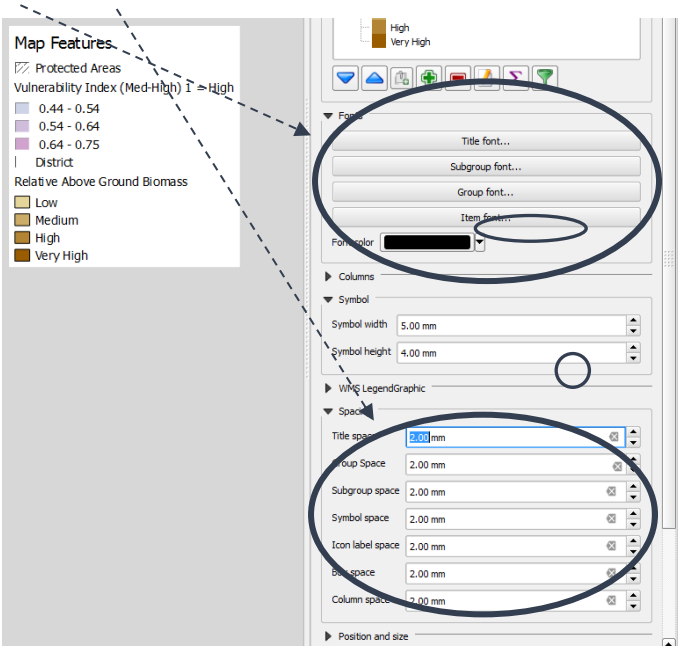
g. Click on the **Select/Move** button  to select the legend

h. Click on the **layer name** and click the **pencil button** to **edit or remove the layer name text.**





i. Change the **font and spacing** on the **legend text**



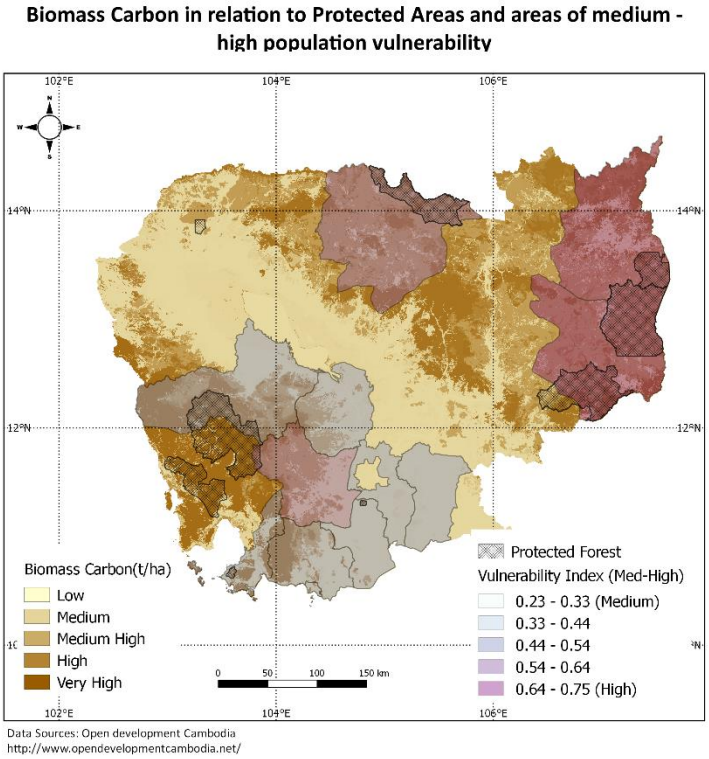
j. **Position the legend** into the map canvas

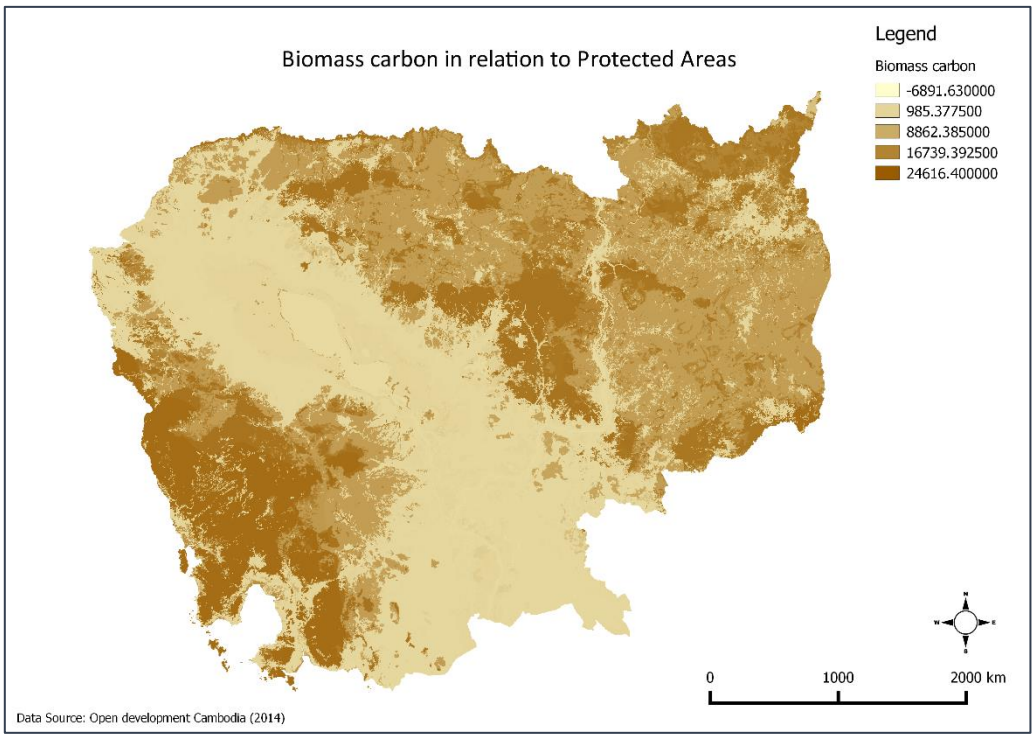
k. Next add some text below the map to acknowledge data sources, etc., using the **add text** button.

I. Finally, from the main menu click **Composer>>export as image** to a common image format such as jpeg or tif file. Alternatively, use the **export map as an image button** 

This tutorial has only provided a very quick introduction to the map composer and there are many other features which are worth spending the time to explore.

Example maps:





2.10. Further resources

http://www.qgis.org/en/site/forusers/trainingmaterial/index.html

http://docs.qgis.org/2.14/en/docs/training_manual/index.html

http://www.qgis.org/en/site/forusers/support.html

http://www.qgisforum.org/

https://anitagraser.com/category/gis/qgis/