



Pacific
Community
Communauté
du Pacifique

QGIS for Census and Survey Mapping

Training manual

13010010 (page 1_1)

13020020 (page 1_1)

13030030 (page 1_1)

13040040 (page 1_1)

13050050 (page 1_1)

13060060 (page 1_1)

13070070 (page 1_1)



SDD

Statistics for
Development
Division

QGIS for Census and Survey Mapping

Training manual

Luis de la Rúa, Phil Bright and Gaelle Le Gall-Queguineur

© Pacific Community (SPC) 2020

All rights for commercial/for profit reproduction or translation, in any form, reserved. SPC authorises the partial reproduction or translation of this material for scientific, educational or research purposes, provided that SPC and the source document are properly acknowledged. Permission to reproduce the document and/or translate in whole, in any form, whether for commercial/for profit or non-profit purposes, must be requested in writing. Original SPC artwork may not be altered or separately published without permission.

Original text: English

Pacific Community Cataloguing-in-publication data

De la Rúa, Luis

QGIS for Census and Survey Mapping: training manual / Luis de la Rúa, Phil Bright and Gaelle Le Gall-Queguineur

1. Census – Methodology – Handbooks, manuals, etc. – Oceania.
2. Census - Handbooks, manuals, etc. – Oceania.
3. Census – Geographical information systems – Handbooks, manuals, etc. – Oceania.
4. Geographic information systems – Oceania.
5. Geographic information systems – Handbooks, manuals, etc. – Oceania.
6. Geographic information systems – Maps – Oceania.

I. De la Rúa, Luis II. Bright, Phil III. Le Gall-Queguineur, Gaelle IV. Title V. Pacific Community

352.7502850995

AACR2

ISBN: 978-982-00-1308-7

ISBN 978-982-00-1308-7



Prepared for publication at SPC's headquarters,
B.P. D5, 98848 Noumea Cedex, New Caledonia,
May 2020

www.spc.int

Contents

Acknowledgement	vi
Foreword	vii
1. Overview and introduction	1
1.1 Introduction to QGIS	1
1.2 Hands-on structure of this manual	1
1.3 Conventions used in the manual	1
2. Software installation and first steps	3
2.1 Download and install QGIS 3	3
2.2 Plugins: Downloading and installation process	5
2.2.1 How to install a new plugin in QGIS	5
2.2.2 How to uninstall a plugin	6
2.2.3 How to enable/disable a plugin	7
2.3 Recommended plugins	7
3. First steps in QGIS	8
3.1 Load vector layers	8
3.1.1 Through the Data Source Manager	8
3.1.2 Through the QGIS Browser	8
3.1.3 Through Windows Explorer	9
3.2 Set basic style	9
3.3 Set basic labels	11
3.4 Save/Open project	12
3.5 Add a basemap	13
3.5.1 QuickMapServices	13
3.5.2 XYZ Tiles	15
3.6 How to deal with projections in QGIS	16
3.6.1 Check the project's projection	16
3.6.2 Check the layer's projection	17
3.6.3 Change the layer's projection	17
3.7 First basic enumerator map layout	19
3.7.1 Create a new print layout	19
3.7.2 Page properties	20
3.7.3 Add a map	20
3.7.4 Add a title	21
3.7.5 Add a scale bar	21
3.7.6 Add an image	22
3.7.7 Add a north arrow	22
3.7.8 Add a legend	22
3.7.9 Export/Print the map	23
4. Point layers: Household locations (basic vector analysis)	24
4.1 Import point layers from different data sources	24
4.1.1 CAPI: Delimited text file (.csv)	24
4.1.2 GPS unit (example for Garmin Etrex) (.gpx format)	26

4.2	Edit point layers	26
4.2.1	Create/Delete features	26
4.2.2	Move features	27
4.2.3	Modify attribute table	28
4.2.4	Join attributes by location (spatial join)	30
5.	Polygon layers: Enumeration areas (basic vector analysis)	32
5.1	Create a new polygon layer: Digitise new features	32
5.2	Snapping	34
5.3	Editing (delineating, attributes)	34
5.4	Split/Merge enumeration areas: Best management practices (code system, delineation)	36
5.4.1	Split EA polygons	38
5.4.2	Merge EA polygons	40
5.5	Layer styles	41
5.5.1	Suitable symbology when displaying administrative boundaries	41
5.5.2	Manage layer styles	42
5.5.3	Layers themes	43
5.5.4	Categories, graduated and rule-based styles	44
5.6	Advanced labelling	48
5.6.1	Custom labelling placement	48
5.6.2	Complete layer symbology with labels	49
6.	Polygon layers: Enumeration areas (advanced vector analysis)	52
6.1	Topology cleaning: Finding and fixing gaps, geometric errors and overlaps	52
6.1.1	Fixing gaps	53
6.1.2	Fixing invalid geometries	54
6.1.3	Fixing overlaps	54
6.2	Table join	56
6.3	Field calculator: Basic expressions	57
6.4	Work with attribute tables	58
6.5	Dissolve	60
6.6	Creating buffers	60
6.6.1	Convert polygons to lines	61
6.6.2	Generate the 1 km buffer around the line layer	61
6.6.3	Extract the part of the buffer	62
6.7	Find closest features to households – schools	62
7.	Automated map production	65
7.1	Layout and Atlas basic configuration	65
7.1.1	Automatic titles	66
7.1.2	Automatic scale bar	66
7.2	Rule-based styles interacting with Atlas (Atlas variables)	66
7.2.1	Style for the polygon layer	67
7.3	Landscape/Portrait layouts	69
7.4	Atlas-controlled tables	72
8.	Working with rasters (terrain data)	74
8.1	Retrieve digital elevation model data from NASA's Earthdata	74
8.2	Improve raster visualisation	75
8.2.1	Hillshade	75

8.2.2	DEM displayed with an elevation colour ramp	76
8.3	Working with 3D map views	78
8.4	Assign elevation data from DEM to point layer	79
9.	Data management and storage: Spatial databases – GeoPackage	82
9.1	Data management and storage using projects and folders.....	82
9.2	Data management and storage using spatial databases (GeoPackage)	83
9.2.1	GeoPackage format	83
10.	Metadata	88
10.1	Populate metadata (standards and compatibility)	88

Acknowledgement

Much of the material in this manual has been developed as a result of the many QGIS workshops and training attachments that have been provided to the Pacific Community's member countries and territories over the past 10 years.

The authors gratefully acknowledge the assistance of a range of interns who have worked with the Pacific Community's Statistics for Development Division and tested the various exercises, provided valuable feedback on the logical workflows, and suggested ways to improve the manual's readability. Thank you Anaïs Walch, Maximilien Riot, Barbara Raubaly and Aidan Myatt.

The authors also gratefully acknowledge Aidan Myatt and Nathan Fabre who proofread the final draft and tested the associated exercises.

Thanks to Gaelle le Gall-Queguineur for the manual's layout, the SPC Publishing Team and Genevieve Farrell who edited all text.

A special thanks to Australia's Department of Foreign Affairs and Trade for ongoing financial support to regional census and survey activities. Without their aid, this manual wouldn't have been possible.

Finally, the authors wish to acknowledge the QGIS development community whose tireless efforts have gone into making such a good open-source GIS package.

Foreword

I am delighted to present this QGIS for Census and Survey Mapping Manual. For many years, the Pacific Community's Statistics for Development Division (SDD) has been providing geographic information system (GIS) technical assistance and training to improve census- and survey-related activities to member countries. Technology has significantly evolved in the last 20 years with satellite imagery and Global Positioning Systems (GPS) enabling more timely and accurate capture of information, which is required to plan and conduct these activities.

One of the limiting factors in the past, even with the improvement of GIS software, was that licensing costs prevented a wide utilisation of the technology. Software was often purchased for large, infrequent projects, with no budget considerations taken into account in regard to maintaining the software over the longer term. This has all changed now that there is a very good open-source application that rivals the main commercial products. All operations required for a Pacific Island National Statistics Office or other government line ministry to undertake a census or survey can be easily handled with QGIS.

This manual responds to a real need to have a step-by-step guide detailing how national statistics offices, and other users, can undertake a range of critical mapping exercises such as converting datasets between coordinate systems, updating administrative boundaries, and preparing field maps. I trust that you will find this manual a useful resource.



Stuart Minchin

Director General

Pacific Community (SPC)

1. Overview and introduction

1.1 Introduction to QGIS

QGIS is a free and open-source geographic information system. This means that no licence or purchasing process is necessary to start using the software.

Why was QGIS chosen for this manual?

- It is free and open source.
- It is user friendly, easy to learn and has a significant amount of support and external resources, such as:
 - QGIS documentation: <https://docs.qgis.org/3.10/en/docs/#>
 - QGIS training manual: https://docs.qgis.org/3.10/en/docs/training_manual/index.html
 - Users and developers community: <http://gis.stackexchange.com/?tags=qgis>
 - Blogs: <http://plugins.qgis.org/planet/>
- It is easy to install, as the installation file is around 500 MB and no licence or internet connection is needed for the installation process.
- It is customisable. There is free access to a wide variety of plugins (the equivalent to extensions in ArcGIS) and tools.
- It is frequently upgraded and updated.
- In the QGIS ecosystem, it is possible to interoperate with GDAL/OGR, SAGA, Orfeo, GRASS or R packages.

However, the main reason that QGIS was chosen is that it is an open-source software that is capable of performing all the mapping tasks included in this manual just as effectively as commercial software.

In this manual, among all the versions available in the QGIS site, the user will use QGIS Long Term Release (LTR) for Windows. The LTR version has been chosen over the latest version, because the LTR is more stable, while still being updated regularly across its one-year lifespan.

1.2 Hands-on structure of this manual

This manual has been conceived to be a compilation of exercises that will teach the user how to perform common mapping tasks related to statistical data collection activities, such as censuses and surveys.

The theoretical component within the lessons has been minimised as much as possible, placing the emphasis on practising the necessary skills to use the software.

The chapters are structured around a series of exercises specifically designed to reinforce the skills the user will rely on to conduct real-life mapping work. This manual explains systematically the processes that need to be followed in order to perform each of the tasks presented. This approach ensures that the user will see tangible improvements in their skills and remain motivated.

In order to use the manual, it is necessary to download and save the accompanying training materials. These materials are organised in folders that correspond to the workflow of each chapter included in the manual.

<https://www.spc.int/DigitalLibrary/SDD/Events/QGIS%20manual>

1.3 Conventions used in the manual

Text formats

Throughout the following chapters, some parts of the text have a specific format. This has been done to highlight the different elements of the workflow and make the instructions easier to follow. These formats are explained as follows:

THIS FORMAT denotes buttons in QGIS windows as well as navigation paths through QGIS menus (**VIEW > PANELS > BROWSER**).

This format identifies QGIS's menus, panels and windows that appear in QGIS.

This format indicates file paths and layer names, for instance, *5_polygon_layers/Layers/HH_EAcode_4326.shp*

This format is used to highlight when the user has to input text, formulas or expressions.


This format signifies keyboard keys.

The use of the mouse

The "click" instructions have been simplified as much as possible to improve the readability of the manual. Below are the descriptions of each of the mouse-related functions:

WHAT THE MANUAL SAYS	DESCRIPTION
Click	Click with the left button
Double-click	Double-click with the left button
Right-click	Click with the right button

Icons embedded in the text

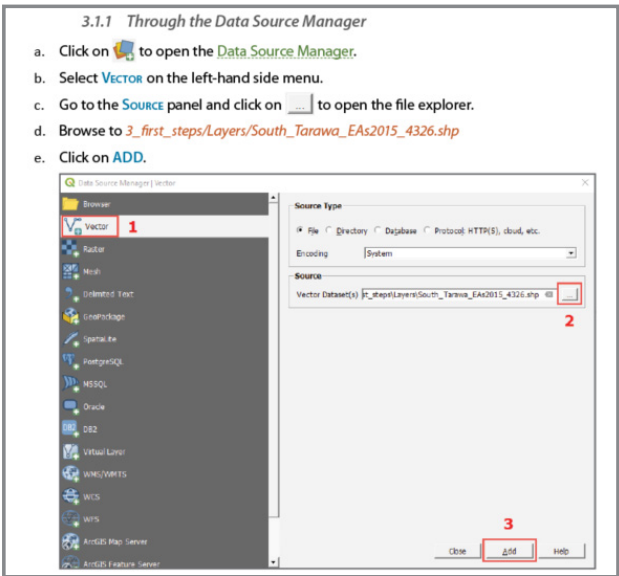
The user will find icons like these  integrated within the text to help them find the different controls and buttons within the QGIS interface.

Panels and numeric sequences

In the manual, the user will find pictures depicting QGIS menus and panels. These screenshots have been included to make sure the instructions are clear.

Throughout the first chapters, labelled panels and windows will help the user navigate the controls and subsections located within various menus.

Note that in the pictures of menus **number** sequences are used, whereas in the text the steps are listed by **letter**. These numbers and letters both indicate the order in which the actions will be undertaken; however, it is important to recognise that there is not necessarily a direct correspondence between the two orders. In the example below, *action 1* in the picture does not correspond to *step a* in the text.



As users progress, it is expected that they will become more familiar with the software. Thus, basic processes will be explained in detail only in the first chapters. The user can always refer to these chapters if they become confused later in the manual.

2. Software installation and first steps

In this chapter, we will learn:

- how to download and install QGIS LTR version;
- what plugins are for and how to download, install and manage them in our QGIS application.

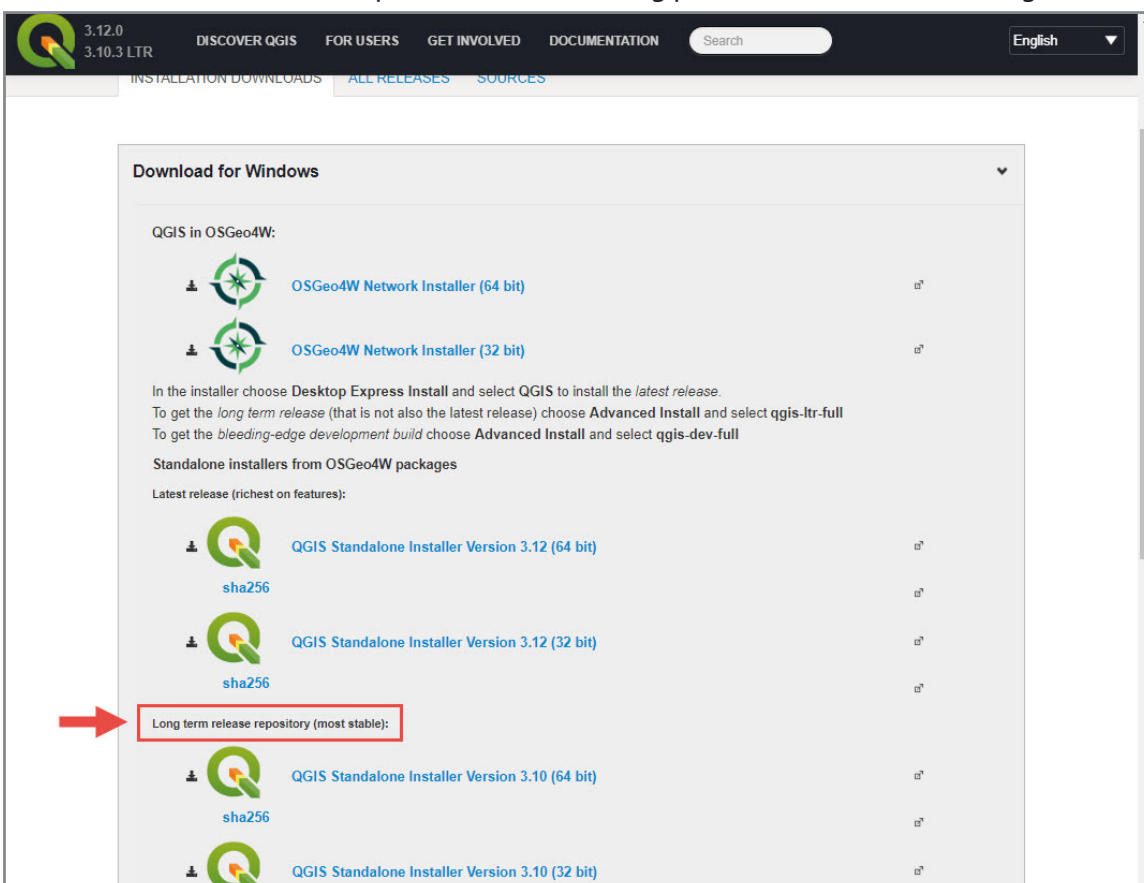
2.1 Download and install QGIS 3

In the download section of the QGIS website <https://www.qgis.org/en/site/forusers/download.html>, different versions of QGIS are available. You will find on the top of the page information about the latest versions available for the different platforms.


We can choose either the 32- or 64-bit versions. For 32-bit computers and operating systems, it is recommended that you install the 32-bit version, whereas for 64-bit computers and operating systems, it is possible to install both versions. The 64-bit version is recommended, because it allows better usage of system memory.

These are the steps to download and install QGIS on your computer:

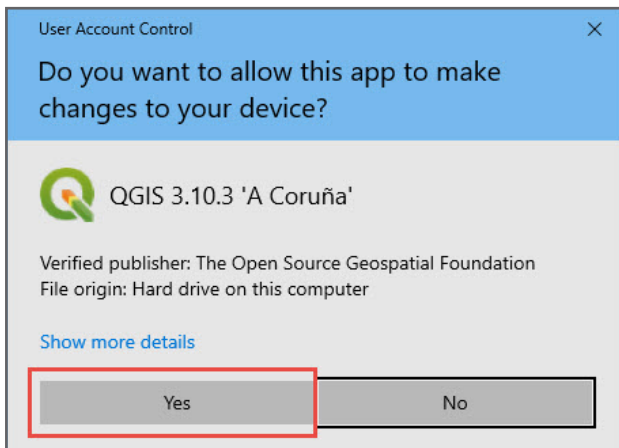
- Open your internet browser and paste this URL address <https://www.qgis.org/en/site/forusers/download.html> on the navigation bar.
- In the section containing OSGeo4W standalone install packages, go to the long term release repository option and choose either the 32- or 64-bit option that is compatible with your computer and operating system. In our case, we will select the 64 bit option. The downloading process will start after clicking on our selected option.



- Once the software is downloaded, go to the location where the installation file has been stored in your computer and double-click on it.

Name	Date modified	Type	Size
 QGIS-OSGeo4W-3.10.3-2-Setup-x86_64.exe	26-Feb-20 12:16	Application	403,709 KB

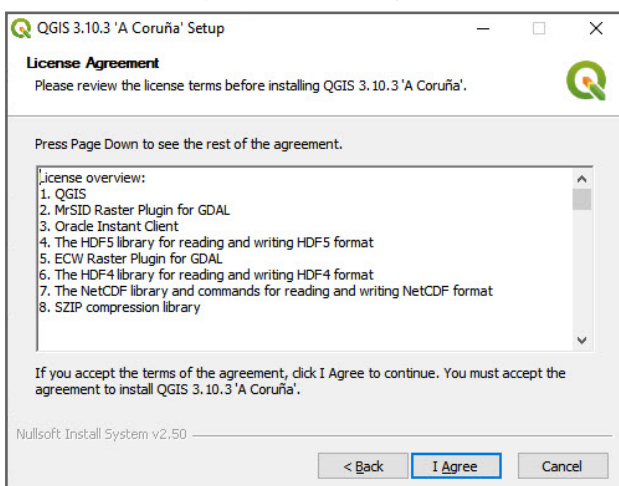
- d. The following dialogue will appear on your screen. Click on **Yes**.



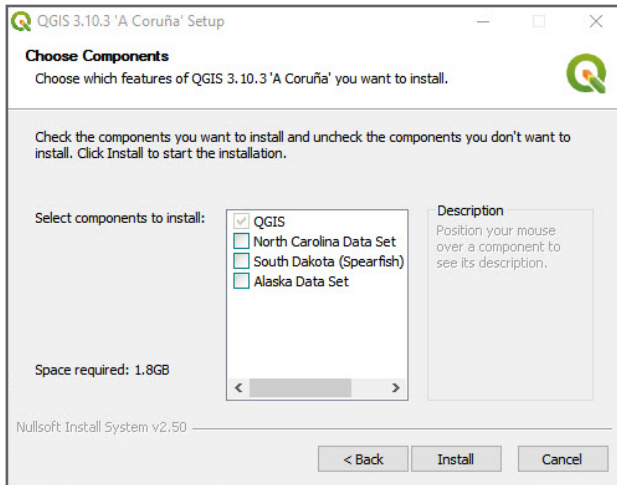
- e. In the **Welcome to the QGIS** dialogue, click on **NEXT**.



- f. In the **License Agreement** dialogue, click on **I AGREE**.



- g. In the **Choose Components** dialogue, leave the default components selected and click on **INSTALL**.



- h. Once the installation process is complete, click on **FINISH**. The software is now installed on your computer.



The installation process is very simple and does not require an internet connection; it should take no longer than 10 minutes. Once the installation file has been downloaded, it is just a matter of following the steps explained above.

A new folder named QGIS 3.10 will be created on your desktop containing all the shortcuts needed to access the different programs included in the installation package. This manual will use QGIS Desktop 3.10 LTR with GRASS 7.

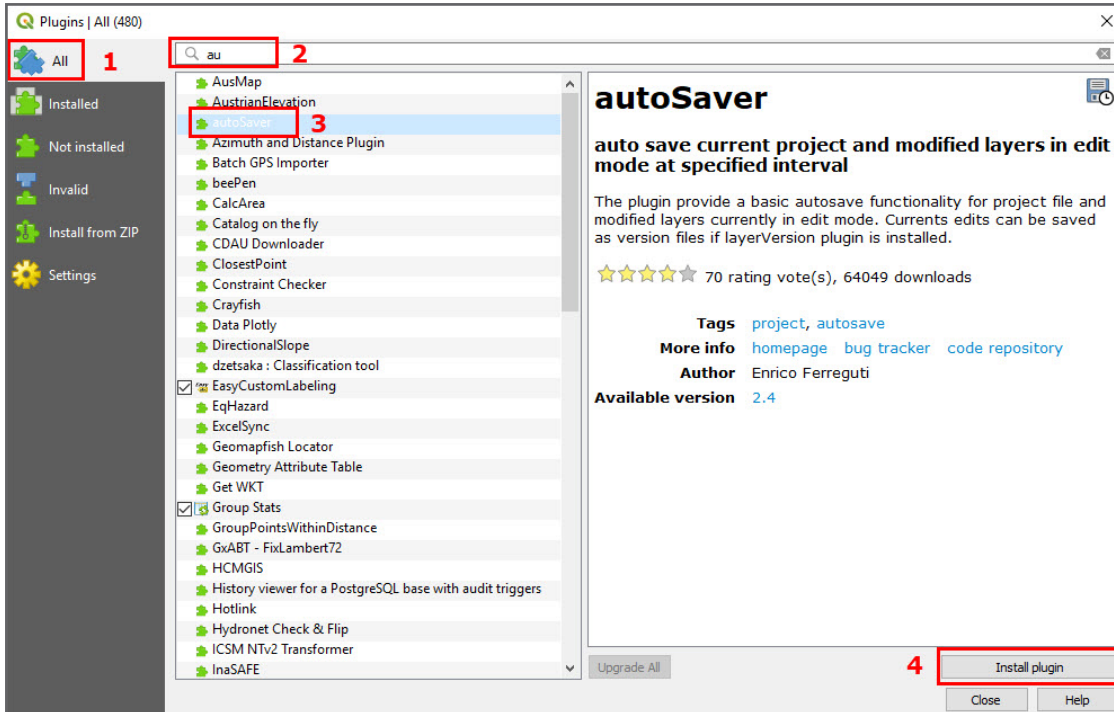
2.2 Plugins: Downloading and installation process

QGIS comes with a lot of built-in functionality. QGIS developers and people in the user community are constantly creating new plugins. The easiest way to access these tools is to install them through the QGIS Plugin Manager, included in the QGIS application. It is important to note that access to these tools and extensions is completely free. This is one of QGIS's strengths compared to other GIS software, for which it is necessary to purchase additional licences to use these specific advanced tools.

2.2.1 How to install a new plugin in QGIS

- Open the QGIS program.
- In the top menu, go to **PLUGINS > MANAGE AND INSTALL PLUGINS...**
- We want to install the **AUTO SAVER** plugin that will be used later in this manual.
- Make sure that in the left panel the option **ALL** is selected.

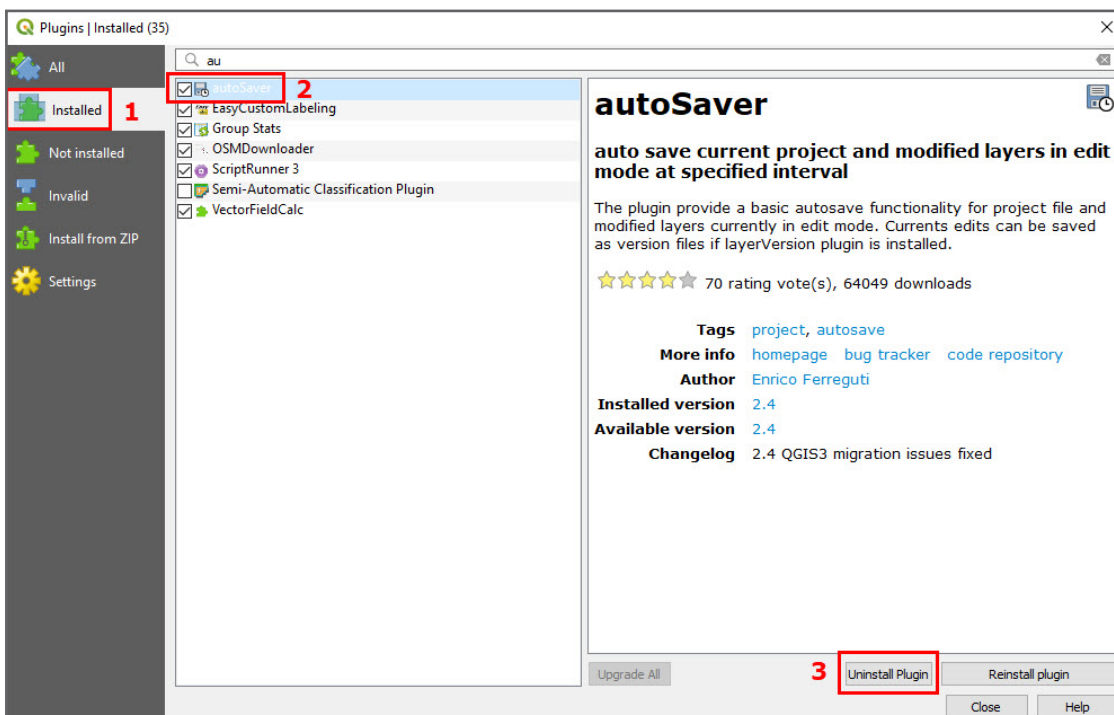
- e. Type: **autosaver** in the search bar.
- f. Select the plugin from the list below.
- g. Click on **INSTALL PLUGIN**.



2.2.2 How to uninstall a plugin

- a. In the top menu, go to **PLUGINS > MANAGE AND INSTALL PLUGINS...**
- b. Go to **INSTALLED** on the left side panel.
- c. Select the plugin you want to uninstall.
- d. Click on **UNINSTALL PLUGIN**.

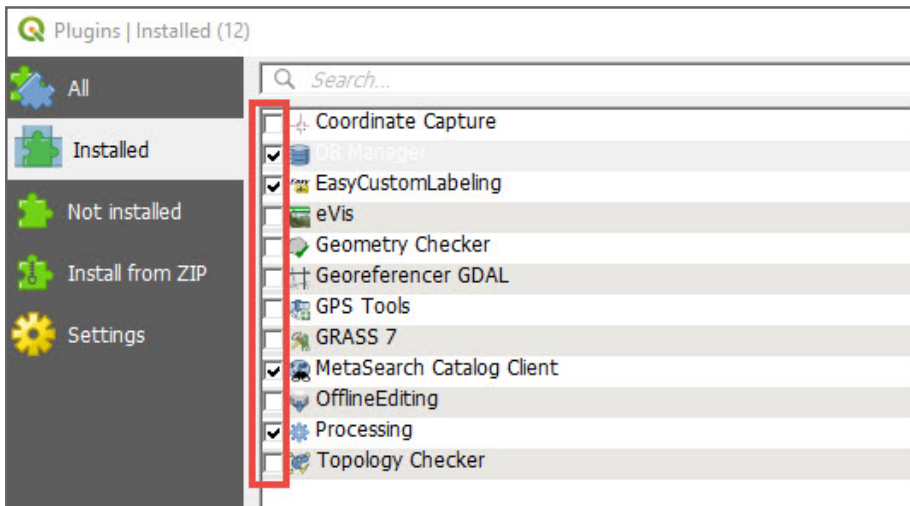
Note that it is not possible to uninstall core plugins as they are built in to the software.



2.2.3 How to enable/disable a plugin

Having too many plugins activated in the QGIS application may cause the program to lag or even crash. To ensure that QGIS is responsive and functions smoothly, it is important to disable plugins as soon as they are no longer in use.

- In the top menu, go to **PLUGINS > MANAGE AND INSTALL PLUGINS...**
- Go to **INSTALLED** on the left-hand side of the window.
- Check/Uncheck the plugins that you want available in the QGIS interface.
- Click on **CLOSE**.



2.3 Recommended plugins

Throughout this manual, we will recommend some plugins that are useful for censuses and surveys projects. For more information about available plugins for QGIS, please refer to the QGIS plugins web portal: <https://plugins.qgis.org/>

- *Digitizing Tools*: This plugin includes additional vector editing/digitising tools missing in the basic QGIS editing tool menu.
- *MMQGIS*: This plugin provides a variety of additional vector analysis tools.
- *OSMDownloader*: This plugin allows the user to download OpenStreetMap (OSM).
- *Point sampling tool*: This plugin collects attributes from vector or raster layers using a sample point layer and is very useful when working with household location layers.
- *QGIS Cloud Plugin*: Allows the user to share projects and maps online through <http://qgiscloud.com>
- *QuickMapServices*: Plugin used to add basemaps like OSM, Bing Maps or Google Maps.
- *SRTM Downloader*: This plugin allows the user to download SRTM tiles from the NASA server. Note that it is first necessary to create an Earthdata login at <https://search.earthdata.nasa.gov> in order to access NASA's datasets.
- *AutoSaver*: This plugin auto saves projects and modified layers at specified intervals.

To find out more about QGIS plugins, go to this link:

https://docs.qgis.org/3.10/en/docs/user_manual/plugins/plugins.html

3. First steps in QGIS



In this chapter you will learn:

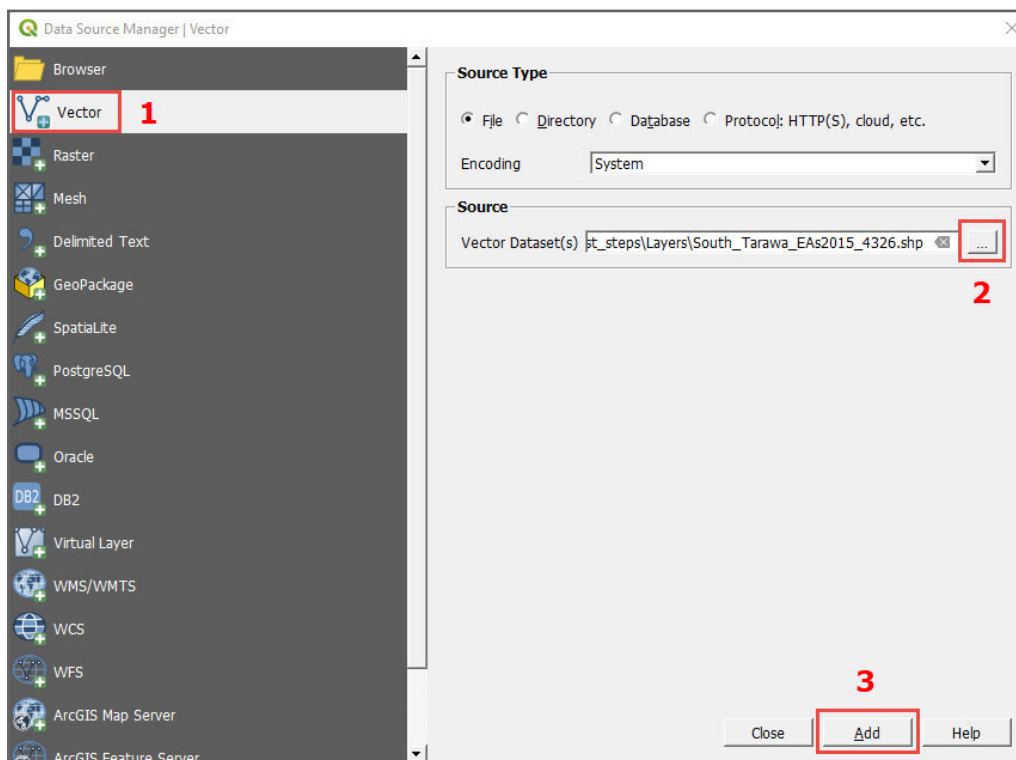
- to orient yourself in the QGIS ecosystem;
- the basics about the project and layout interfaces;
- how project files function in the QGIS environment.

3.1 Load vector layers

There are three ways to add a layer into the map canvas.

3.1.1 Through the Data Source Manager

- Click on  to open the [Data Source Manager](#).
- Select **VECTOR** on the left-hand side menu.
- Go to the **SOURCE** panel and click on  to open the file explorer.
- Browse to [3_first_steps/Layers/South_Tarawa_EAs2015_4326.shp](#)
- Click on **ADD**.



3.1.2 Through the QGIS Browser

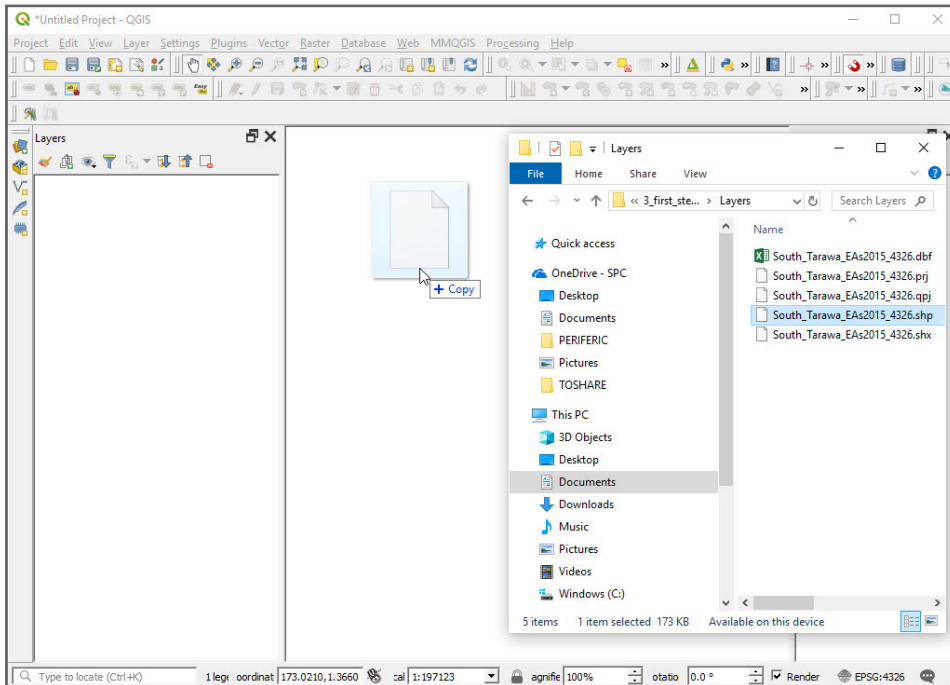
The **Browser** can be found either in the [Data Source Manager](#) panel or as a QGIS panel located in the interface. If the **Browser** panel is not displayed by default, in the top menu, go to **VIEW > PANELS > BROWSER**.

The **Browser** allows the user to navigate the computer's file system and manage your GIS-related files from within QGIS.

- Go to the [Browser](#).
- Navigate within the folders tree to find [3_first_steps/Layers/South_Tarawa_EAs2015_4326.shp](#)
- Double-click on it or drag and drop the file onto the canvas.

3.1.3 Through Windows Explorer

To open a shapefile from Windows Explorer, navigate up to *3_first_steps/Layers/* and drag and drop the *.shp* extension file onto the map canvas.



After following the steps explained above, *South_Tarawa_EAs2015_4326* layer will be displayed in the *Map Canvas* and in the *Layers* panel.

IMPORTANT

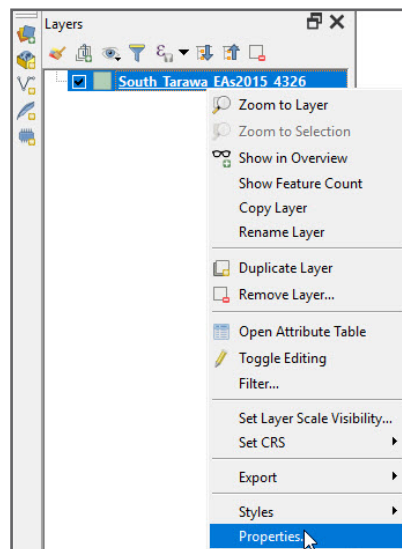
Shapefile files need three auxiliary file extensions to function as a layer in GIS software. If these extensions are not together in the same folder, the layer will not display in the mapping canvas.

The **mandatory** extensions are *.shp* (stores the geometry), *.shx* (index position) and *.dbf* (standard database containing the attribute table).

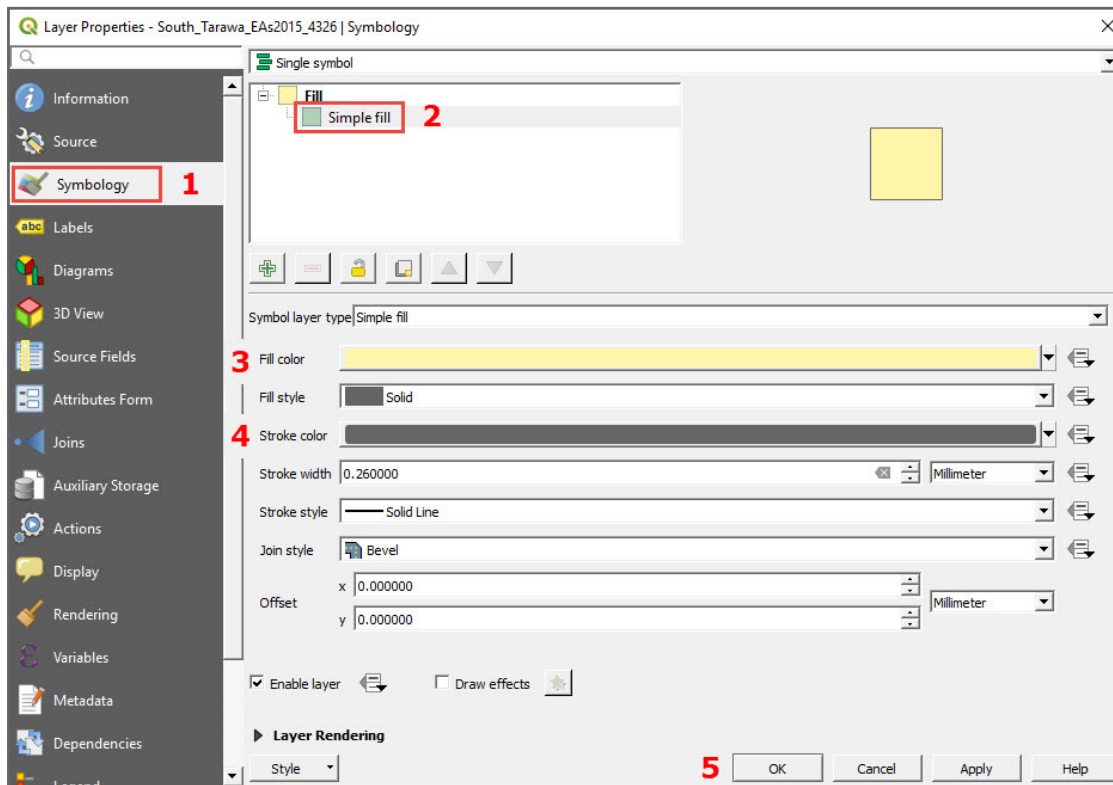
The *.prj* extension is not mandatory, but including it is strongly recommended as it contains coordinate system information.

3.2 Set basic style

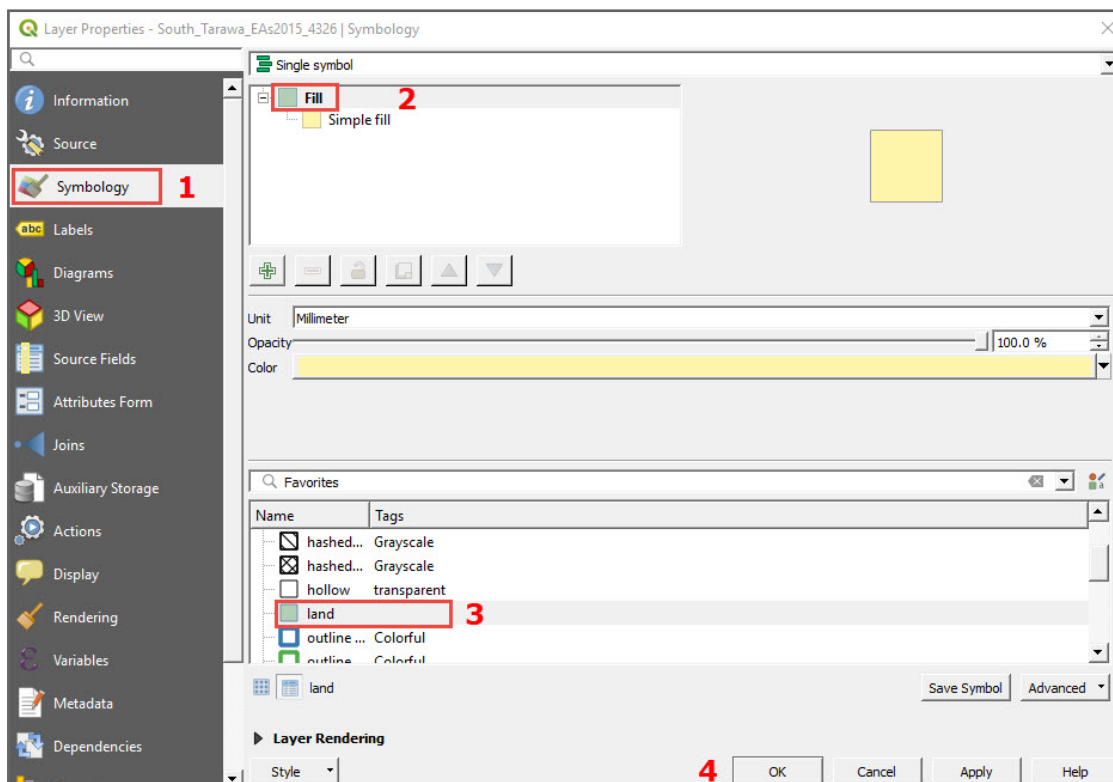
- To open the *Layer Properties* window, go to the *Layers* panel, right-click on the layer and select *PROPERTIES*, or double-click over the layer.



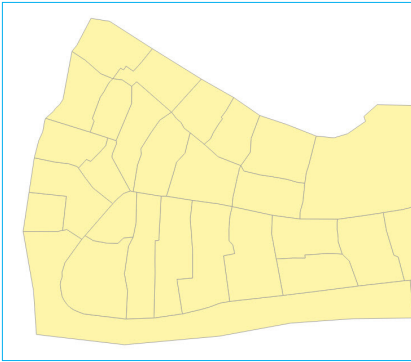
- b. On the left side of the menu, go to the **SYMBOLOLOGY** section where parameters such as fill and outline properties can be set.
- c. It is possible to set your own style by selecting a colour for the fill and the outline and clicking **OK**.



- d. Alternatively, you can select one of the predetermined styles available.

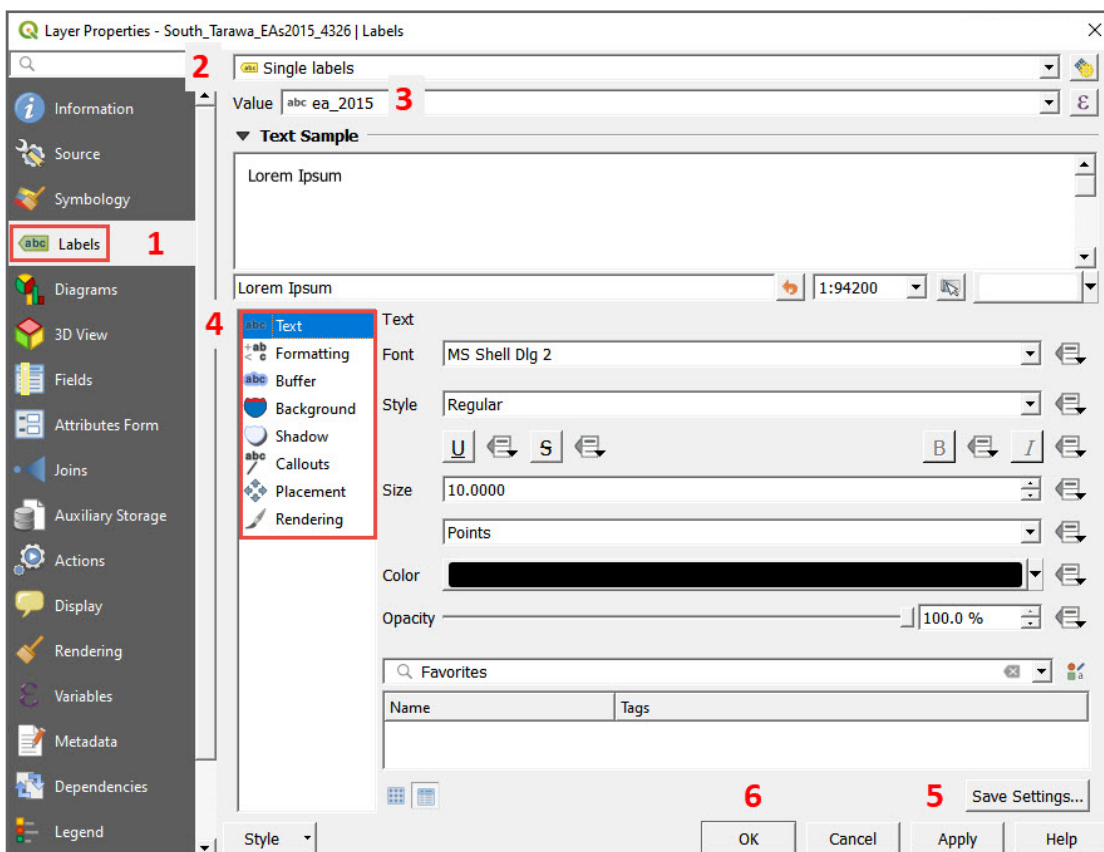


- e. Click **APPLY** to preview the results.
- f. Click **OK** to set the new style.

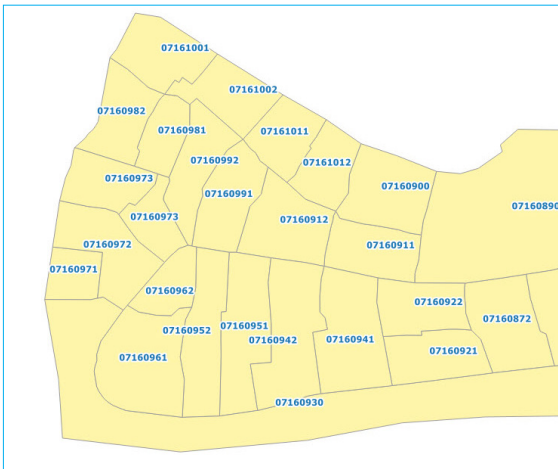


3.3 Set basic labels

- Open the **Layer Properties**.
- On the left side of the menu, select **LABELS**.
- In the drop-down menu, replace the option **No LABELS** with **SINGLE LABELS**.
- In the **VALUE** drop-down menu, select the attribute that is going to be used to label the layer. In this case, we will select **ea_2015**, the field that stores the enumeration area (EA) code of each EA polygon.
- Complete to your requirements the following formatting options:
 - TEXT**: parameters related to the label's font, style, size or colour.
 - FORMATTING**: paragraph and number formatting options.
 - BUFFER**: parameters to add a coloured buffer around the labels to improve contrast and visibility in the map.
 - BACKGROUND**: settings to set a panel with different sizes and shapes behind the labels.
 - SHADOW**: settings to display a shadow behind the labels.
 - CALLOUTS**: to connect labels and features.
 - PLACEMENT**: parameters to set the most suitable locations for the labels.
 - RENDERING**: controls whether the labels are visible on the map or not, depending on different factors like the zoom level or the interaction with other features in the map.



- f. Click **APPLY** to preview the results on the map and, once you are happy with it, click **OK** to save the changes.



3.4 Save/Open project





QGIS sessions are called projects. Projects allow the users to store map layers, overlay orders and symbologies in a specially designed file format.

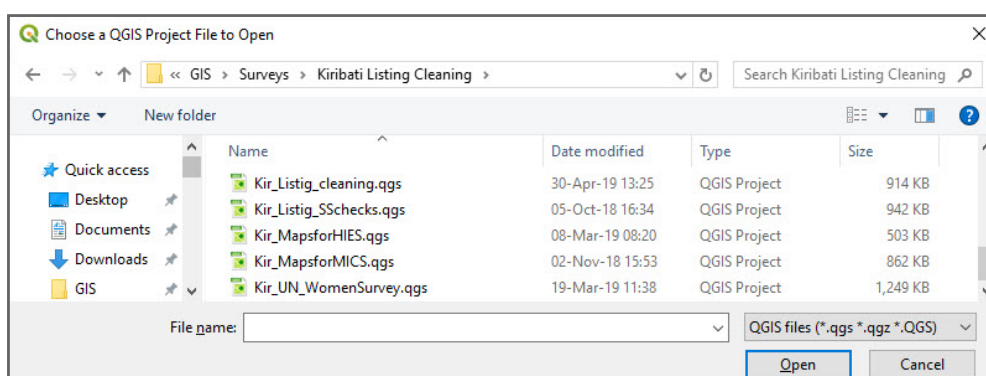
By and large, the QGIS project file stores the following information:

- layers added in the canvas
- layer properties, including symbolisation and styles
- projection for the map view
- last viewed extent
- print layouts
- print layout elements with settings
- print layout Atlas settings
- digitising settings
- table relations
- project default styles
- plugins settings
- queries stored in the DB Manager.

IMPORTANT

The layers loaded in the project are not stored in the project file. The project “memorises” the layers’ paths and retrieves them from their locations. This means that if we change the location of one of the layers or we delete it, the next time we open the project, the layer will not be added into the canvas as the project will not “know” where to find it.

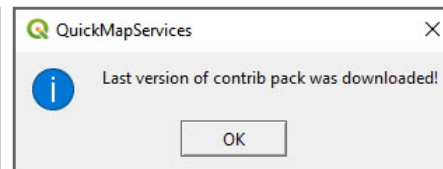
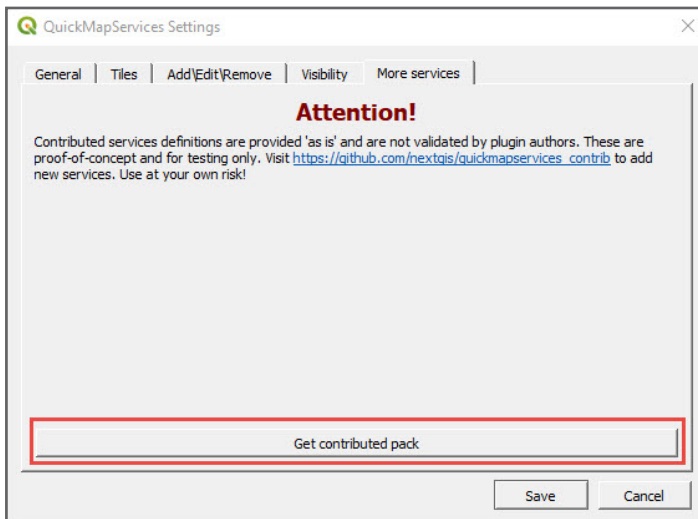
- a. To save the project the first time, click on , select the location to store it and click on the **SAVE** button.
- b. To save any changes to the project, click on . It is strongly recommended that you save your changes as often as possible. QGIS does not automatically save changes, which means that if for some reason the program crashes, you will lose all that was not saved previously.
- c. Click on  to open a new blank project.
- d. To open an existing project, click on , navigate to find the project’s location (.qgs extension) and click on **OPEN**.



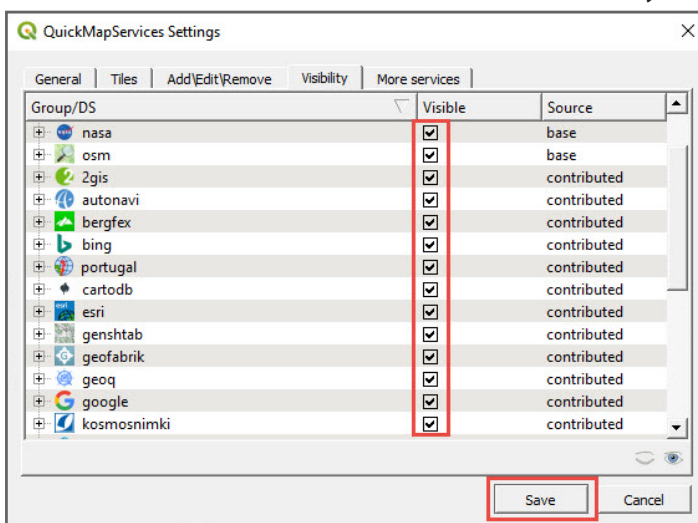
3.5 Add a basemap

3.5.1 QuickMapServices

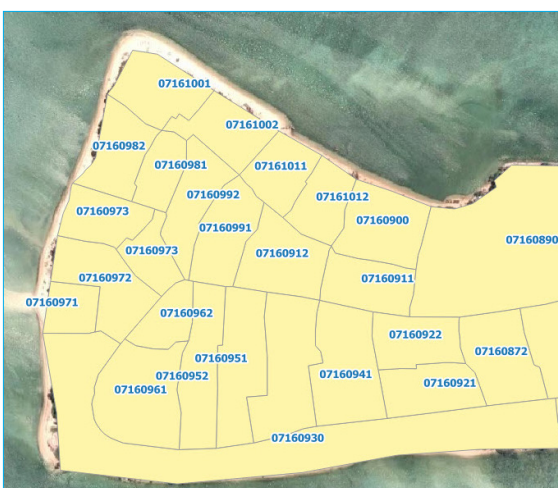
- Install the **QUICKMAPSERVICES** plugin (for more information, see chapter 2.2).
- In the top menu ribbon, go to **WEB > QUICKMAPSERVICES > SETTINGS > MORE SERVICES** and click on **GET CONTRIBUTED PACK**.



- Go to **VISIBILITY** and check/uncheck the services that you want to be available and click on **SAVE**.

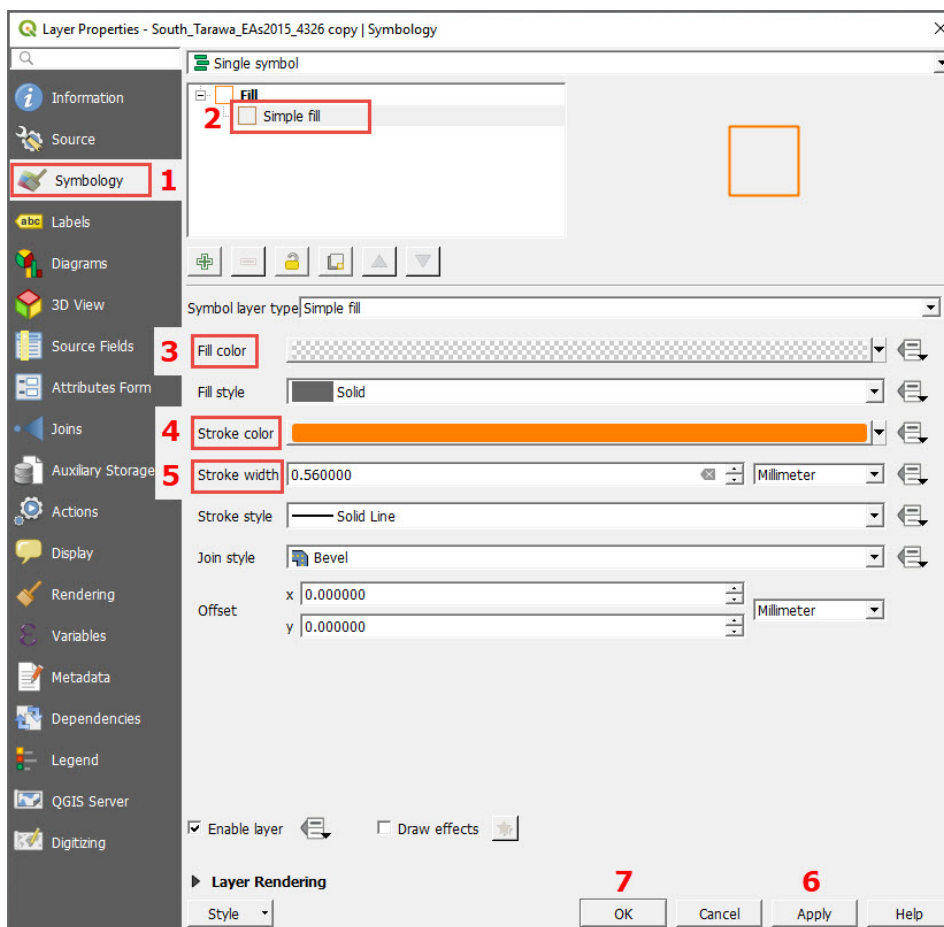


- Then, to load a satellite image background, go to **WEB > QUICKMAPSERVICES > GOOGLE > GOOGLE SATELLITE**.



To improve the readability of the map when using a satellite image background, it is recommended that styles with transparent fills are used.

- Open **Layer Properties** by double-clicking on the layer.
- Go to **SYMBOLOLOGY** and click on **SIMPLE FILL** to modify the polygon style settings.
- In **FILL COLOR**, select transparent fill.
- In **STROKE COLOR**, select a colour for the outline of the polygon that contrasts with the background in order to improve the visibility of the boundaries.
- In **STROKE WIDTH**, find a compromise between the level of detail and the visibility of the polygon's limits.



- Click **APPLY** to preview the results on the map and, once you are happy with them, click **OK** to save the changes.



3.5.2 XYZ Tiles

There are two ways to create XYZ Tiles connections:


1. Manual set-up

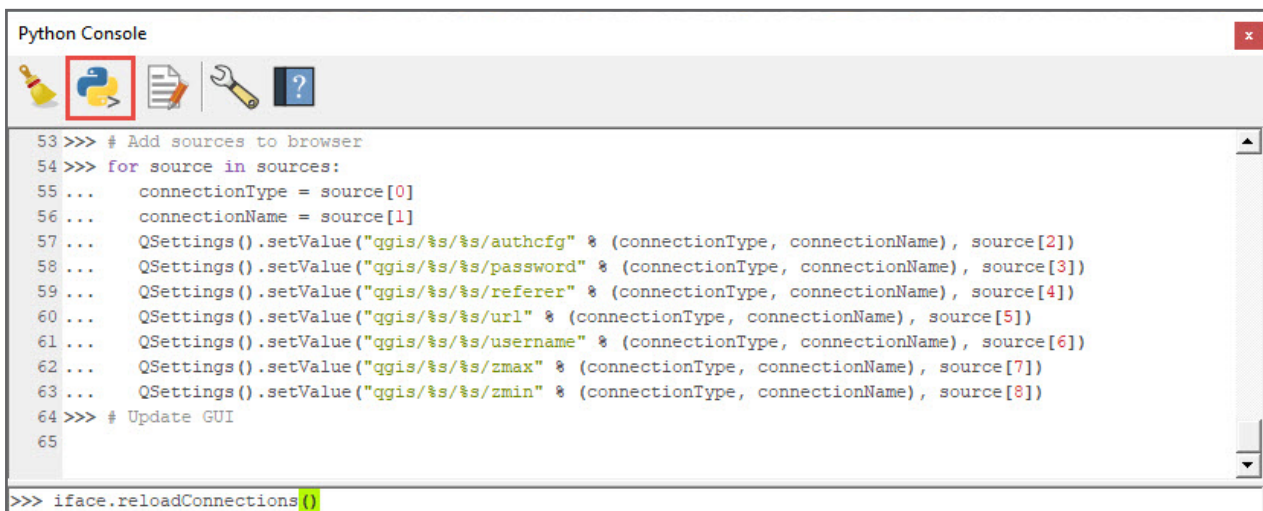
- In the **Browser** panel, right-click over **XYZ TILES** and select **NEW CONNECTION...**
- Under **NAME**, add the name we want see on the **Browser** panel for this connection, such as **Google Satellite**.
- In *3_first_steps/Other/Paths XYZ TILE SERVER.txt*, you will find the URLs for a selection of Tile Map Services (TMS). Copy the URL from the text file and paste it into the **URL** bar.
- Click **OK**.
- In the **Browser** panel, below **XYZ TILES**, the connection **GOOGLE SATELLITE** should now be available.
- Display the satellite image background from Google on the map canvas by double-clicking on **GOOGLE SATELLITE**.

2. Python script set-up¹

We can set up a large number of TMS at once by using this Python script posted in https://raw.githubusercontent.com/klakar/QGIS_resources/master/collections/Geosupportsystem/python/qgis_basemaps.py

The script is also available in *3_first_steps/Other/Script XYZ TILES.txt*. Load the TMS by following these steps:

- In the top menu, go to **PLUGINS > PYTHON CONSOLE**.
- In the **PYTHON CONSOLE**, paste the script in the panel located at the bottom.
- Click on  to run the command.

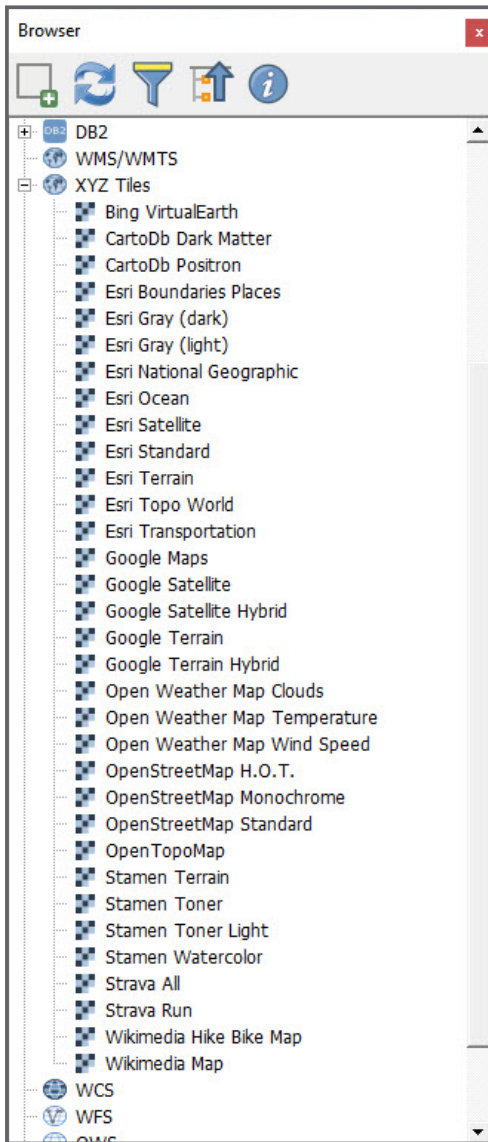


```

53 >>> # Add sources to browser
54 >>> for source in sources:
55 ...     connectionType = source[0]
56 ...     connectionName = source[1]
57 ...     QSettings().setValue("qgis/%s/%s/authcfg" % (connectionType, connectionName), source[2])
58 ...     QSettings().setValue("qgis/%s/%s/password" % (connectionType, connectionName), source[3])
59 ...     QSettings().setValue("qgis/%s/%s/referer" % (connectionType, connectionName), source[4])
60 ...     QSettings().setValue("qgis/%s/%s/url" % (connectionType, connectionName), source[5])
61 ...     QSettings().setValue("qgis/%s/%s/username" % (connectionType, connectionName), source[6])
62 ...     QSettings().setValue("qgis/%s/%s/zmax" % (connectionType, connectionName), source[7])
63 ...     QSettings().setValue("qgis/%s/%s/zmin" % (connectionType, connectionName), source[8])
64 >>> # Update GUI
65
>>> iface.reloadConnections()
  
```

¹ This chapter is based on an *open.gis.lab* blog post: <https://opengislab.com/blog/2018/4/15/add-basemaps-in-qgis-30>

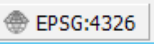
- d. In the **Browser** panel, under **XYZ Tiles** you will find a significant number of TMS available.



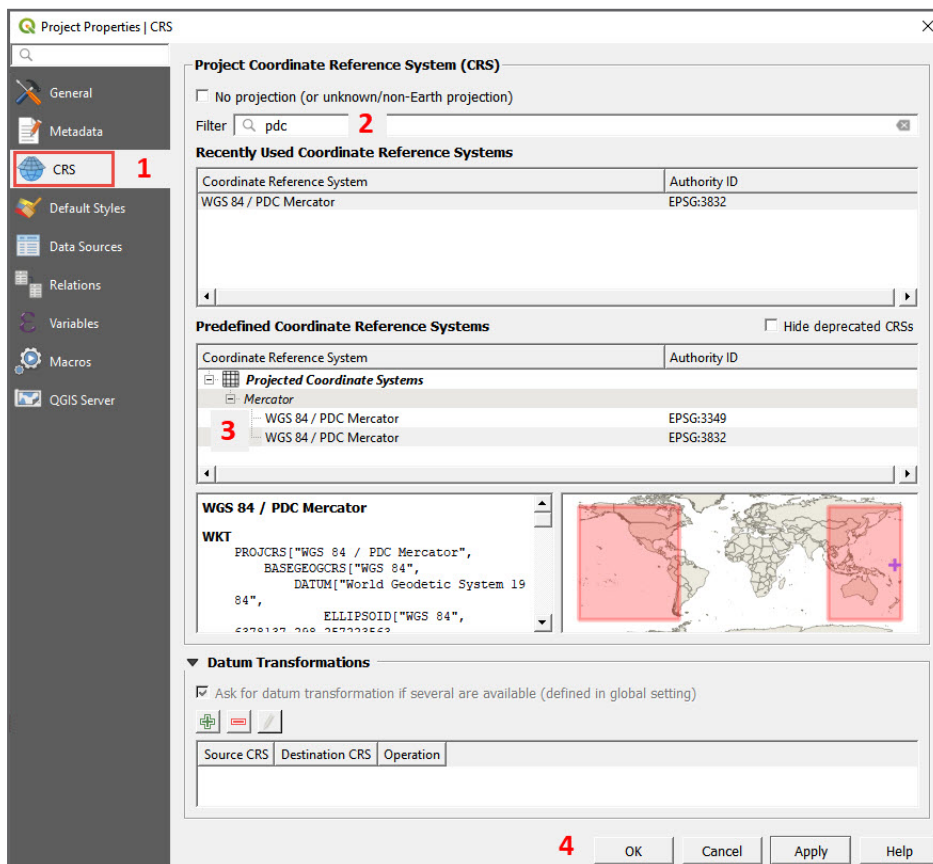
3.6 How to deal with projections in QGIS

By default, projects in QGIS open in WGS 84 Coordinates Reference System (CRS), of which the EPSG code is 4326. QGIS reprojects data "on the fly" (it was called "OTF" in previous versions). This means that even if several layers have different CRS, QGIS will attempt to represent them in the same extent.

3.6.1 Check the project's projection

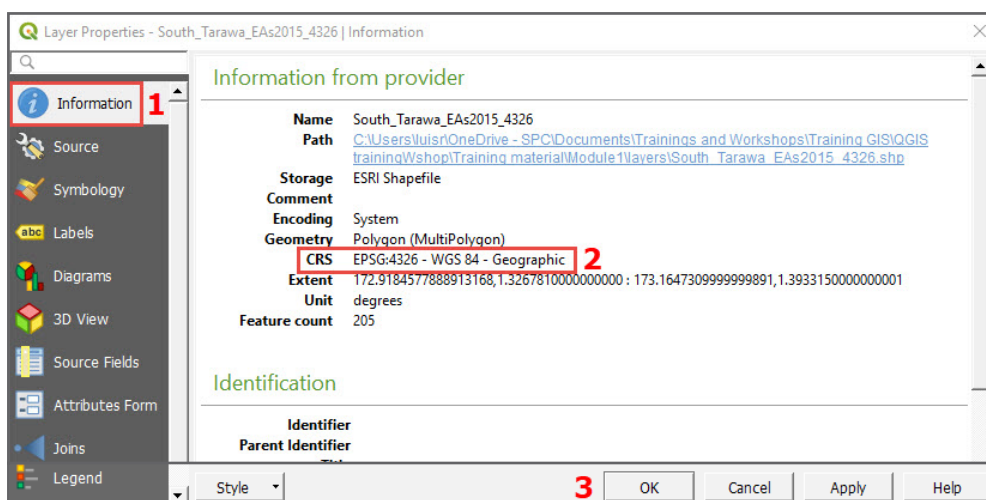
- In the bottom-right corner of the QGIS interface the CRS used by the project is displayed.
- Click on  to open **Project Properties** and go to **CRS**.
- In this panel, it is possible to select the CRS that will be used by our project.
- Use the search bar to find a suitable CRS for your project. In this case, we will search for "PDC Mercator".
- Select the CRS with code EPSG:3832.

f. Click **OK**.



3.6.2 Check the layer's projection

- Open [3_first_steps/Layers/South_Tarawa_EAs2015_4326.shp](#)
- Open **Layer Properties** to check which CRS the layer is using (remember, to open **Layer Properties** double-click on the layer's name in the **Layers** panel).
- Go to **INFORMATION**. In the **INFORMATION FROM PROVIDER** section, you will find the CRS used by the layer. Click **OK**.

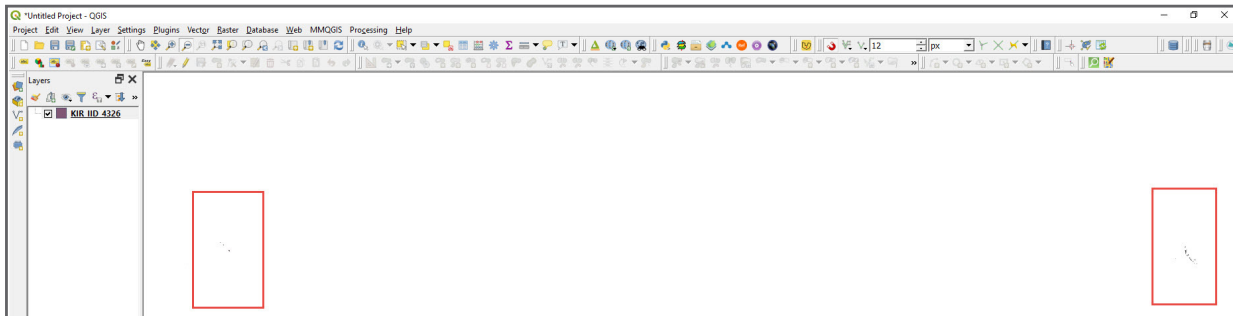


3.6.3 Change the layer's projection

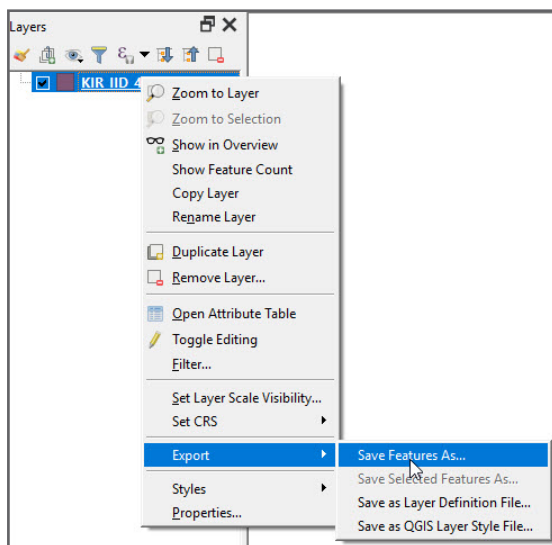
- Open [3_first_steps/Layers/KIR_IID_4326.shp](#), which corresponds to the island boundaries for Kiribati.



You will notice that two groups of islands are displayed on the opposite sides of the map. This is because the International Date Line crosses through the middle of Kiribati's geographical extent. The default QGIS CRS, WGS 84,

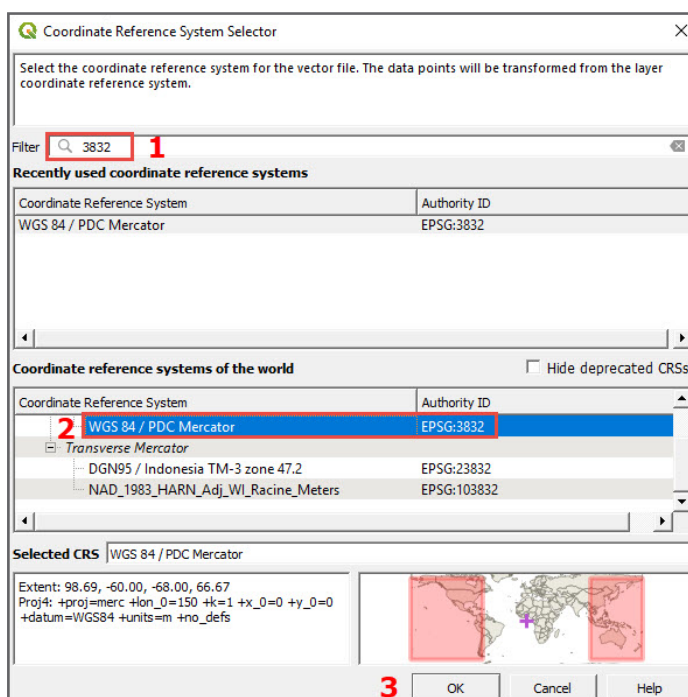
is centred on meridian 0, but our map needs to be centred on meridian 180. To solve this problem, we are going to reproject our layer into a new CRS.



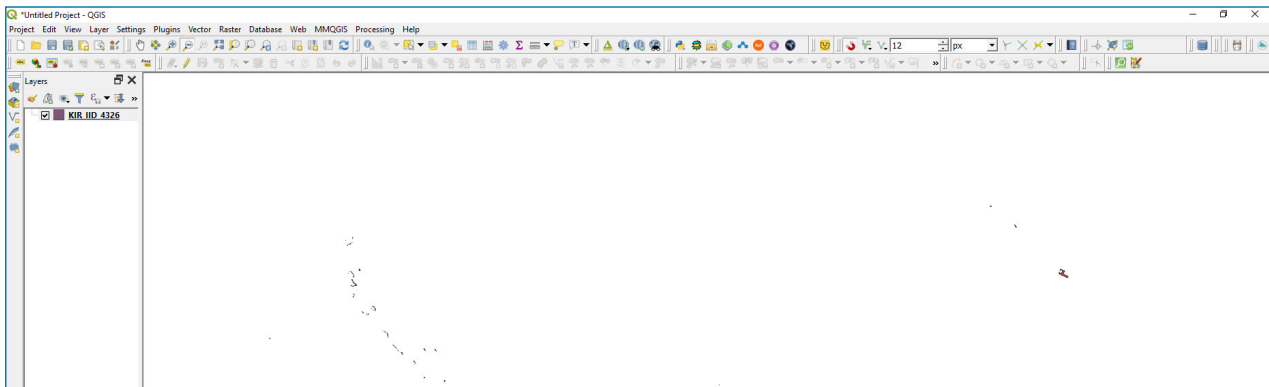
- b. On the **Layers** panel, right-click on the layer's name and go to **EXPORT > SAVE FEATURES AS...**



- c. Next to **FILE NAME**, click on  to open the file explorer and select the name and location of the new layer.
- d. Next to the **CRS** bar, click on  to open the **Coordinate Reference System Selector**.
- e. In the **FILTER** bar, type: **3832**
- f. Select the **WGS 84 / PDC MERCATOR** CRS in one of the panels below and click **OK**.




- g. Back on the [Save Vector Layer as...](#) panel, click on the **OK** button.
- h. Change the project's projection to CRS PDC Mercator EPSG:3832 by following the steps explained at the beginning of the chapter.
- i. On the map canvas, the islands will be displayed properly, as the projection has been centred on the Pacific region.




3.7 First basic enumerator map layout

The objective for this section is to create an enumerator map for South Tarawa (Kiribati) for the EA 7030072. Before we start working with the map layout, we are going to prepare the map in a blank project.

- a. Open a new QGIS session or a new project by clicking on .
- b. Load [3_first_steps/Layers/South_Tarawa_EAs2015_4326.shp](#)
- c. Set a transparent fill style and white buffered labels for the EA codes.
- d. Add a Google Satellite background from [XYZ Tiles](#).
- e. Save the project in [3_first_steps/](#) folder.
- f. After following the steps above, our map should look similar to the image below.

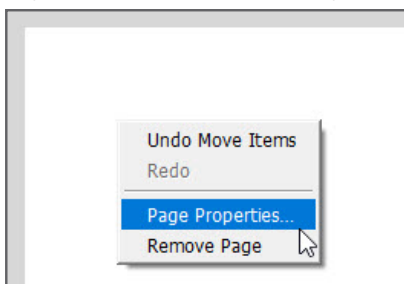


3.7.1 Create a new print layout

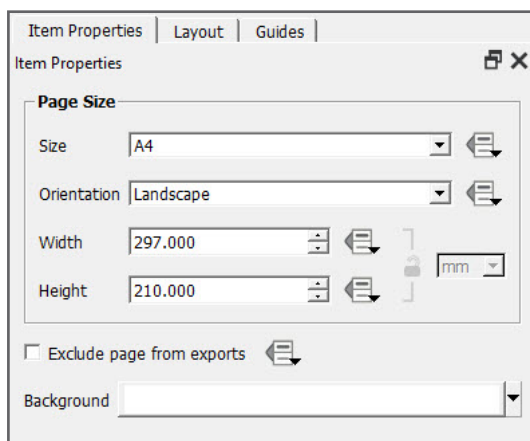
- a. To open a new layout, click on , or, in the top menu, go to **PROJECT > NEW PRINT LAYOUT**.
- b. Give the layout a name, then click **OK** and the [Print Layout](#) interface will appear.


3.7.2 Page properties

- a. Right-click on the blank page and click on **PAGE PROPERTIES...**






- b. Go to the **ITEM PROPERTIES** tab located in the menu on the right side of the screen.
- c. Go to **SIZE** and select **A4** from the drop-down menu.
- d. Go to **ORIENTATION** and select **LANDSCAPE**.
- e. In **BACKGROUND**, select a colour for the page background.




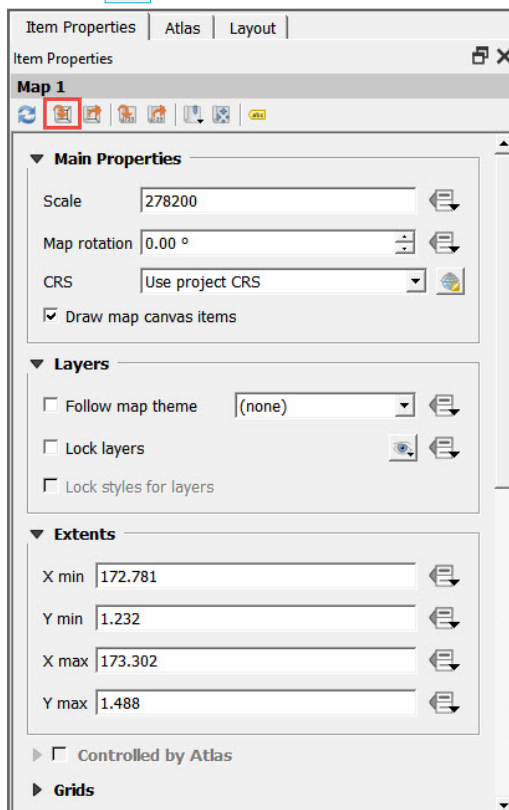
Throughout the following steps, do not forget to save your changes regularly by clicking on .

3.7.3 Add a map


- a. To add a map canvas, click on .
- b. Draw a rectangle where the map will be located.
- c. Using , it is possible to select the map canvas (and any other element created on the layout) to drag or resize it.
- d. Use  to move (zoom and drag) the content inside the map canvas and to centre the map according to your preferences.
- e. On the right side of the **Print Layout** interface, you will find various menus organised in different tabs.

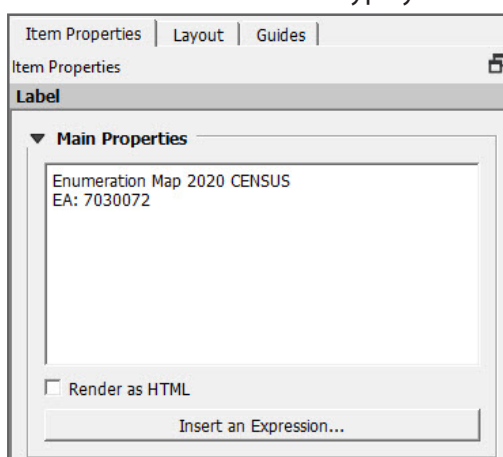
With the map canvas selected, click on **ITEM PROPERTIES**. Within this menu we can configure settings such as the size, the scale or the layers displayed in the map, among others. We will go through this menu in greater depth in the following chapters of the manual.

- f. If you want to copy the map extent from the main QGIS interface to the print layout, go to **ITEM PROPERTIES** and click on .




3.7.4 Add a title

- To add a new title, click on .
- Draw a rectangle where you want the title to be located.
- Go to **ITEM PROPERTIES** and type your desired title in the **MAIN PROPERTIES** section.



- In **APPEARANCE**, select the font type, the size, the colour and the alignment of the text.


3.7.5 Add a scale bar

- Click on  to add a scale bar.
- Draw a rectangle where you want the scale bar to be located.
- In the **ITEM PROPERTIES** menu, it is possible to configure the settings of the scale bar, such as the style, the units or the number of segments.


3.7.6 Add an image

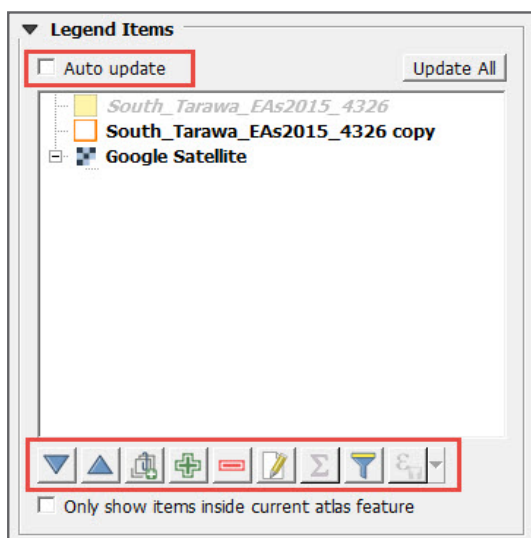
- Click on  to add an image. In this example, we are going to add a generic logo next to the title.
- Draw a rectangle where you want the image to be located.
- Go to the **ITEM PROPERTIES** menu. In the **MAIN PROPERTIES**, click on .
- Add the image saved at *3_first_steps/Images/QGIS logo.jpg* and click **OPEN**.



3.7.7 Add a north arrow

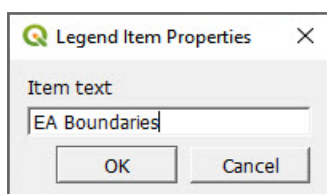
- Click on  to add another image.
- Draw a rectangle where you want the north arrow to be located.
- Go to the **ITEM PROPERTIES** menu. In the **SEARCH DIRECTORIES** section, you will find a screen displaying SVG objects including different models of north arrows.
- In the **SVG PARAMETERS** section, it is possible to set the fill and the outline settings.

3.7.8 Add a legend

- Click on  to add a legend.
- Draw a rectangle where you want the legend to be located.
- Go to the **ITEM PROPERTIES** menu. In the **LEGEND ITEMS** section, uncheck **AUTO UPDATE** to manually control the contents of the legend. You will notice that the controls underneath the preview panel are now active.



- To delete one of the items, select it and click on .
- Either double-click on the item or click on  to change the text of the item and make it more succinct.



Once you are happy with the layout, which should look something like the following map, you are ready to export the map.



- 

To learn more about layouts, go to: https://docs.qgis.org/3.10/en/docs/user_manual/print_composer/index.html

4. Point layers: Household locations (basic vector analysis)

4.1 Import point layers from different data sources



Point layers are mainly used in censuses and surveys to represent households (referred to from now as "HHs") or facilities like schools, hospitals, etc. These point locations are commonly collected using GPS units, tablets or smartphones, generating different file formats depending on the device and/or the application used.

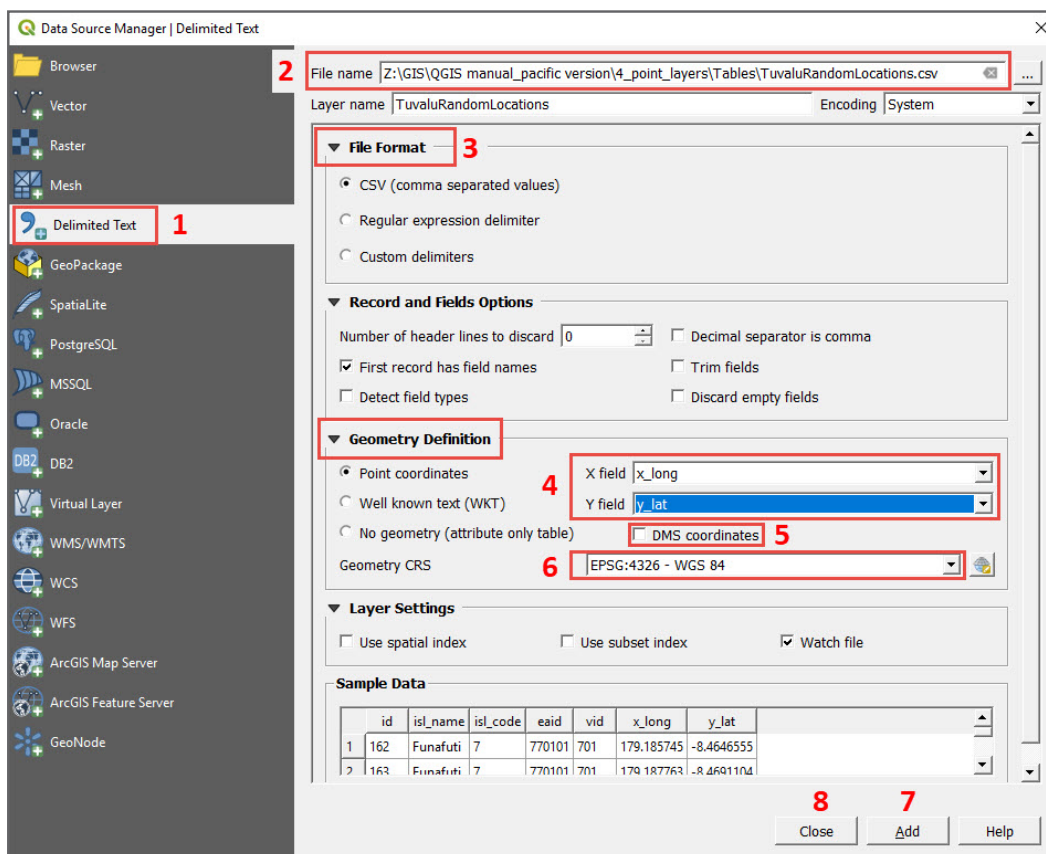
In this chapter, we will examine how to load a point layer generated with either a GPS unit or a computer-assisted personal interview (CAPI) application into QGIS. In both cases, before starting to work with the file, we must determine:

- the CRS that has been used for the data collection;
- the units and the format used to express the points' locations, making sure that we use ones that QGIS can "read". For instance, using WGS 84, the CRS used in GPS, we have to ensure that the coordinates are expressed either in decimal degrees or in degrees/minutes/seconds to avoid errors when plotting the points.


4.1.1 CAPI: Delimited text file (.csv)

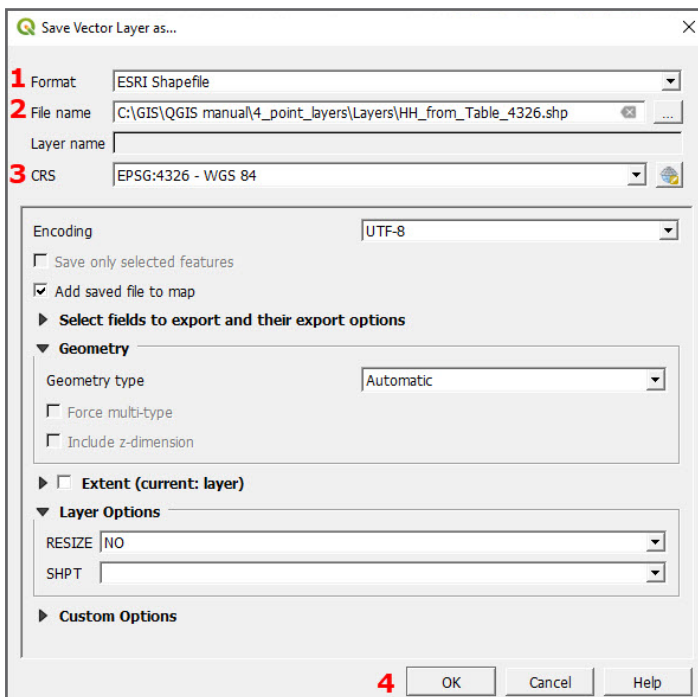
This section will explain how to import and plot GPS data from a CAPI database. QGIS does not import tables in Excel format (.xls or .xlsx extensions). You will first need to save your tables into CSV (MS-DOS) format.

- To load the table into QGIS, in the top menu go to **LAYER > DATA SOURCE MANAGER** or click on .
- On the left side of the menu, select **DELIMITED TEXT**.
- Go to the **FILE NAME** panel and click on  to open the file explorer.
- Open **4_point_layers/Tables/TuvaluRandomLocations.csv**
- In **FILE FORMAT**, select the **CSV (COMMA SEPARATED VALUES)** option.
- Under **GEOMETRY DEFINITION**, select the **POINT COORDINATES** option and select the fields corresponding to the latitude and longitude coordinates in the **X FIELD** and **Y FIELD** panels. Make sure that the **DMS COORDINATES** option is unchecked as our coordinates are expressed on Decimal Degrees, not on Degrees Minutes and Seconds format. For **GEOMETRY CRS**, select EPSG:4326 – WGS 84.
- Click on **ADD** and then on **CLOSE**.

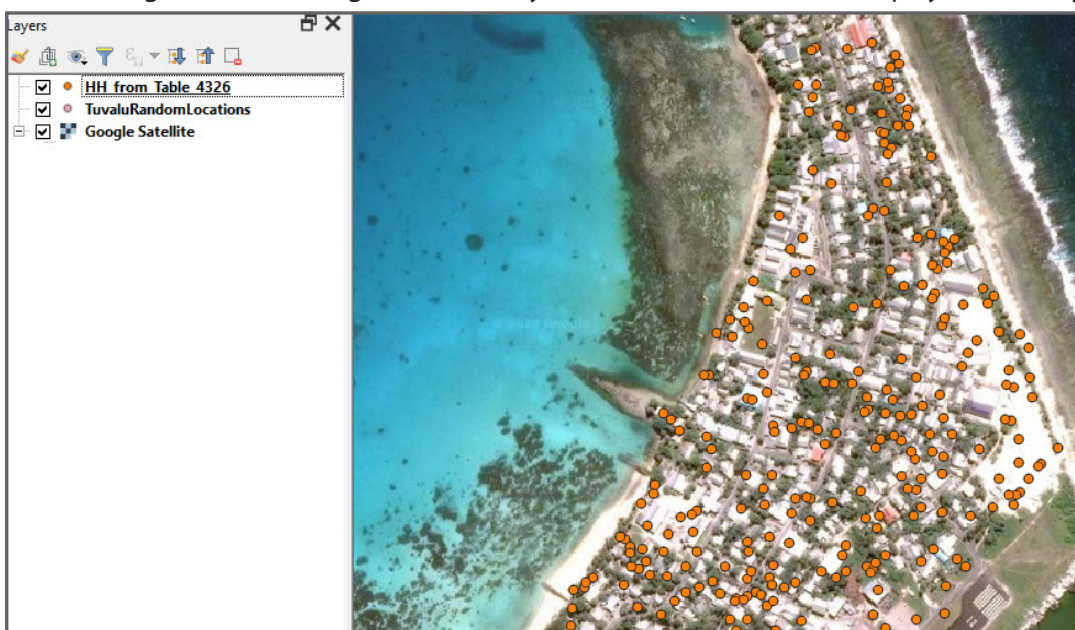


The corresponding cloud of points will be displayed on the map canvas. Note that this layer is not a proper layer; QGIS is drawing the points "on the fly" by reading the coordinates from the table. This means that, although the points are displayed, it is not possible to undertake any editing, like generating or deleting points, for example. To resolve this, we will export the table into a shapefile.

- h. In the **Layers** panel, right-click on the "layer" and go to **EXPORT > SAVE FEATURES AS...**
- i. In **FORMAT**, select **ESRI SHAPEFILE**.
- j. Click on  and select the location where the shapefile will be stored (*4_point_layers/Layers/* is the recommended path).
- k. In **CRS**, ensure that **EPSG:4326 – WGS 84** is selected.
- l. Click on **OK**.





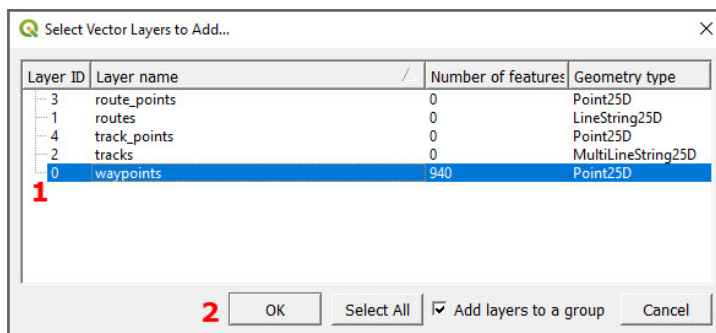
- m. Load a Google Satellite background to verify that the HH locations are displayed correctly.



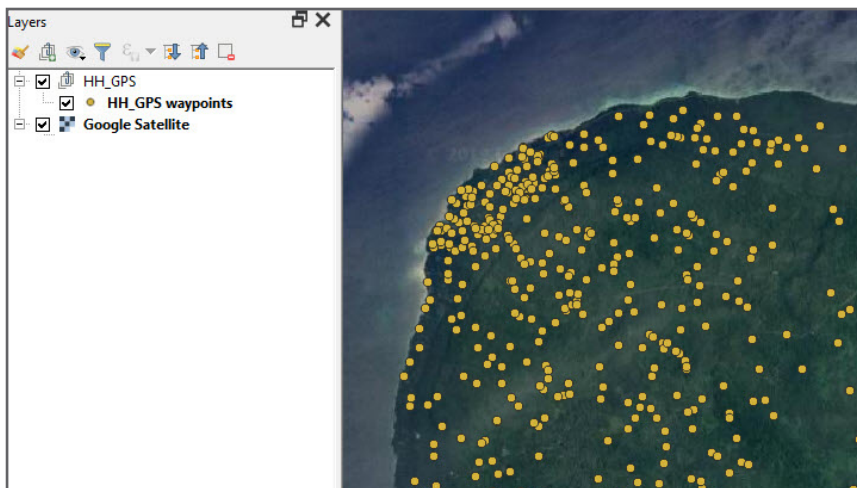
4.1.2 GPS unit (example for Garmin Etrex) (.gpx format)

Garmin Etrex 10/20/30 models can be connected via USB to your computer and GPS points can be imported using the .gpx format, which can be opened directly in QGIS.

- To load the .gpx file, in the top menu go to **LAYER > DATA SOURCE MANAGER** or click on .
- On the left side of the menu, select **VECTOR**.
- Go to the **FILE NAME** panel and click on  to open the file explorer.
- Open *4_point_layers/Etrex/HH_GPS.gpx*
- Click on **Add**.
- In the **Select Vector Layers to Add...** panel select the **WAYPOINTS** option and click **OK**.



- Close the **Data Source Manager**.
- If the new cloud of points does not appear on the map canvas, in the **Layers** panel right-click on the *HH_GPS waypoints* layer and select **Zoom to Layer**.
- Load a Google Satellite background to check that the GPS waypoints are displayed correctly.



Note that this layer, as in the previous example with .csv files, is not stored as a shapefile. This limits the operations that can be conducted within the QGIS environment.


- To export this layer into shapefile format, follow the same steps as that for exporting .csv files into .shp, and save it in *4_point_layers/Layers/*

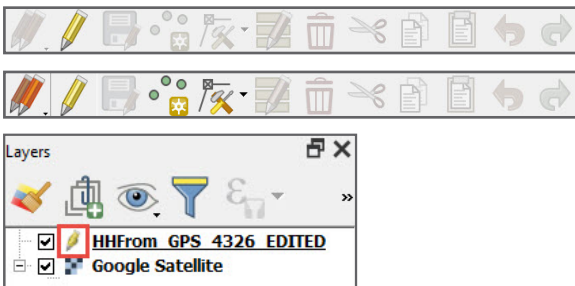
4.2 Edit point layers

4.2.1 Create/Delete features




- Open a new project  and load *4_point_layers/Layers/HHFrom_GPS_4326.shp* into the map canvas.
- Open a satellite image background. This will be useful while we edit the layer.

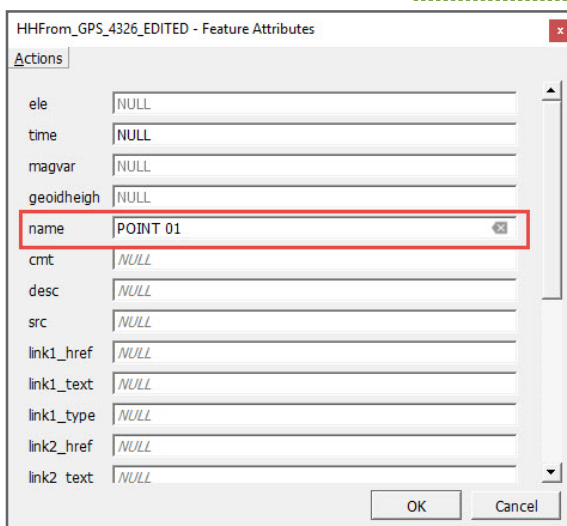
When editing a layer, it is recommended that you make a copy of it and modify the copy instead of the original. This way, if you make a mistake, like erasing geometries by accident, the original file will remain as a backup to recover the lost data.



- Make a copy by exporting the layer into `4_point_layers/Layers/` and name the layer `HHFrom_GPS_4326_EDITED.shp`, for example.
- Remove the original shapefile from the **Layers** panel by right-clicking on the layer and selecting **REMOVE LAYER...**
- Select `HHFrom_GPS_4326_EDITED` in the **Layers** panel and click on  to start the editing session. You will notice that some of the controls of the **DIGITIZING TOOLBAR** are activated and that the pencil symbol appears next to the label in the **Layers** panel.



At this point, we want to add some plots that are hypothetically missing from the GPS dataset.

- Zoom to the location where you will plot the new location.
- Click on . You will notice that your cursor changes from  to .
- Place the cursor over the new point location and click.
- Fill at least one of the fields in the **Features Attributes** panel and click **OK**.



- Repeat the process with some more points and click on  to save the changes.
- To stop the editing session, click again on .




4.2.2 Move features

There are two ways to move a feature in QGIS. The first way is to use the **ADVANCED DIGITIZING TOOLBAR**.






- Right-click on the top menu, and in the **TOOLBARS** section, select **ADVANCED DIGITIZING TOOLBAR**. This toolbar (below) will be aggregated to the top menu with all the controls deactivated.



- Click on  to start the editing session. You will notice that some of the controls in the toolbar will be activated.

- c. Click on . Your mouse cursor will change to this symbol .
- d. Click on the point you would like to change, then move the cursor to the new location and click for a second time. The point will appear in its new location.
- e. Click on  to save the changes.

The second method to move points uses the **VERTEX TOOL**, which is located in the **DIGITIZING TOOLBAR**.

- a. Click on  and your mouse cursor will change to .
- b. Move the cursor over the point you wish to move and you will see that the cursor will change to .
- c. Click on the point and your cursor will change to .
- d. Move the point to its new position and click to place it.
- e. Click on  to save the changes.

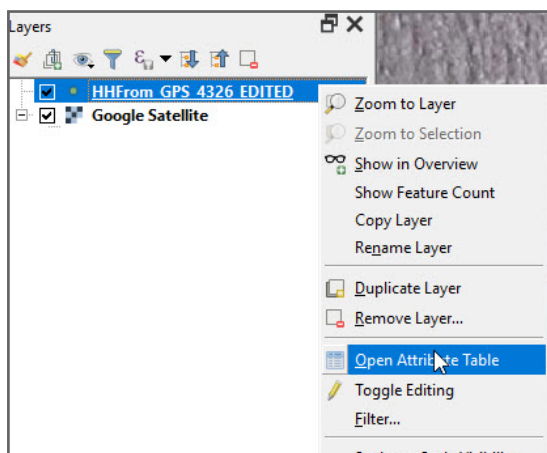
These two methods are very similar as they both use the same sequence: left-click + move feature + left-click.

4.2.3 Modify attribute table



In this subsection, you will keep working with the *HHFrom_GPS_4326_EDITED* layer.

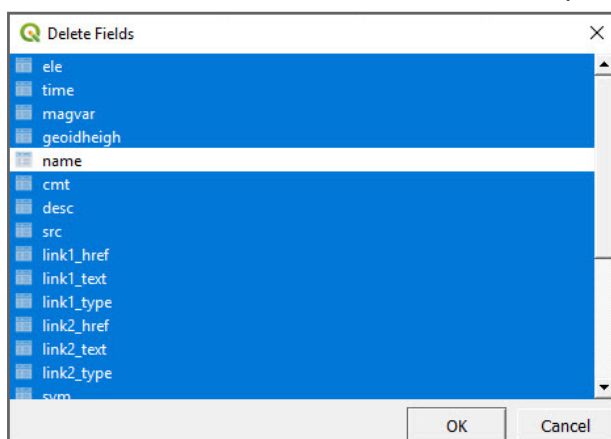
- a. Select the layer in the **Layers** panel and open the **ATTRIBUTE TABLE** by clicking on  located in the top menu.


The other way to access the **ATTRIBUTE TABLE** is by right-clicking on the layer in the **Layers** panel and selecting **OPEN ATTRIBUTE TABLE**.

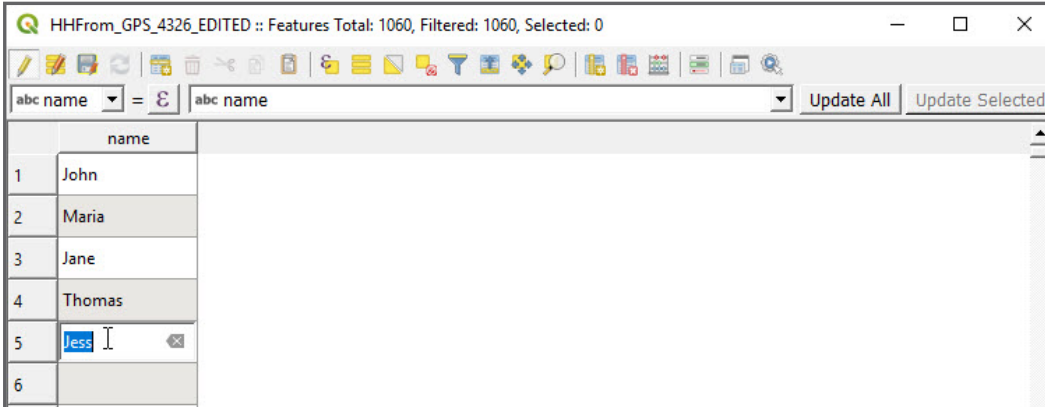


Notice that the **ATTRIBUTE TABLE** contains several fields but all of them are empty. They are not required for this exercise, so we will remove all of them except the field **NAME**.


- b. To start the editing session, click on . This control can be found in both the main QGIS and **ATTRIBUTE TABLE** windows.
- c. In the **ATTRIBUTE TABLE**, click on  in the menu ribbon at the top of the window.
- d. Select the fields to delete in the **Delete Fields** panel and click **OK**.

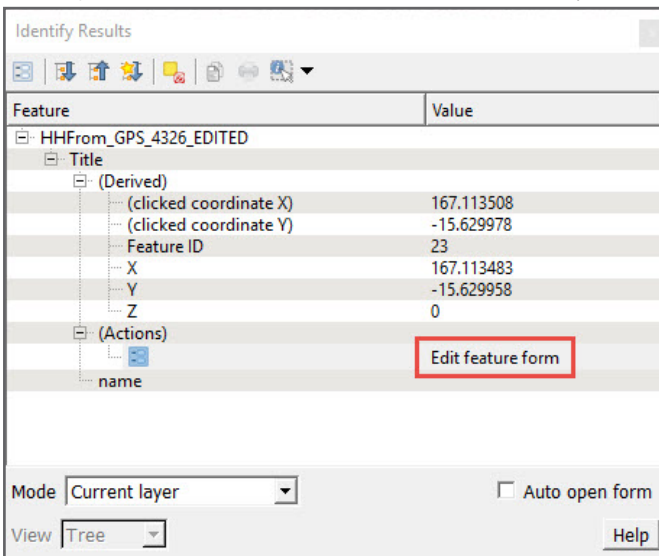


- e. Click on  to save the changes. As a result, the **ATTRIBUTE TABLE** now contains only the field **NAME**.
- f. With the editing session still activated, we can modify the cells in the **ATTRIBUTE TABLE**. In this instance, we will randomly populate some names in the field **NAME** to test how it works.



	name
1	John
2	Maria
3	Jane
4	Thomas
5	Jess
6	


- g. Click on  and select one of the points on the map canvas and the **Identify Results** panel will be displayed.
- h. Go to **ACTIONS**. If the editing session is activated, the option **EDIT FEATURE FORM** will be available (when the editing session is deactivated, the option displayed is **VIEW FEATURE FORM**).

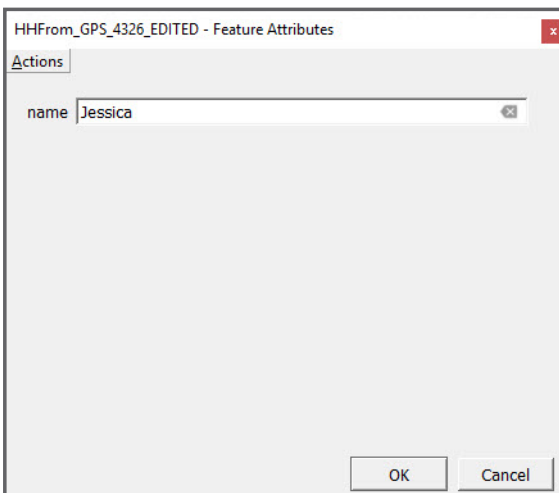


Feature	Value
HHFrom_GPS_4326_EDITED	
Title	
(Derived)	
(clicked coordinate X)	167.113508
(clicked coordinate Y)	-15.629978
Feature ID	23
X	167.113483
Y	-15.629958
Z	0
(Actions)	
name	Edit feature form

Mode: Current layer ☐ Auto open form

View: Tree Help

- i. Click on **EDIT FEATURE FORM**, fill the fields appropriately and click **OK**. The modifications undertaken in the **EDIT FEATURE FORM** will be reflected in the **ATTRIBUTE TABLE**. Then click on  to save the changes.




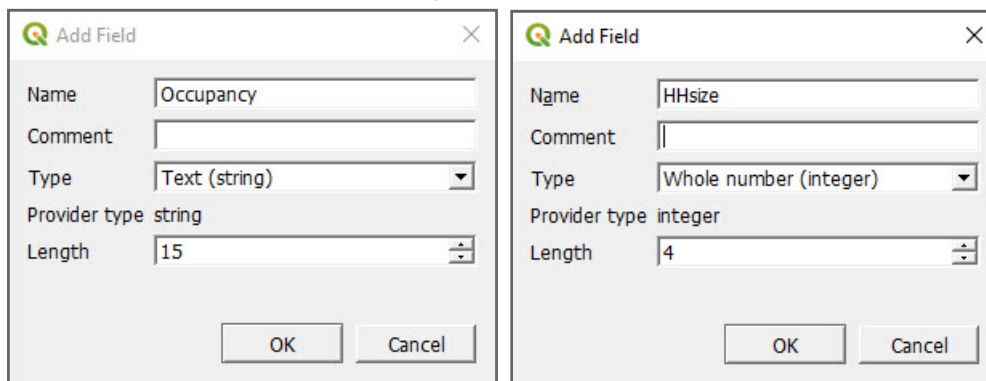
HHFrom_GPS_4326_EDITED - Feature Attributes

Actions


name: Jessica

OK Cancel

- j. Go back to the **ATTRIBUTE TABLE**. Make sure that the editing session is activated and then click on  to create a new field (column) in the **ATTRIBUTE TABLE**.
- k. In **NAME**, type a name for the field.
- l. In **TYPE**, we will define the type of data the new field is going to store:
 - **WHOLE NUMBER** for data like HH size, number of rooms in the dwelling or questionnaire codes.
 - **DECIMAL NUMBER** for data that needs the use of decimals like percentages or rates.
 - **TEXT** for data like names or occupancy status.
 - **DATE** and **DATE & TIME** to store data like date of the interview or date of birth.
- m. Create two fields: one for occupancy status and the other for the number of people living in the HH.





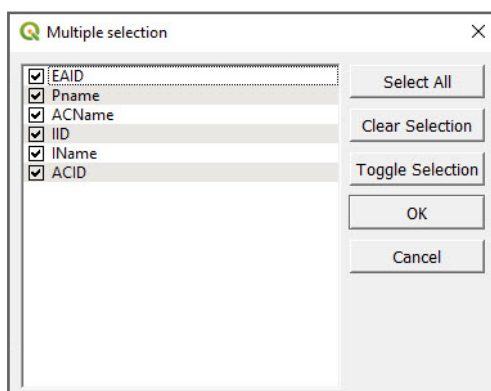
The image shows two side-by-side screenshots of the 'Add Field' dialog box in QGIS. The left dialog has 'Name' set to 'Occupancy', 'Type' set to 'Text (string)', and 'Length' set to 15. The right dialog has 'Name' set to 'HHsize', 'Type' set to 'Whole number (integer)', and 'Length' set to 4. Both dialogs have 'OK' and 'Cancel' buttons at the bottom.

- n. Populate some rows using **EDIT FEATURE FORM** and the **ATTRIBUTE TABLE** and click on  to save the edits.


4.2.4 Join attributes by location (spatial join)

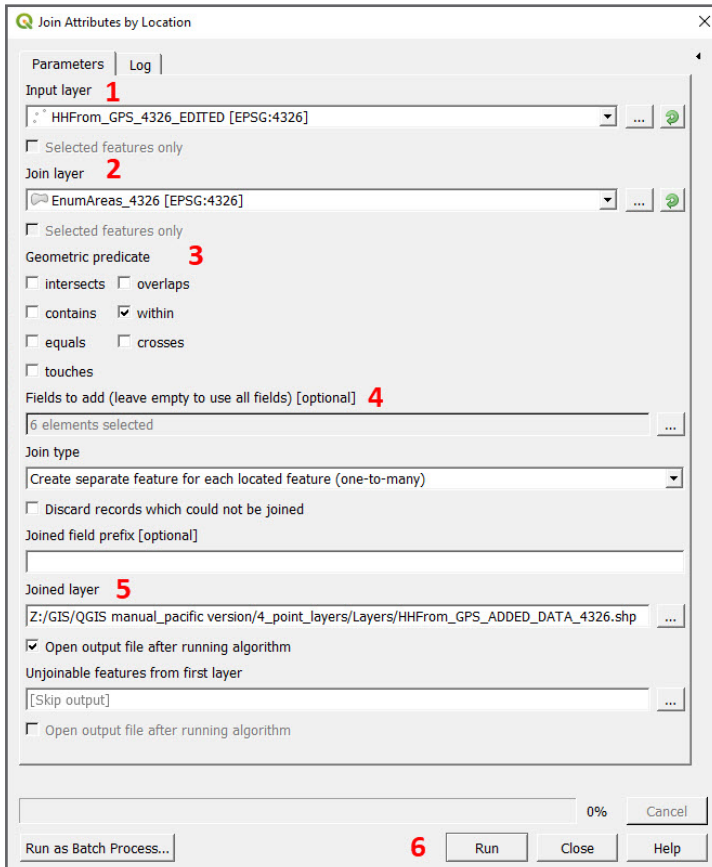
We are going to add some information to the GPS points' **ATTRIBUTE TABLE** using the enumeration areas layer. The information is going to be transferred from the polygon layer to the point layer using a spatial relationship.

- a. Open a new project  and load *4_point_layers/Layers/HHFrom_GPS_4326_EDITED.shp* and *4_point_layers/Layers/EnumAreas_4326.shp* into the map canvas.
- b. In the **Layers** panel, place the point layer above the polygon layer to allow the visualisation of both layers.
- c. In the top menu, go to **VECTOR > DATA MANAGEMENT TOOLS > JOIN ATTRIBUTES BY LOCATION**.
- d. In **INPUT LAYER**, select *HHFrom_GPS_4326_EDITED.shp*, the point layer that is going to take the information from the polygon layer.
- e. In **JOIN LAYER**, select *EnumAreas_4326.shp*, the layer that is going to provide the information.
- f. In **GEOMETRIC PREDICATE**, select **WITHIN**.
- g. In **FIELDS TO ADD**, click on  and select the fields you want to add into the point layer and click **OK**.



The image shows a screenshot of the 'Multiple selection' dialog box in QGIS. It has a list of fields on the left: EAID, Pname, ACName, IID, IName, and ACID. All of these fields are checked with a checkbox. On the right side of the dialog, there are five buttons: 'Select All', 'Clear Selection', 'Toggle Selection', 'OK', and 'Cancel'.

- h. In **JOINED LAYER**, click on  and select the location for the new point layer and its name (*4_point_layers/Layers/HHFrom_GPS_ADDED_DATA_4326.shp*, for instance).
- i. Click on **RUN**.




- j. In the **Layers** panel the new point layer will appear as a **JOINED LAYER**. Check in its **ATTRIBUTE TABLE** to ensure that the new fields from *EnumAreas_4326.shp* have been added.

5. Polygon layers: Enumeration areas (basic vector analysis)

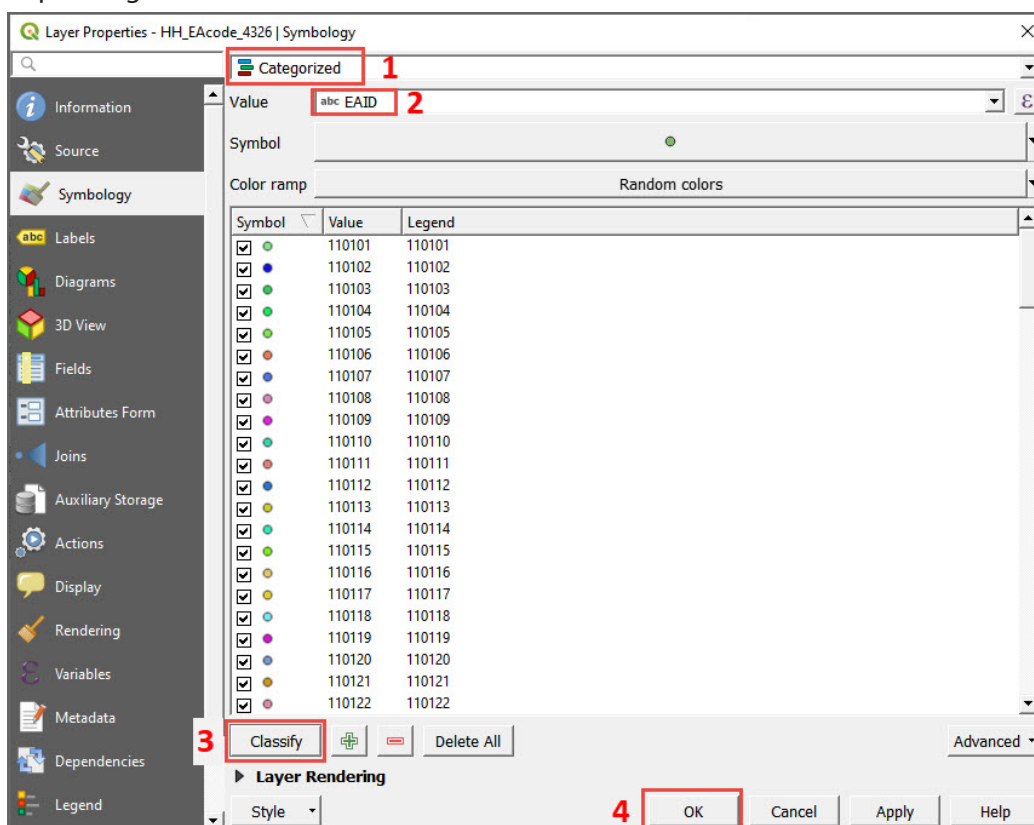
5.1 Create a new polygon layer: Digitise new features

First, we will prepare the project file so that we can undertake the exercise.

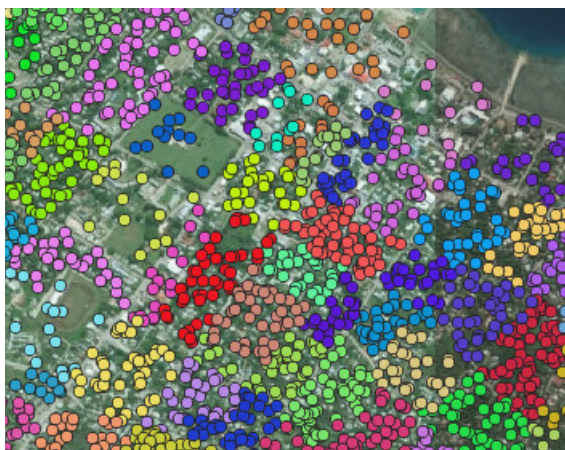
- Open a new project  and load *5_polygon_layers/Layers/HH_EAcode_4326.shp* into the map canvas.
- Load a satellite background underneath the point layer. This will be useful when delineating the enumeration area (EA) boundaries.

The HH location layer contains a field with the EA codes; this will help us to determine the boundaries of each EA.



- In the **Layers** panel, open the **Layer Properties** menu and go to **SYMBOLOLOGY**.
- In the first top drop-down menu, select **CATEGORIZED**.
- In **VALUE**, select the EAID field and click on **CLASSIFY**. Note that the points are displayed using different colours depending on their EA code.

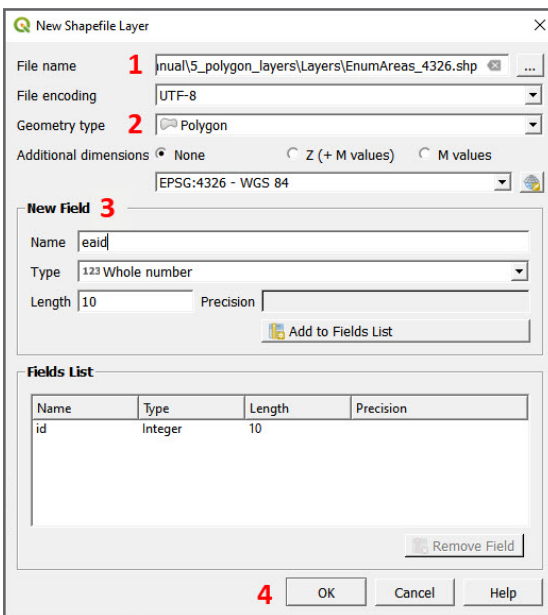


- Click **OK**. The map should look similar to this:



The next step is to create a layer from scratch that corresponds to the EA boundaries.

- g. Click on , or, in the top menu, go to **LAYER > CREATE LAYER > NEW SHAPEFILE LAYER...**
- h. In **FILE NAME**, click on  to set the name and the location of the new shapefile (e.g. *5_polygon_layers/Layers/EnumAreas_4326.shp*).
- i. For **GEOMETRY TYPE**, select **POLYGON**.
- j. For the **CRS**, choose EPSG:4326 – WGS 84.
- k. Using the **NEW FIELD** section, we will create a field with **NAME: eaid**, **TYPE: Whole number**, and **LENGTH: 10**. Then click on **ADD TO FIELDS LIST**.



New Shapefile Layer

File name: **1** nual\5_polygon_layers\Layers\EnumAreas_4326.shp

File encoding: UTF-8

Geometry type: **2** Polygon

Additional dimensions: ☒ None ☐ Z (+ M values) ☐ M values

CRS: EPSG:4326 - WGS 84

New Field **3**

Name: eaid




Type: 123 Whole number

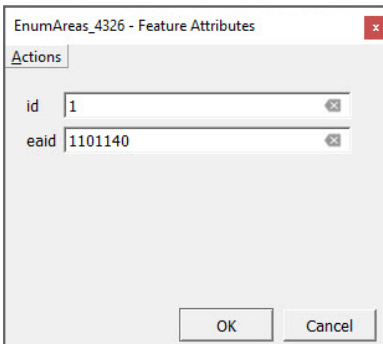
Length: 10 Precision:

Fields List

Name	Type	Length	Precision
id	Integer	10	

4 OK Cancel Help

- l. Click **OK** and the layer will be added to the **Layers** panel (there will be no polygon displayed because the layer is still "empty").
- m. Select the layer in the **Layers** panel and click on  to start the editing session.
- n. Click on  to add a new polygon. The mouse cursor will turn into a . Remember that even when you are using the digitising tool, you can zoom in and out on your map by rolling the mouse wheel, and you can pan around by holding down the mouse wheel and dragging around in the map.
- o. Trace the EA boundary by clicking along the limits of the EA. Use natural and artificial features to guide your demarcations.
- p. Right-click to finish drawing the polygon, and the **Feature Attributes** dialog will be displayed. Fill the fields with the appropriate information and click **OK**.



EnumAreas_4326 - Feature Attributes


Attributes

id: 1

eaid: 1101140

OK Cancel

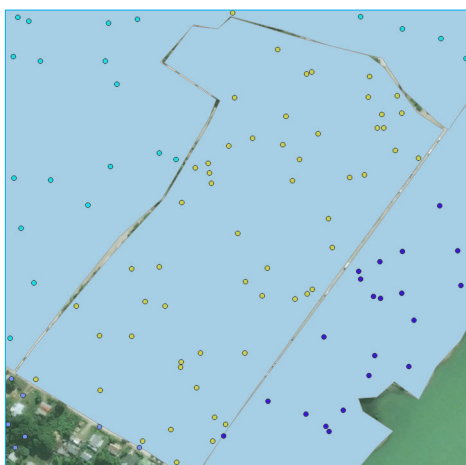


- q. Create more EA polygons by following the steps explained above. Do not forget to frequently save your changes to the layer by clicking on .

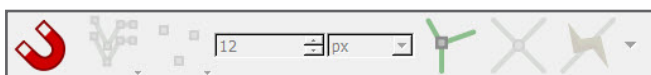
5.2 Snapping




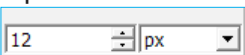


The snapping tool allows the user to snap objects to each other during the digitising process. This is a time-saving tool, which also reduces the number of topology errors (gaps and overlaps between polygons).

Next, we will clean the topology of the layer we have just created. Given that we did not use the snapping tool when creating our first polygons, the polygon boundaries do not match to each other; therefore, the layer looks similar to the following image.



- a. If the **SNAPPING TOOLBAR** is not available in the top menu, right-click on the top menu ribbon and select **SNAPPING TOOLBAR** in the **TOOLBARS** section.

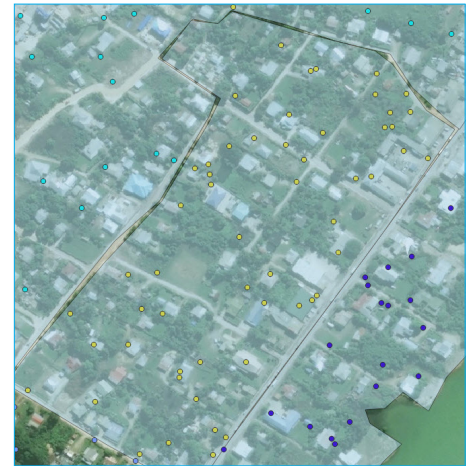
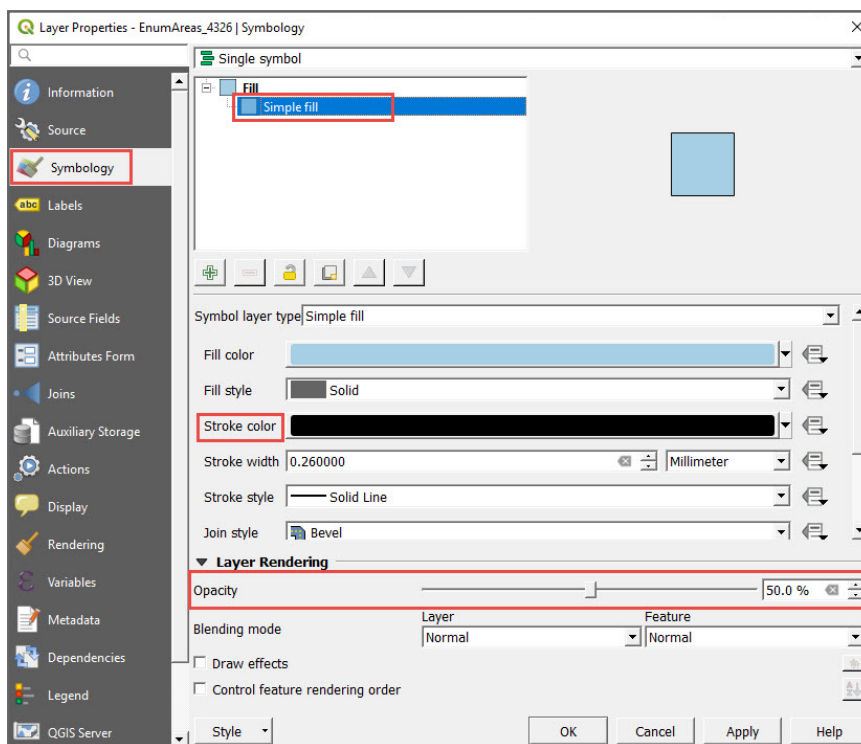




- b. Click on  to enable/disable the snapping tool.
- c. Click on  to select in which layers the snapping tool is enabled: **ALL LAYERS**, **ACTIVE LAYER** or **ADVANCED CONFIGURATION**. Select **ACTIVE LAYER** as this is the simplest option and will make learning how to use this tool easier.
- d. Click on  to select whether the snapping tool works for **VERTEX**, for **SEGMENT** or for both **VERTEX AND SEGMENT**. Select the third option: **VERTEX AND SEGMENT**.
- e. Use this menu  to set the **TOLERANCE** of the snapping tool. We can increase/decrease the tolerance using either pixels or map units. It is a good idea to conduct some trials to make sure that you have configured the tolerance to an appropriate level.
- f. Click on  to enable **TOPOLOGICAL EDITING** (when using this tool, features that share a vertex will be modified at the same time when you move this shared vertex). This is very useful to delineate and modify the boundaries between EA polygons.
- g. Click on  to enable/disable the **SNAPPING ON INTERSECTION**. This tool allows you to snap intersections that do not have a vertex.

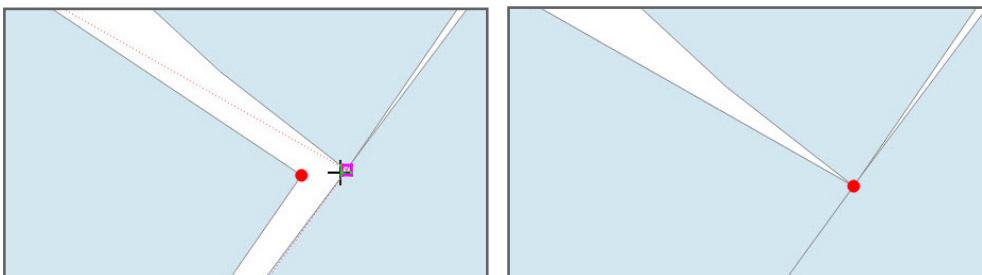
5.3 Editing (delineating, attributes)

Now that the snapping tool is enabled, we will clean and improve the existing polygons, making sure that the neighbouring polygons share clean and clear boundaries.

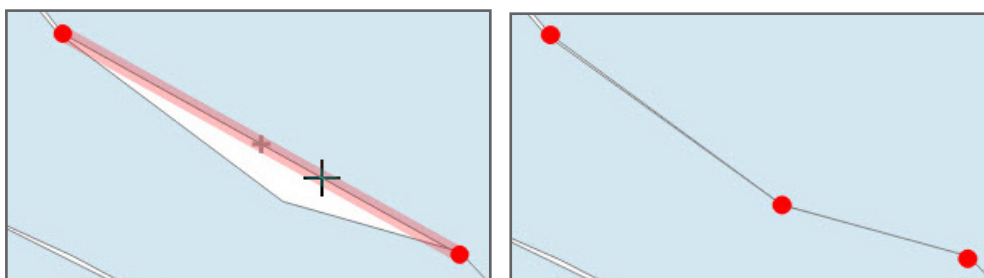
- a. In the **Layers** panel, open the **Layer Properties** menu and go to **SYMBOLOLOGY**. Click on **SIMPLE FILL**.
- b. Reduce the **OPACITY** to 50% to allow the satellite background to be visualised, and set a high contrast colour for the **STROKE**. Being able to clearly see the polygons' boundaries helps immensely when correcting any errors.



- c. In the **Layers** panel, select *EnumAreas_4326.shp* and start an editing session .
- d. Click on  to activate the **VERTEX TOOL**. You will notice that the polygons light up in red when the cursor is above them.
- e. **Move a vertex:** Select the vertex by clicking on it. Move the cursor close to a different vertex or line where the vertex will be relocated; the vertex will be "attracted" and will match perfectly. Click again to place the vertex in its new location.



- f. **Create a new vertex:** When hovering the cursor over the edge of the polygon, a suggested new node will appear in the centre of the segment. Click on it and fix it to the new position.



- g. **Delete a vertex:** Select the vertex by holding **Shift** and clicking on it or by clicking and dragging a rectangle around one or more vertices. When the vertex is selected the colour changes to blue. To delete the selected vertices, press **Delete**.

- h. **Lock a feature before editing:** We can lock a feature for editing by right-clicking on it. Once it is locked, the editing operations will be applied only to this polygon. This is very useful when editing several layers close to each other. In this type of situation, the selection and modification of vertices and segments can be difficult and will force you to work with the mouse and the zoom to accurately select a specific vertex.


Now we will drag/create/delete vertices to "stitch" together the boundaries between the EA polygons. Use the satellite image background to better define the boundaries using roads, streets and natural landmarks where possible.

- i. Do not forget to save edits in the layer by clicking on .



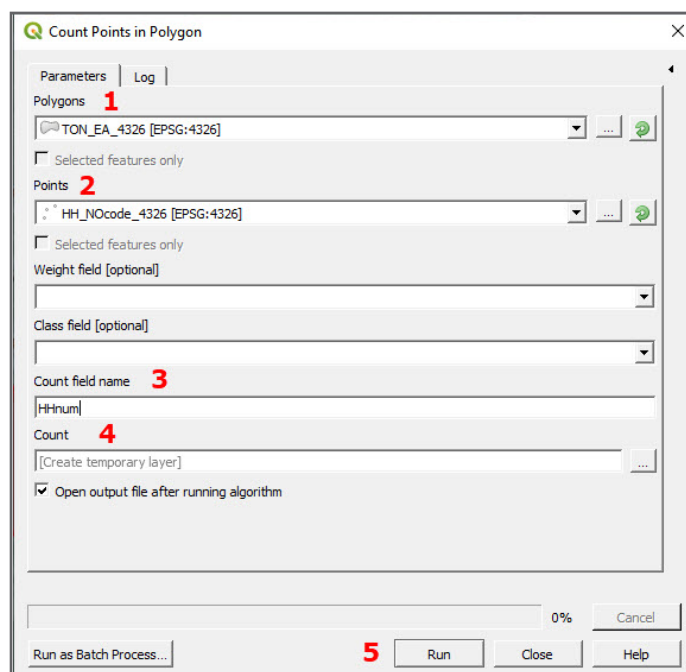
5.4 Split/Merge enumeration areas: Best management practices (code system, delineation)


In this exercise, we will analyse the EA framework and calculate the number of HH contained within each polygon. Then we will update the layer by splitting and merging polygons to meet the condition that each EA must contain between 40 and 60 HH.

- Open a new QGIS session or a new project by clicking on .
- Load *5_polygon_layers/Layers/HH_NOcode_4326.shp* and *5_polygon_layers/Layers/TON_EA_4326.shp* layers.
- Load a satellite image background.

To count the number of HH within each EA (the number of points within each polygon) we will use the **COUNT POINTS IN POLYGON** tool.



- In the top menu, go to **VECTOR > ANALYSIS TOOLS > COUNT POINTS IN POLYGON** tool.
- In the **POLYGONS** section, select *TON_EA_4326.shp*
- In the **POINTS** section, select *HH_NOcode_4326.shp*
- In the **COUNT FIELD NAME**, type: **HHnum**
- Leave the **COUNT** section blank; the tool will create a temporary layer, which is sufficient for our needs at the moment.
- Click **RUN**, and when the process is finished, **CLOSE** the tool.

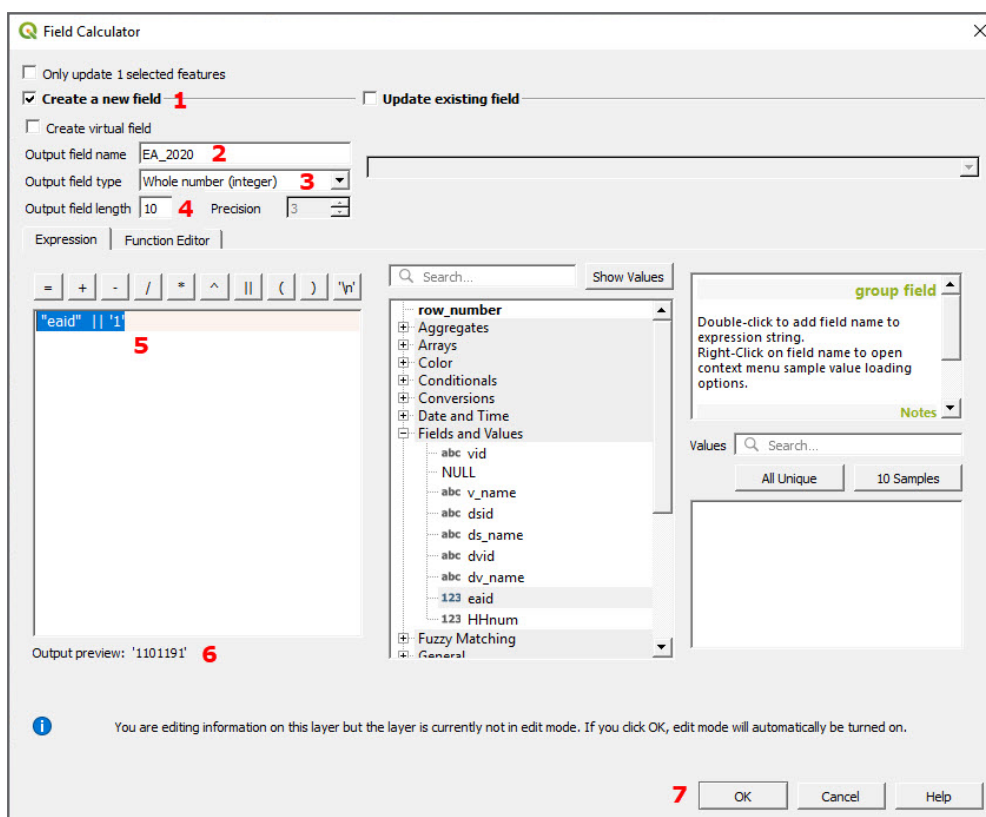


- j. A layer named *Count* will show in the **Layers** panel. Open its **ATTRIBUTE TABLE**  and check that the **HHNUM** field is displayed therein.

Using the **HHNUM** field we are now able to assess which EA polygons need to be adjusted to meet the EA size conditions. The EAs containing more than 60 HH will be **split** into smaller EAs, whereas the EAs with less than 40 HH will be **merged** with other adjacent polygons.


It is also necessary to create a new field to store the new EA codes for this updated EA framework. Rather than creating completely new codes, we will add a digit to previous EA codes to indicate the EAs that have been split (if we expect to split one of the EAs in more than 10 parts, then we will need to add two digits). For instance, after splitting the EA 110119, the resulting two new EAs will be coded as 1101191 and 1101192 respectively. If EA 110121 does not need to be split, it will be simply coded as 1101211.

- Go to the *Count* layer's **ATTRIBUTE TABLE**  and open the **FIELD CALCULATOR** by clicking on .
- Check the option **CREATE A NEW FIELD**.
- In **OUTPUT FIELD NAME**, type: **EA_2020**
- In **OUTPUT FIELD TYPE**, select the **WHOLE NUMBER (INTEGER)** option.
- In **OUTPUT FIELD LENGTH**, type: **10**
- In the **Expression** panel, type: **"eaid" || '1'**
- In **OUTPUT PREVIEW**, check that there are no error messages.
- Click **OK** and check the **ATTRIBUTE TABLE** to ensure that the field has been correctly generated.








- In the **Layers** panel, right-click over the *Count* layer and go to **EXPORT > SAVE FEATURES As...** and save it as *5_polygon_layers/Layers/TON_EA_2020_4326.shp*



We now have all the elements to start the updating process. From this point onwards, all the edits (splits, merge and recoding operations) will be done to *TON_EA_2020_4326.shp*

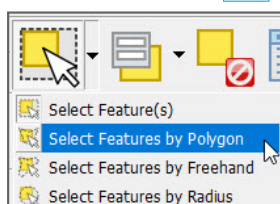
- j. To prevent unwanted changes in the original layer, *TON_EA_4326.shp*, we will remove it from the **Layers** panel by right-clicking on the layer and selecting **REMOVE LAYER**. Do not forget to save the changes to your project frequently by clicking on .

5.4.1 Split EA polygons

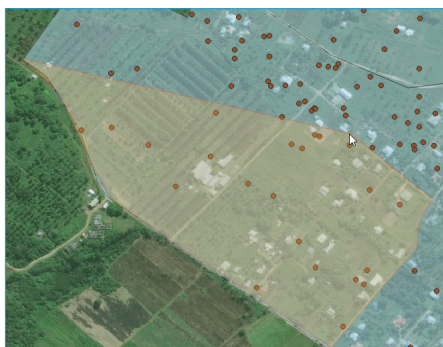
- Set the style of the layer with a transparent fill so that the satellite layer is visible underneath the polygon layer.
- Toggle the editing mode  for the layer *TON_EA_2020_4326.shp*
- Open the **ATTRIBUTE TABLE**  and sort the rows by **HHNUM** field by clicking on the field heading. Select an EA with more than 60 HH (e.g. EA 120307 with 217 HH inside) and click on  to zoom to the selected polygon. The EA polygon will appear in the map canvas highlighted in yellow.
- When splitting polygons, we will need to use  to select the polygons and  to clear the selection. Remember that before we start selecting the features from a layer, it is necessary to select the target layer in the **Layers** panel.

For example, for the EA 120307, we need to divide the polygon into four to five parts in order to meet the EA size requirements (40–60 HH). At the same time, we must have in mind that the limits of these new EAs need to be easily identifiable on the ground.

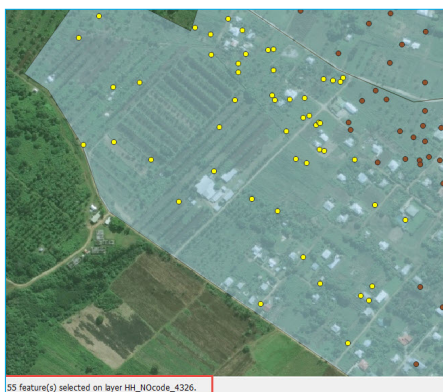
- Select *HH_NOcode_4326.shp* in the **Layers** panel and click on the tool **SELECT FEATURES BY POLYGON** (click on the arrow next to the  button to display the drop-down menu and click on .




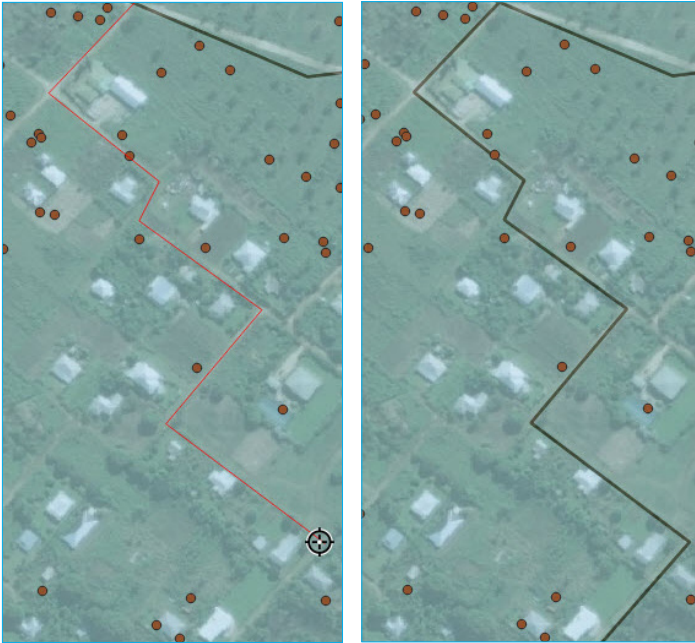
- Delineate a polygon by clicking consecutively to surround the points that will be included in the new split. Then right-click to finish the selection process.




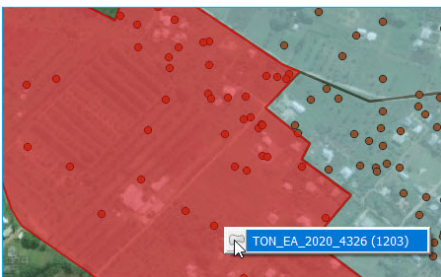
- The selected points will be highlighted in yellow. At the bottom of the interface, a message will appear indicating the number of points selected. There are 55 points selected with clear boundaries for our drafted polygon; this means that we can proceed with the polygon splitting process.




- h. Select *TON_EA_2020_4326.shp*, make sure that the editing session  is activated, and click on the **SPLIT FEATURES** button  located in the **ADVANCED DIGITIZING TOOLBAR**. Then trace the line that will cut the polygon in two parts by clicking consecutively on the left button. Click on the right button to finish the new boundary. When delineating the new boundary, make sure that the start and the end points of the line are out of the polygon that we want to split.



- i. Now that the EA has been divided into two features, we will double-check the number of points contained inside the new EAs. Select the point layer in the **Layers** panel, select  and right-click onto the new polygon. Select the polygon *TON_EA_2020_4326.shp* in the dialogue displayed. All the points within the polygon will be automatically selected. Check the number of points in the message located at the bottom of the interface.



- j. After splitting the polygon, you will find two identical rows in the layer's **ATTRIBUTE TABLE**. Consequently, it is necessary to assign a different EA code to the new EA polygon. Select the new EA polygon using  and find the row that corresponds to the polygon highlighted in blue in the **ATTRIBUTE TABLE**. Assign a new code to the field **EA_2020** (e.g. 1203072).

- k. Click on  to save your edits.

Now we will repeat these steps to create four EAs coded 1203071, 1203072, 1203073 and 1203074 containing 40–60 HH each. The process should be repeated with all the EAs with more than 60 HH inside.



5.4.2 Merge EA polygons



If there are EAs containing too few HH, we can merge them with other existing EAs in order to meet survey-sampling conditions or to better manage fieldwork.

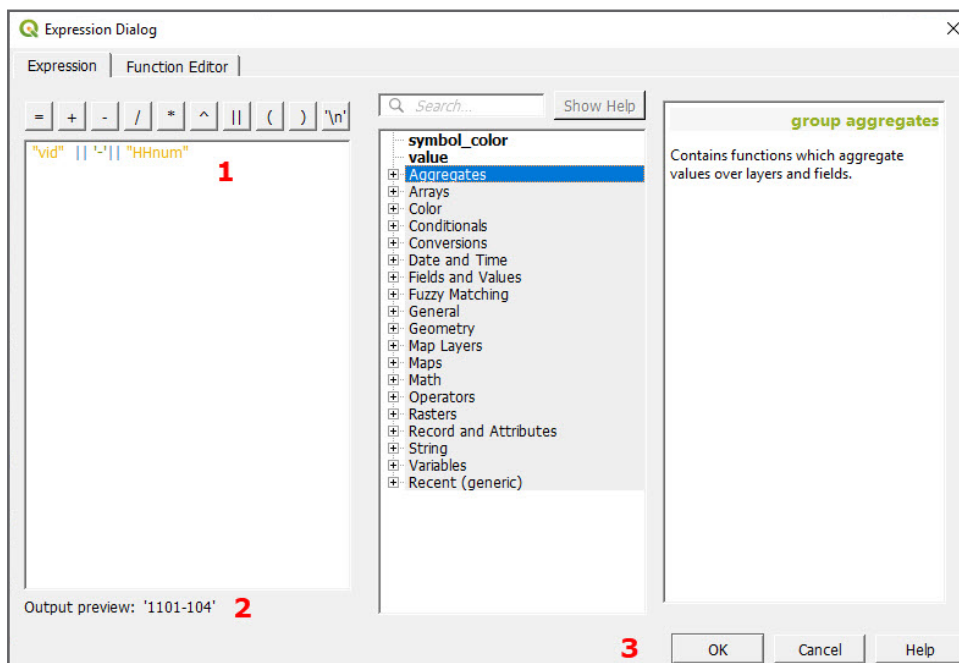
IMPORTANT

Only EAs belonging to the same village/district/ward can be merged together. By following this rule, the administrative levels' hierarchy will be preserved.

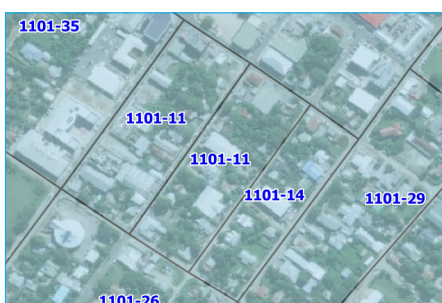
- Open the **ATTRIBUTE TABLE**  and sort the rows by **HHNUM** field by clicking on the field heading. Select one of the EAs with less than 40 HH.

We will use labels to help identify the EAs that need to be merged and whether or not they can be merged with those adjacent.




- Select **TON_EA_2020_4326.shp**, open the **Layer Properties** panel and go to the **LABELS** section.
- Select the **SINGLE LABELS** option in the first drop-down menu.
- In the **VALUE** menu, click on  to open the **Expression Dialog** and type the following expression in the blank panel: `"vid" || '-' || "HHnum"`
 - With this expression, we are creating a label that displays the village code and the number of HHs together.
 - An alternative method is to use the **IDENTIFY FEATURES** tool  and check one by one the information regarding each polygon.
- Check the **OUTPUT PREVIEW** message that there are no errors in the expression and click **OK**.

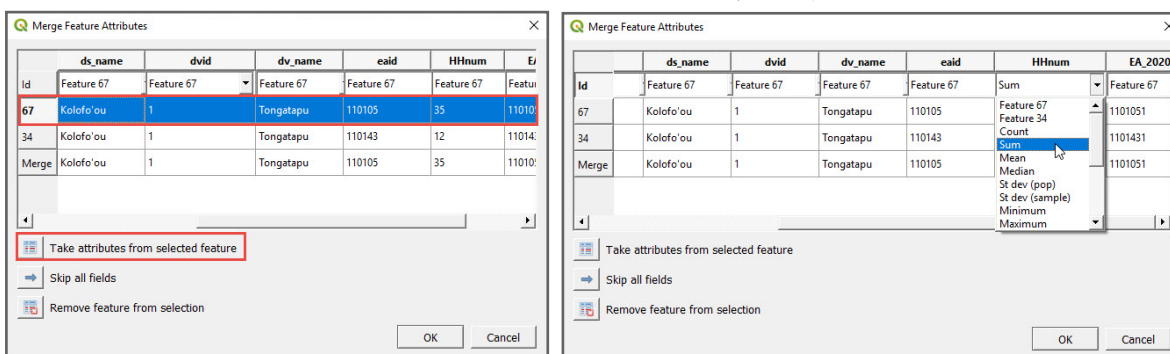


- Set a visible label style in the map (big fonts and a contrasting colour) and click **OK**.



With these labels displayed on the map, we can easily identify which EAs need to be merged and, among these, which ones meet the condition of belonging to the same village (two EA polygons belong to the same village when the first two digits of their EA codes are equal).

- Make sure that the editing session is activated .
- Use the  button and select the multiple EAs that will be merged into one by pressing **Shift** + clicking.
- Click on the **MERGE SELECTED FEATURES** tool .
- The **Merge Features Attributes** panel will be displayed. In this panel, we can control which values will keep the fields of the merged polygon.
- In this example, we will select one of the rows and then click on **TAKE ATTRIBUTES FROM SELECTED FEATURE**.
- Another option is to fill the fields of the row titled **MERGE** using the options located in the drop-down menus in the top row. In this instance, we will add the number of HH by using the option **SUM** in the **HHNUM** field.



- Once the fields are ready, click **OK** to complete the merging process.



5.5 Layer styles

5.5.1 Suitable symbology when displaying administrative boundaries

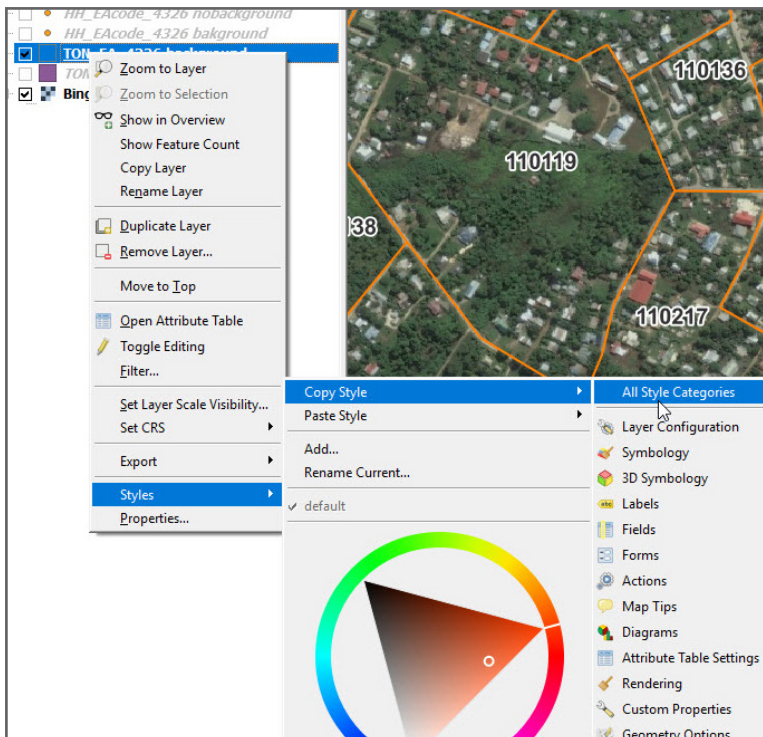
When representing administrative boundaries, it is necessary to establish some basic standards in order to prepare clean and comprehensive maps. When we load a polygon layer into the map canvas, QGIS sets by default a random symbology that, in most cases, is not suitable.

It is important to prioritise an appropriate symbology if you will be working with a layer for a long period of time or it will be included in a map.

Fill: We tend to use pale/pastel colours and avoid bright and dark colours. If you are planning to use a satellite image background, you will need to adjust the transparency of any polygon layers to make this background visible beneath.

Border/Stroke: We tend to use colours that contrast with the fill colour to better distinguish the boundaries of the polygons. We can play with the width of the line to increase or decrease the limit's visualisation, keeping in mind that the wider the lines, the less accurate they become in the map.

- h. A way to copy a layer's format is by using the **COPY/PASTE** styles tool. Right-click on the layer in the **Layers** panel and select **STYLES > COPY STYLE > ALL STYLE CATEGORIES**.
- i. Select a different polygon layer and go to **STYLES > PASTE STYLE > ALL STYLE CATEGORIES**. By selecting **ALL STYLE CATEGORIES**, you will transfer all the settings already configured in the original layer. To transfer only one of the categories, we will choose one of the categories displayed in the menu and paste it into the other layer.



5.5.3 Layers themes

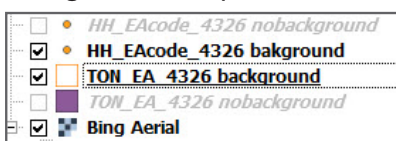
The **THEMES** tool , located at the top of the **Layers** panel, allows the user to create themes to:


- control the visibility of the layers in the map canvas;
- reference the style of each layer included in the theme;
- run some of the settings related to the legend configuration in the **Print Layout** interface.

This tool is very useful when there are different layouts and maps configured in one single project. This allows us to change from one map to another without checking/unchecking each layer one by one.

In this example, we will set two themes: one theme for a map with satellite background and another for a map without background.

- a. In the **Layers** panel, select the layer with the satellite image background. The layer style has already been configured in the previous section.

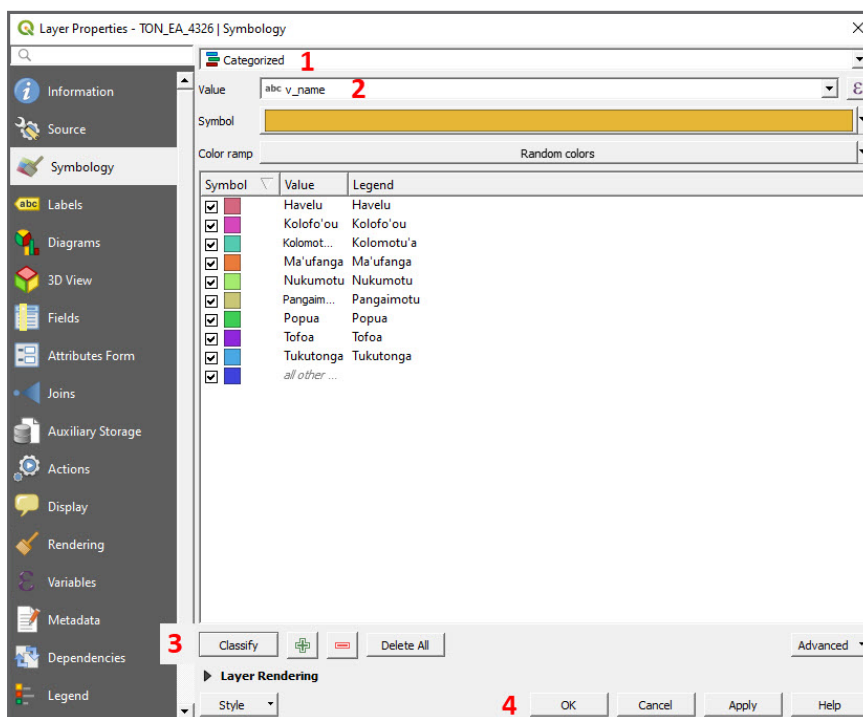


- b. Click on  and select the **ADD THEME** option.
- c. Add a name for the new theme (e.g. Background) and click on **OK**.
- d. When you open the **THEMES** menu, you will notice that the theme created is now available.
- e. Next, create a theme for the layers without the satellite background (do not forget to disable the satellite layer) and practise switching between themes in the map interface.

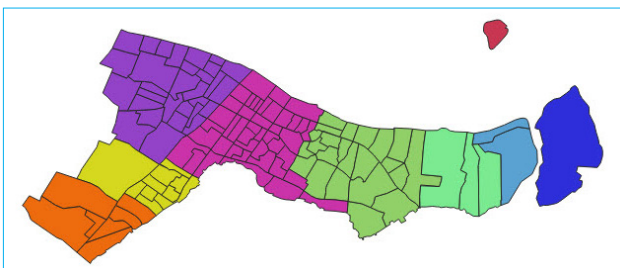
5.5.4 Categories, graduated and rule-based styles

Symbology using categories

- Load the layer `5_polygon_layers/Layers/TON_EA_Pop_4326.shp` into the map canvas.
- Open the **Layer Properties** panel and go to **SYMBOLOLOGY**.
- In the top drop-down menu, select **CATEGORIZED**.
- In **VALUE**, chose the field that we want to use to generate the different categories. In this example, we want to map different villages in the map, so we will choose either the village code (**VID**) or the village name (**V_NAME**).
- Click on **CLASSIFY** and all the categories will be displayed in the panel above. It is possible to check/uncheck the villages you do not want to display on the map. If you double-click on a symbol, the **Symbol Selector** panel will appear, allowing you to change the colour of each category individually.



- When you have finished modifying the symbology click **OK**.




Graduated symbols

Graduated symbols can be used to generate a choropleth map (a thematic map where areas are shaded or coloured in proportion to the measurement of a continuous variable). When using a choropleth map, the variable **MUST** be standardised. The most common ways to standardise data are to divide the data by the **area** or by the **total number** of elements in this area (in our case, people or HHs).

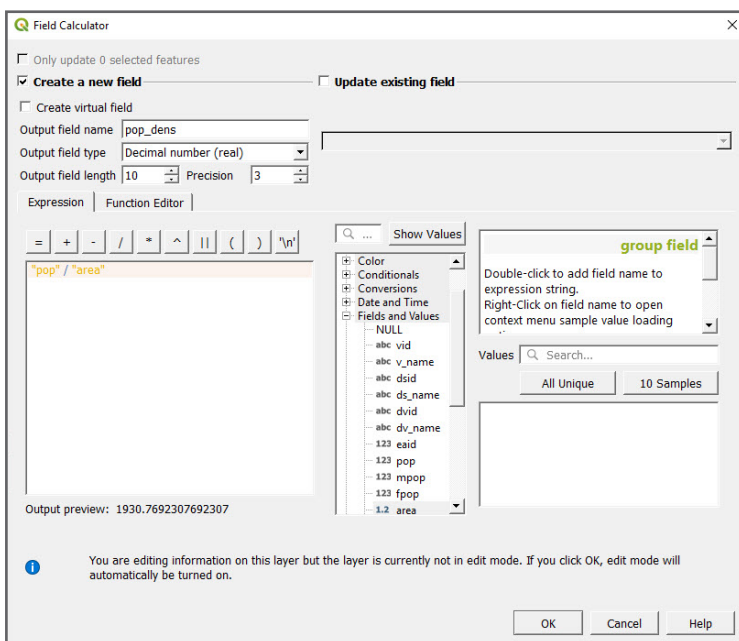
Before starting to use the graduated symbols we need to standardise our population data using the area and afterwards create a field with the population density information.

We will first create the field that stores the area of each EA polygon.

- a. Load again or duplicate the *TON_EA_Pop_4326.shp* layer.
- b. Open the **ATTRIBUTE TABLE** and then open the **FIELD CALCULATOR** .
- c. Using the **FIELD CALCULATOR** we are going to create a field that represents the population density.
- d. In **OUTPUT FIELD NAME**, type: *area*
- e. In **OUTPUT FIELD TYPE**, select **DECIMAL NUMBER (REAL)** with **FIELD LENGTH** = 10 and **PRECISION** = 3
- f. In the **Expression** panel, type: $\$area / 1000000$
(Note that, by default, when using WGS 84, QGIS will calculate the areas on square metres; we divide by 1,000,000 to convert the area units into square kilometres, which is a more standard unit to measure population density.)
- g. Click **OK** and check that the field has been correctly created in the **ATTRIBUTE TABLE**.

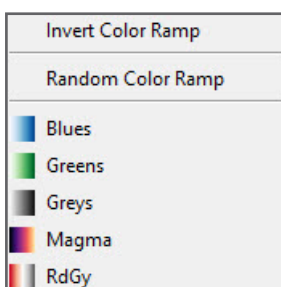
Then we calculate the population density by dividing the population by the area.

- h. In **OUTPUT FIELD NAME**, type: *pop_dens*
- i. In **OUTPUT FIELD TYPE**, select **DECIMAL NUMBER (REAL)** with **FIELD LENGTH** = 10 and **PRECISION** = 3
- j. In the **Expression** panel, type: $"pop" / "area"$
- k. Click **OK** and check that the field has been correctly created in the **ATTRIBUTE TABLE**.

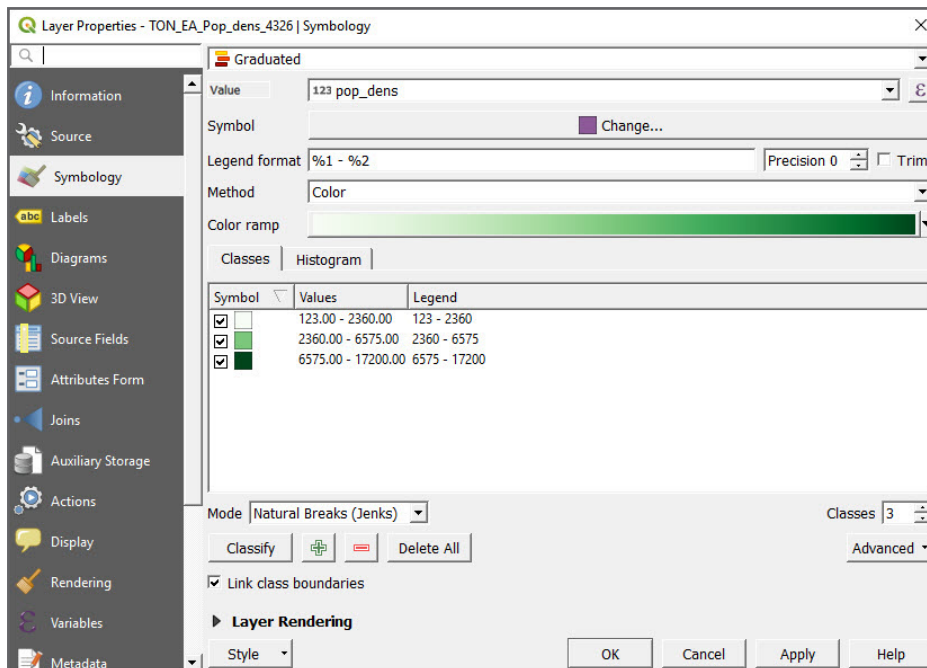


Now that we have the population density field, we can start designing our choropleth map.

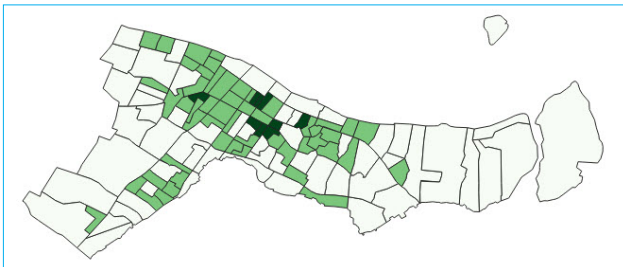
- l. Open the **Layer Properties** panel and go to the **SYMBOLOLOGY** section.
- m. In the top drop-down menu, select the **GRADUATED** option.
- n. In the **VALUE** section, select the **POP_DENS** field.
- o. Click on the arrow located at the right of the **COLOR RAMP** to open the drop-down menu.
- p. Select one of the proposed colour ramps.



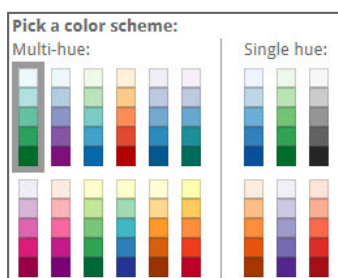
- q. In **MODE**, select the **NATURAL BREAKS (JENKS)** method to classify the data.
- r. In **CLASSES**, choose **3** and click **CLASSIFY**.



- s. Click **OK**.

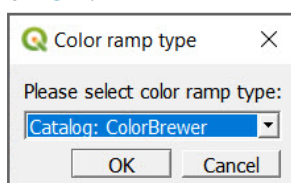


Population densities are best represented by green, orange or brown colour ramps. In general, it is best to use colours that have clearly distinguishable shades. In the image below we can see some of the palettes proposed at the COLORBREW 2.0 website (<http://colorbrewer2.org>).

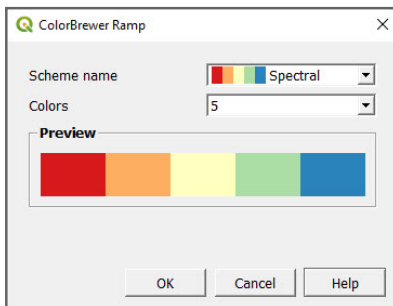


Colour brewer palettes are available in QGIS.

- a. Go to the **Layer Properties** panel and select **SYMBOLOLOGY**, then click on the arrow located to the right of the **COLOR RAMP** to open the drop-down menu.
- b. In the drop-down menu, select **CREATE NEW COLOR RAMP...**, choose the **CATALOG: COLORBREW** option and click on **OK**.





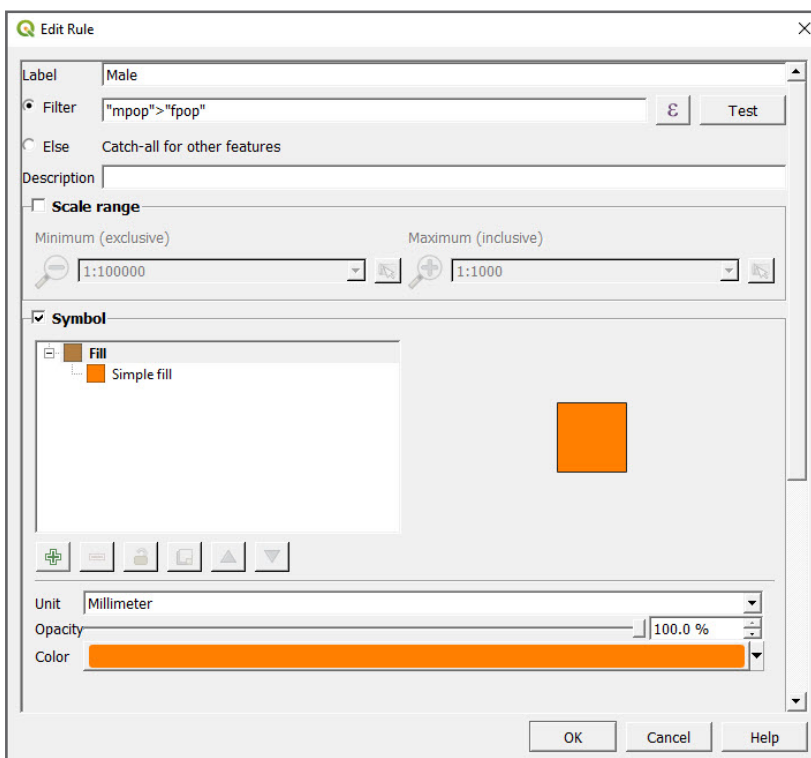
- c. A specific menu to configure the colour ramp using colour brewer schemes will appear after clicking on **OK**.




Rule-based symbols

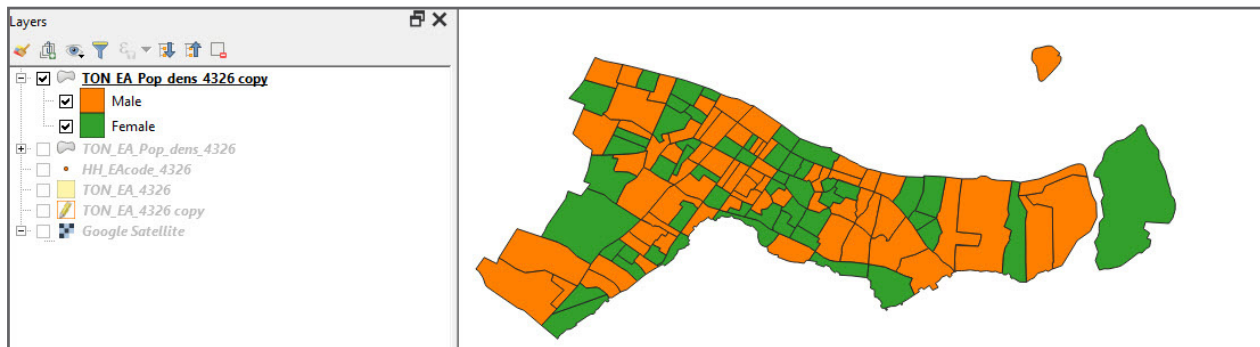
In QGIS, it is possible to set rules to control a layer's symbology. For this example, we will set different symbols for EAs where there are more males than females and vice versa.

- Reload or duplicate the *TON_EA_Pop_4326.shp* layer.
- Open the **Layer Properties** panel and go to the **SYMBOLOLOGY** section.
- In the top drop-down menu, select the **RULE-BASED** option.
- Click on  to add the first rule and the **Edit Rule** panel will appear.
- In **LABEL**, type: **male** or the name you want for this category.
- In **FILTER**, click on , type the following expression: `"mpop">"fpop"` in the **Expression** panel and click **OK**.
- Click on **TEST** to check whether the expression works or not. Select a colour for the symbol and click **OK**.



- Click on  to add the second rule.
- In **LABEL**, type: **female**
- Check the **ELSE** option. This will catch all the EAs not included in the previous rules. In this case, this rule will bear on the EAs with fewer numbers of males than females.


- k. Click **OK** and check the results on the map interface.

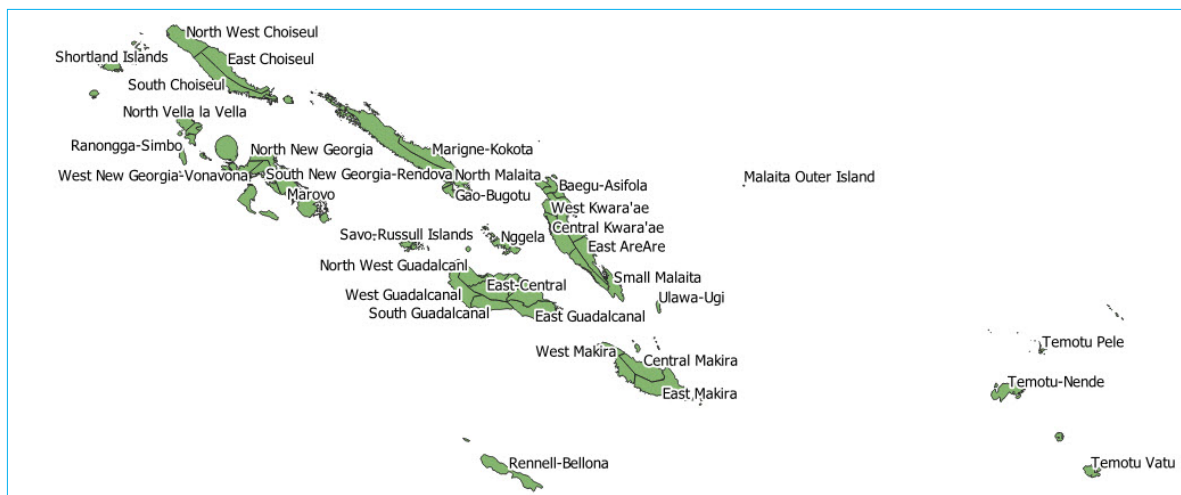


5.6 Advanced labelling

In this section, you will learn some ways to improve your labelling skills, which will help you to improve the quality and visibility of the information displayed.

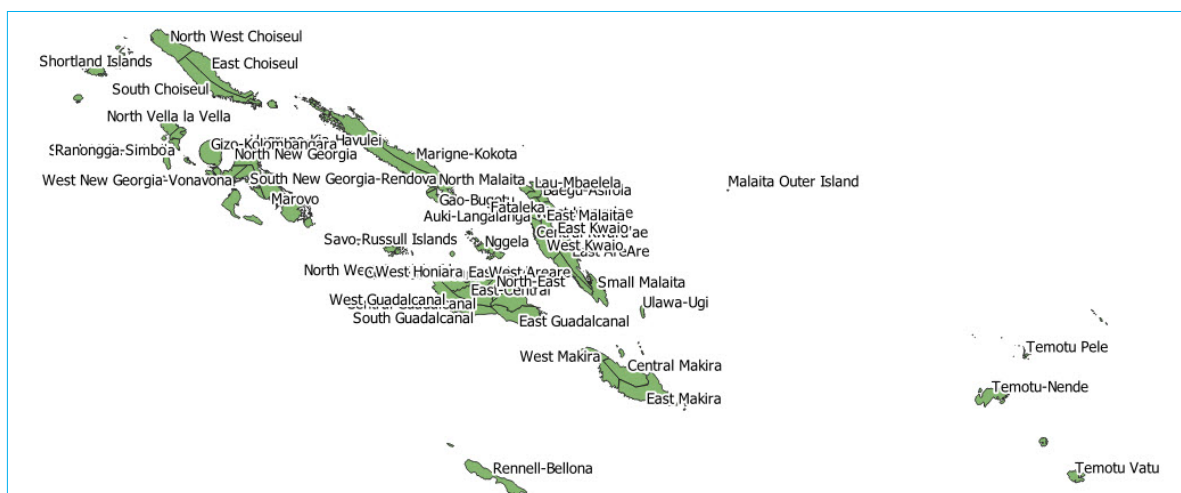
5.6.1 Custom labelling placement

- Open a new QGIS session or a new project by clicking on .
- Load `5_polygon_layers/Layers/Sol_Pop_cid_4326.shp`
- Open the **Layer Properties** panel and go to the **LABELS** section. Generate labels using the **CNAME** field and set a proper format to improve the readability of the layers.











Note that in the image above there are several labels missing. If there are a significant number of labels in the displayed area, QGIS "hides" by default the labels that overlap with others.

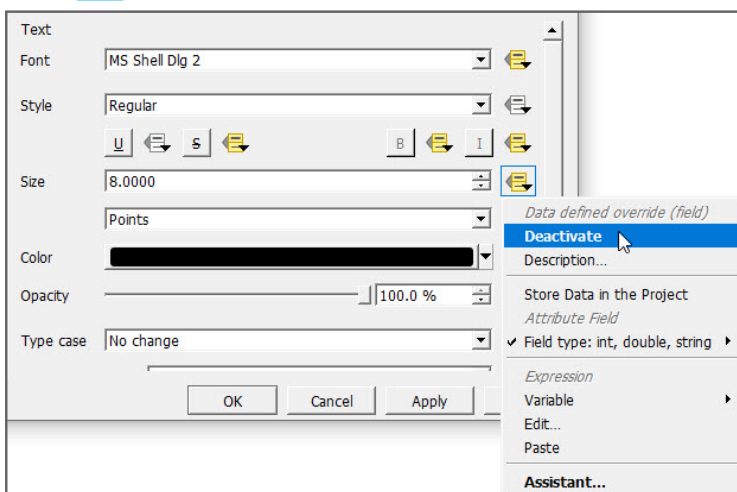
- To change this, under **LABELS**, select the **RENDERING** submenu and check the option **SHOW ALL LABELS FOR THIS LAYER**.



To solve the problem with label placement we will use the labelling engine that comes built in inside QGIS 3.10 LTR. Among other functions, this tool allows the user to modify each label as an independent entity and set the position of each label manually, which is very useful when producing layouts with large amounts of labels.


- e. If this toolbar  is not visible in the top menu, right-click on the top menu, and in the **TOOLBARS** section, select **LABELS TOOLBAR**.
- f. Click on  to open the **Layer Styling** menu.
- g. To show/hide labels, select . Hide the label by pressing **Shift** + clicking. To show the label again, click over the feature.
- h. To change the location of the labels, select , then click and hold over one of the labels and drag it to its new position.
- i. To rotate labels, select , then click and hold over the label to change its orientation.
- j. To change the format of an individual label, select , then click over the label you want to modify. A menu will appear allowing you to change the settings, such as the font and the buffer.

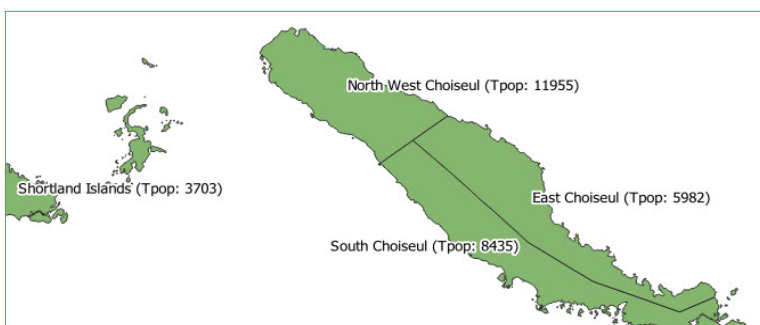
We are still able to modify settings from the **LABELS** menu in **Layer Properties**. It is important to keep in mind that once we have activated a tool from the **LABELS TOOLBAR**, the **LABELS TOOLBAR** will exclusively control the label settings replacing the **LABELS** menu. However, it is possible to return control to the **LABELS** menu. For example, to be able to again modify the size setting from the **LABELS** menu, click on  and then select **DEACTIVATE**. The control will change to . From now on, the parameter is controlled exclusively from the menu.



5.6.2 Complete layer symbology with labels

In this exercise, we will use labels to add additional information to our map. For example, we will display the population figures for each council area in the labels thanks to QGIS's simple expression language commands.

- a. Load **5_polygon_layers/Layers/Sol_Pop_cid_4326.shp**
- b. Open the **Layer Properties** panel and go to **LABELS**. Select the **SINGLE LABELS** option and click on .
- c. Insert the following expression: **"CName" || ' (Tpop: ' || "sol_tpop" || ')**
- d. Modify the settings (font size, buffer) to improve the readability of the layers.




Using an expression, we will now add values to the labels without needing to create new fields.

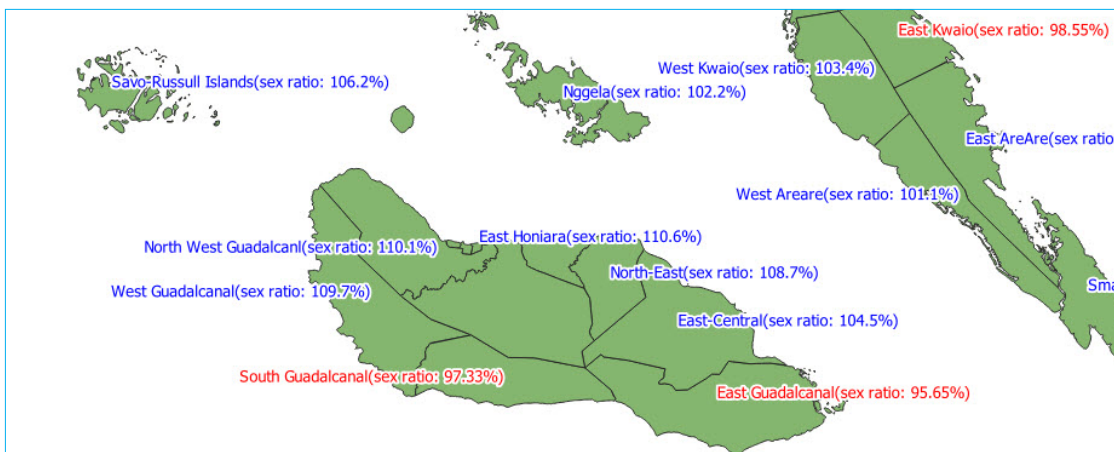
- e. By entering the following expression: `"CName" || '(sex ratio: ' || left(("sol_mpop" / "sol_fpop"),5) || '%')` the sex ratio for each council area will be added to the label.

Note that we could have created a new field on the **ATTRIBUTE TABLE** using `left(("sol_mpop" / "sol_fpop"),5)` and this new field could have been used to control the content of the layers. However, the method shown above is faster and more flexible.


We can also use expressions to control the colour of the labels.

- f. In the **LABELS** section, go to the **TEXT** subsection and at the right side of the **COLOR** control, click on  and select **EDIT**.
- g. An **Expression String Builder** panel will show. Enter the following expression:
`case when ("sol_mpop" / "sol_fpop") >= 1 then color_rgb(0,0,255) when ("sol_mpop" / "sol_fpop") < 1 then color_rgb(255,0,0) end`

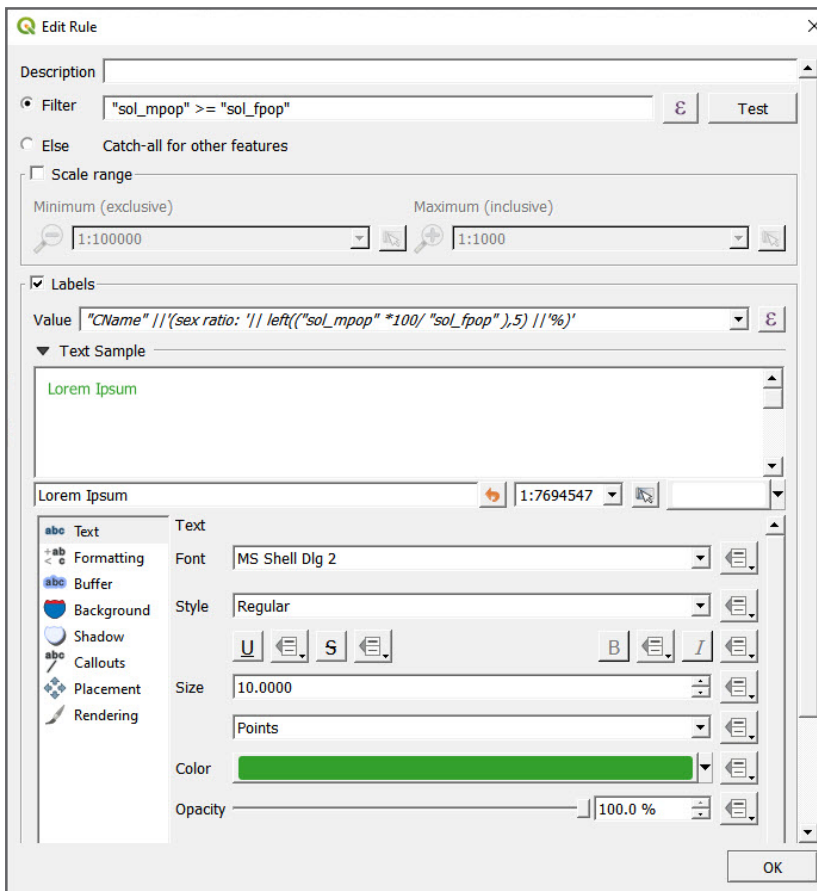
You can now see on the map that the labels' colours are controlled according to whether the sex ratio is greater or less than 100%.




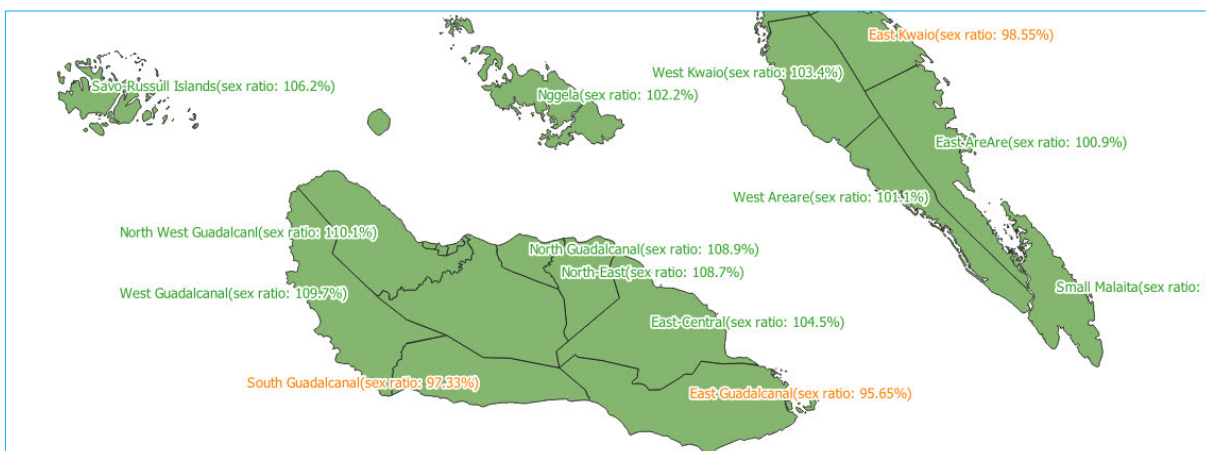
As an alternative to the expressions method, we could use the rule-based labelling option. We still need to use expressions but they are simpler.

- a. Load `5_polygon_layers/Layers/Sol_Pop_cid_4326.shp`
- b. Open the **Layer Properties** panel and go to the **LABELS** section. Select **RULE-BASED LABELING** and click on  to add a new rule.
- c. In **FILTER**, add the following expression for the cases where the number of males is greater than the number of females: `"sol_mpop" >= "sol_fpop"`
- d. Under **VALUE**, we will still use the same expression to generate the compound labels:
`"CName" || '(sex ratio: ' || left(("sol_mpop" *100/ "sol_fpop"),5) || '%')`

- e. Set the **COLOR** (green, for instance), the **BUFFER** and all other settings to improve readability.





- f. Add a new rule .
- g. In **FILTER**, insert the following expression: `"sol_mpop" < "sol_fpop"`
- h. An alternative option is to check the option **ELSE**.
- i. Use the same expression for the labels at **VALUE**.
- j. Set the colour (orange), buffer and all other settings to improve readability.

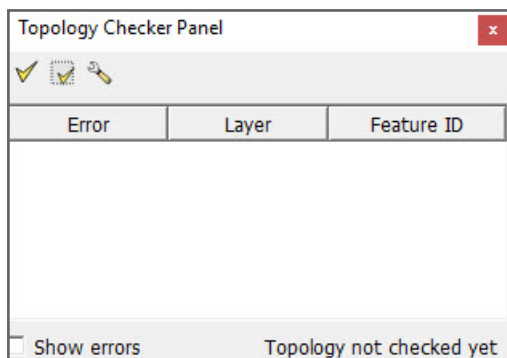



6. Polygon layers: Enumeration areas (advanced vector analysis)

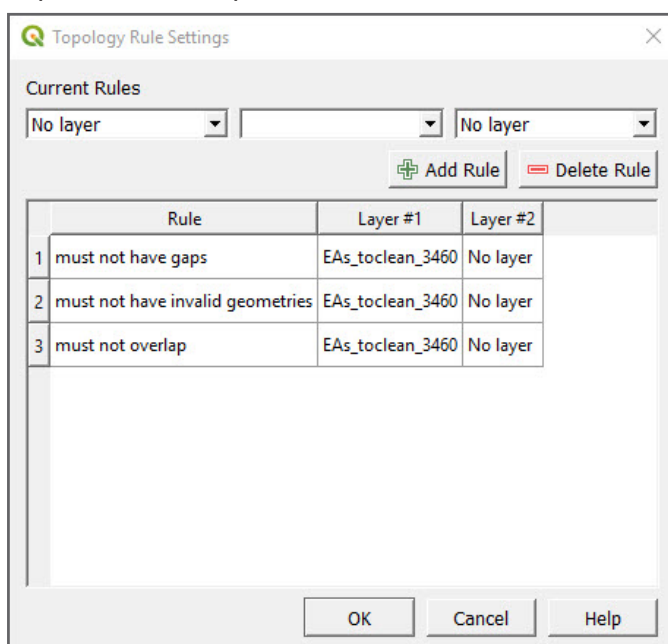
6.1 Topology cleaning: Finding and fixing gaps, geometric errors and overlaps


QGIS has a collection of snapping/intersection tools that are useful for creating new features while avoiding topological errors. For layers that already contain errors, there is a plugin that simplifies the tedious task of finding the often very small overlaps, gaps, etc., and repairing them.

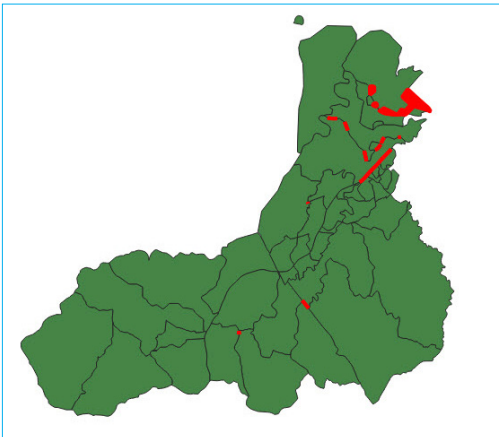
- Open a new QGIS session or a new project by clicking on .
- Load [6_polygon_layers_advanced/layers/EAs_toclean_3460.shp](#). It is recommended that you create a copy of the file and edit the copy rather than the original. We will save the original as a backup in case of any irreparable mistakes.
- Go to **PLUGINS > MANAGE AND INSTALL PLUGINS** and make sure that the **TOPOLOGY CHECKER** plugin is installed and enabled.
- Open the **Topology Checker** panel either by going to **VECTOR > TOPOLOGY CHECKER** or by clicking on  in the top menu. A panel will appear, like the one below.






- Click on **CONFIGURE**  and the **Topology Rule Settings** will appear.
- In the first drop-down menu, select the layer for which we are going to check the topology; in this example, [EAs_toclean_3460.shp](#)
- In the next drop-down menu, select **MUST NOT HAVE GAPS** (this finds any gap errors contained in the layer). Next, click on **Add Rule** and the new rule will be added to the panel located below.
- Repeat the same operation for **MUST NOT HAVE INVALID GEOMETRIES** and **MUST NOT OVERLAP** rules and click **OK**.




- i. Click on  to validate all the rules over the layer. A list containing all the topology errors will be shown.
- j. Check the **SHOW ERRORS** option located at the bottom-left corner of the menu to highlight the errors on the map.

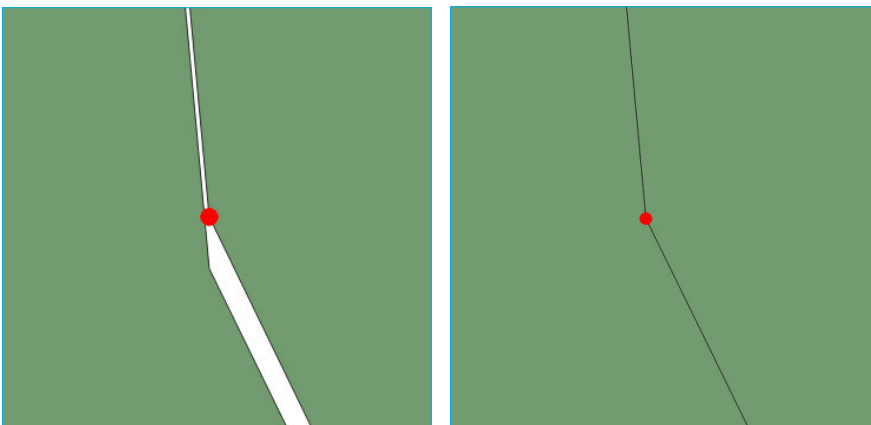





- k. Before we start fixing the various errors, we need to first activate the editing session .
- l. Check that the **SNAPPING** tool  is enabled and the **TOPOLOGICAL EDITING** option  deactivated.
- m. Make sure that the reference system used in the project is the same as that used for the layer to ensure that the program zooms on the right place when selecting the errors to be corrected.

6.1.1 Fixing gaps

When working with administrative boundaries, all polygons must form a continuous surface without gaps inside or between polygons. It is important to remember that two polygons with coincident boundaries have to maintain a NODE-TO-NODE connection. This means that if you snap a node to an adjoining polygon's side, unconnected to the pre-existing nodes, this will generate a gap error, even though there is not a void between the two polygons.

- a. In the **Topology Checker** panel, click on one of the **GAPS** errors and the map will zoom over it. Uncheck the **SHOW ERRORS** option to improve the visibility of the gap.
- b. Activate the **VERTEX TOOL** , click on the vertex and drag it to make it match with the opposite one.




- c. In case you need to create or delete a vertex to fix a topology error you need to follow these steps.
Create a vertex: When hovering with the cursor over the boundary of the polygon, a virtual new node appears on the centre of the segment. Click on it and move it to the desired position.
Delete a vertex: Select the vertex by pressing **Shift** + clicking on it or by clicking and dragging a rectangle around one or more vertices. When a vertex is selected, the colour will change to blue. To delete the selected vertices, press **Delete**.
- d. Click on **VALIDATE EXTENT**  to ensure that the gap error has been corrected in the zone we are currently working. If the topology problems are fixed, no errors will show in the **Topology Checker** panel. Click again on the **VALIDATE ALL** button  and correct a few more gaps to correctly learn and understand this process.
- e. Click on  to save the edits.

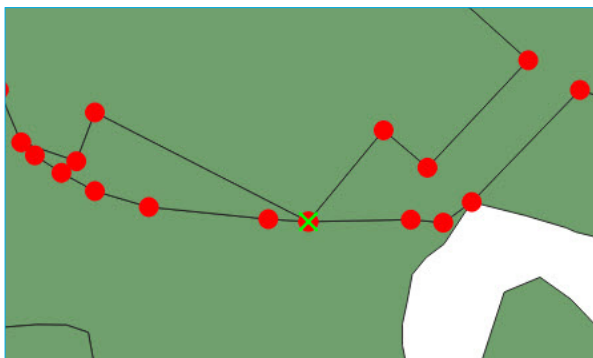
6.1.2 Fixing invalid geometries

If an invalid geometry error is detected, it means that the polygon structure is incorrect.

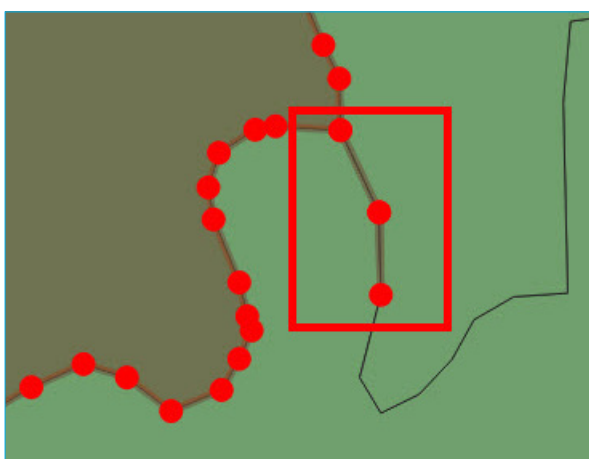
- a. At the **Topology Checker** panel, click one of the **INVALID GEOMETRIES** errors to zoom over it.

The easiest invalid geometries errors are the ones generated by two or more overlapping vertices.

- b. Use the **VERTEX TOOL**  and lock the polygon by right-clicking on it. The overlapping vertices are easy to spot, as they appear highlighted with a green cross. To fix these types of errors it is necessary to delete or separate the overlapping vertices.




In other cases, the polygon is totally compressed, generating a line.



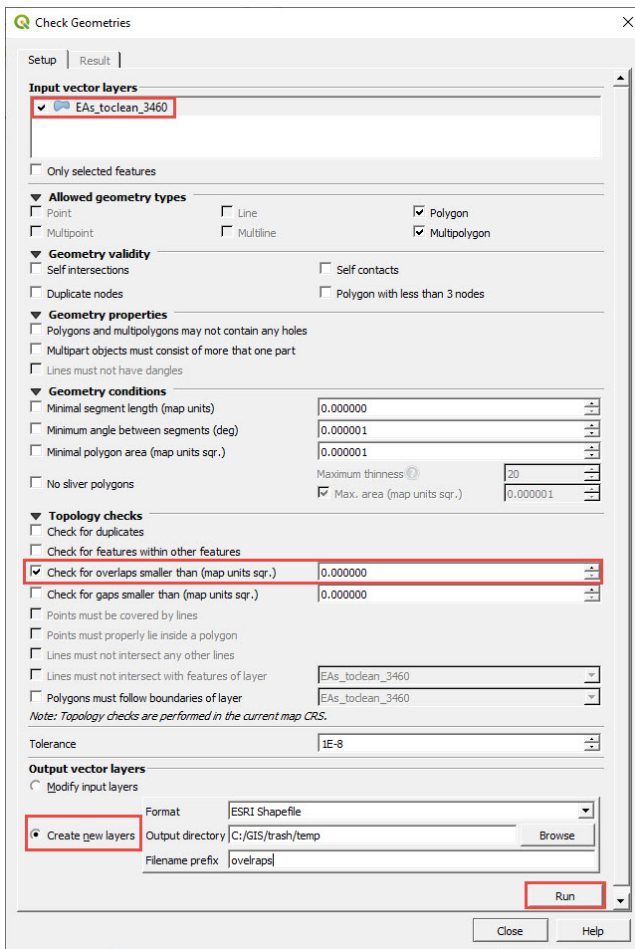
6.1.3 Fixing overlaps

- a. In the **Topology Checker** panel, click one of the **OVERLAPS** errors to zoom to it. Notice that the entire polygon containing the error is highlighted in green.

The problem we face here is that we do not know the precise location of the overlap. In most cases, finding this overlap is a tedious process that can be accelerated by using the built-in Geometry checking tool.


- b. Deactivate the editing session  for the *EAs_toclean_3460* layer.
- c. Go to **VECTOR > CHECK GEOMETRIES...** to open the **Check Geometries** panel.
- d. Select the **SETUP** tab to configure the checks that will be undertaken by the tool.
- e. In **INPUT VECTOR LAYERS**, make sure that the layer *EAs_toclean_3460* is selected.
- f. In **ALLOWED GEOMETRY TYPES**, check **POLYGON** and **MULTIPOLYGON** options.
- g. Given that our main objective is to accurately locate the overlaps, we will uncheck all the options enabled by default in the **GEOMETRY VALIDITY**, **GEOMETRY PROPERTIES** and **GEOMETRY CONDITIONS** sections.
- h. In **TOPOLOGY CHECKS**, select **CHECK FOR OVERLAPS SMALLER THAN (MAP UNITS SQR.)** and leave the default value 0.000000.
- i. In **OUTPUT VECTOR LAYERS**, check the **CREATE NEW LAYERS** and select the format and location for the new layer.

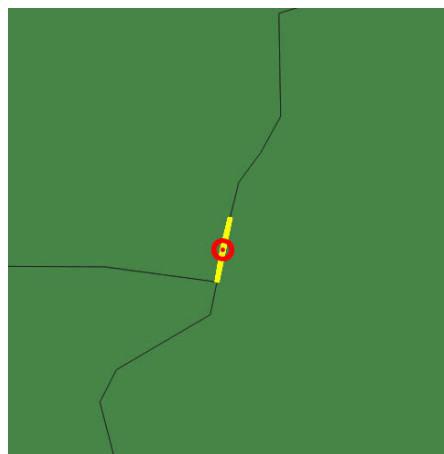
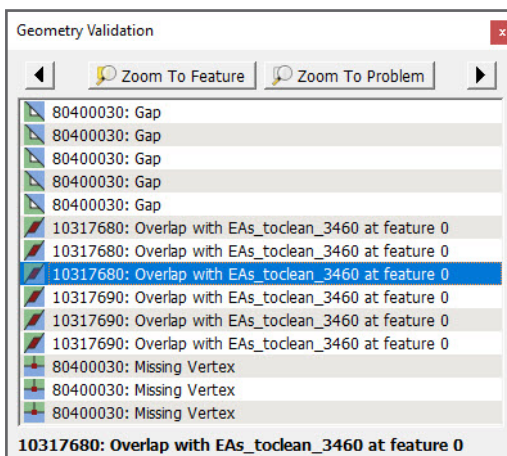
- j. Click on **Run** to start the checking process.




- k. The **RESULT** tab will be automatically opened and will display all the overlap errors in the table at the **GEOMETRY CHECK RESULT SECTION**.
- l. In **WHEN A ROW IS SELECTED, MOVE TO CANVAS TO** section, make sure that the options **ERROR** and **HIGHLIGHT CONTOUR OF SELECTED FEATURES** are checked.

As a result of the checking process, a new layer named *overlapsEAs_toclean_3460* will be added in the **Layers** panel.

- m. Put this new layer below *EAs_toclean_3460*. We will use *overlapsEAs_toclean_3460* to locate the errors, but we will still be editing and fixing *EAs_toclean_3460*.
- n. Activate the editing session  for the *EAs_toclean_3460* layer.
- o. Then in the **Check Geometries** panel, click on one of the rows in the table. The map will zoom to the exact position where the overlap error is located, highlighting it in yellow, and surrounding it with a red circle.





- p. Using the **VERTEX TOOL**, drag, create and delete nodes to align the boundaries, ensuring that there are no missing or unshared vertices along the boundary. This is one of the main reasons why overlap errors occur.
- q. It is recommended that you first clean all the gaps before starting with the overlap errors, as many gap and overlap errors are closely related at the boundaries between polygons.
- r. Do not forget to save your edits regularly by clicking on .


Prior to working with a polygon layer, it is recommended that you check and fix the topology. Topology errors can cause a variety of problems when undertaking more complex operations with the layers.

6.2 Table join


In this section, we will import external data from a table and connect it to a shapefile. First, we will load the shapefile of the ward boundaries of Solomon Islands.

- a. Open a new QGIS session or a new project by clicking on .
- b. Load *6_polygon_layers_advanced/layers/Sol_Ward_4326.shp*
- c. Open the **ATTRIBUTE TABLE**  and check the available information, including codes and names for the wards and the provinces.

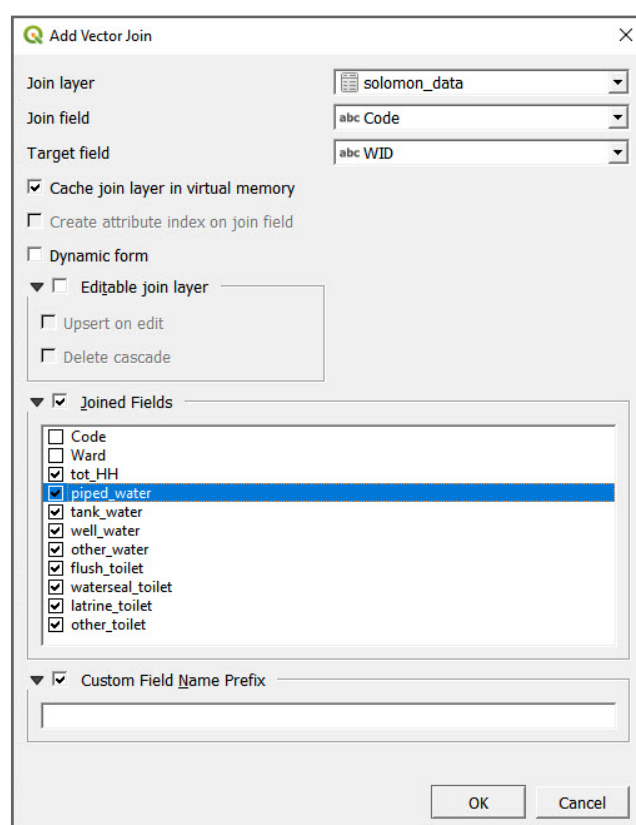
When importing tables into QGIS, it is important to bear in mind that QGIS cannot read *.xls* or *.xlsx* files. Thus it is necessary to save all tables in Excel in CSV (MS-DOS) format. The table we will import contains water and sanitation data from the 2009 census at ward level.

- d. Go to **LAYER > DATA SOURCE MANAGER** or click on .
- e. Go to the **DELIMITED TEXT** section.
- f. In **FILE NAME**, select *6_polygon_layers_advanced/tables/solomon_data.csv*
- g. In **FILE FORMAT**, check the **CSV (COMMA SEPARATED VALUES)** option.
- h. In **GEOMETRY DEFINITION**, check the **NO GEOMETRY** option.
- i. Check the **SAMPLE DATA** to ensure that the preview of the data looks good and click **Add**. The table will be displayed in the **Layers** panel.

Now we are going to import the external table into the **ATTRIBUTE TABLE** of the shapefile and add new fields to our layer.

- j. Open *Sol_Ward_4326.shp*. From the **Layer Properties** panel, go to the **JOINS** section.
- k. Click on  to open the **Add Vector Join** menu.
- l. In **JOIN LAYER**, select *solomon_data*
- m. In **JOIN FIELD**, select **Code**
- n. In **TARGET FIELD**, select **WID**
- o. In **JOINED FIELDS**, select the fields that you want to transfer from the *solomon_data* table to the layer's **ATTRIBUTE TABLE**. In this instance, we will select all the fields except **Code** and **Ward** as they are already included in the layer.
- p. Remove all the text that appears by default in **CUSTOM FIELD NAME PREFIX**.
- q. Click **OK** and check in the **ATTRIBUTE TABLE** if the new fields have been added.

Note that for the moment these fields are temporary. To store the fields permanently within the layer's **ATTRIBUTE TABLE**, we need to save the layer with the attached table as a new shapefile.




- r. Right-click on the layer and select **EXPORT > SAVE FEATURES AS...**
- s. Enter the name and the location of the new layer and click **OK**. We will call this layer *Sol_ward_censusdata.shp*

6.3 Field calculator: Basic expressions

In this section, we will use the field calculator to manipulate data imported from tables and prepare fields with water and sanitation indicators that can be mapped using choropleths (this symbology must be used with rates or percentages).

- a. Load *6_polygon_layers_advanced/layers/Sol_Ward_CensusDatatest_4326.shp*


Using the imported fields, we are going to create the following water, sanitation and hygiene (WASH) indicators: percentage of HHs with access to safe drinking water sources and percentage of HHs with access to safe toilet facilities. For these examples, we will consider piped and tank water as safe drinking water sources. Flush and water sealed will be considered as safe toilet facilities. This is a GIS practice exercise and we are aware that WASH technical considerations are much more complex when classifying water and sanitation sources and facilities as safe/unsafe. Therefore, the results from this exercise should not be taken into account as a contrasted analysis.

- b. Open the **ATTRIBUTE TABLE** and click on  to open the **FIELD CALCULATOR**.
- c. Check the option **CREATE A NEW FIELD**.
- d. In **OUTPUT FIELD NAME**, type: *safe_water*
- e. In **OUTPUT FIELD TYPE**, select **DECIMAL NUMBER (REAL)**.
- f. In **OUTPUT FIELD LENGTH**, set **3**, and for **PRECISION**, set **2** (we are working with percentages like 20.25% or 100.00%; therefore, we do not expect longer strings).
- g. In the **Expression** panel, type the following formula:

$$(\text{to_int}(\text{"piped_w"}) + \text{to_int}(\text{"tank_w"})) / \text{to_int}(\text{"tot_HH"}) * 100$$

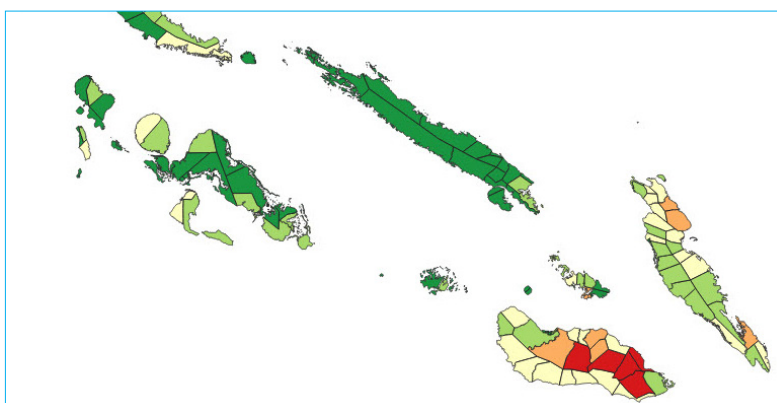
Note that in the formula to calculate the percentage ($\text{"piped_w"} + \text{"tank_w"} / \text{"tot_HH"} * 100$) we have to add the **to_int** (transform to integer) operator because the fields are in string format (chain of characters). When using string format fields, the **+** operator concatenates the characters (52 + 83 = 5283) rather than calculates the mathematical operation (52 + 83 = 135), which is the result that we are looking for.

- h. To generate the field *safe_toile*, follow the same steps but use the following formula:

$$(\text{to_int}(\text{"flush_t"}) + \text{to_int}(\text{"wtrseal_t"})) / \text{to_int}(\text{"tot_HH"}) * 100$$
- i. Do not forget to save any edits to the shapefile by clicking on .

These calculations could have been carried out in Excel, then importing the table into QGIS and linking it to the shapefile. There is no single way to solve problems in GIS; each user will find their own way to complete tasks. The idea of this exercise is to show that we can generate new information in the **ATTRIBUTE TABLE**.

Now, try to map the *safe_water* and the *safe_toile* indicators using a graduated symbology based on what you have learned in previous chapters. These types of maps are very useful for planners and decision-makers when targeting zones where it is necessary to improve WASH conditions and facilities.



6.4 Work with attribute tables

In the previous chapters, we learned how to select features using spatial conditions (e.g. points within polygons). Using the **ATTRIBUTE TABLE**, we can use logical expressions to filter and select data within each field, as if we were using a spreadsheet.

In the following, we show some examples of using the selection and the filter tools from the **ATTRIBUTE TABLE**.

- Load *6_polygon_layers_advanced/layers/Sol_ward_Data.shp*
- Open the **ATTRIBUTE TABLE** of the *Sol_ward_Data.shp*. Note that the field *tot_HH* is now in integer format (we can easily identify that because the figures are aligned on the right, or checking that in the **SOURCE FIELDS** section in the **Layer Properties** panel).
- Click on each line to select a feature and the row will be highlighted in blue. At the same time at the top of the panel we will see a message stating the number of features that are selected and/or filtered.
- By holding **CTRL** + clicking we can add items to the current selection one by one.

Sol_ward_Data :: Features Total: 183, Filtered: 183, Selected: 7

	WID	WName	pid	PName	tot_HH	safe_water	safe_toile
28	202	Inner Shortl...	2	Western	448	98.20	7.59
29	203	Simbo	2	Western	314	99.60	12.10
30	204	North Rano...	2	Western	92	96.70	9.78
31	205	Central Ran...	2	Western	488	69.00	20.90
32	206	South Rano...	2	Western	644	52.30	14.20
33	207	Vonunu	2	Western	645	86.00	37.90
34	208	Bikua	2	Western	754	91.10	10.00
35	209	Dovele	2	Western	378	73.80	15.60
36	210	Iringgla	2	Western	501	87.00	6.39
37	211	Gizo	2	Western	1335	88.30	60.60
38	212	South Kolo...	2	Western	722	61.90	35.80
39	213	Vonavona	2	Western	990	95.10	15.60
40	214	Kusaghe	2	Western	332	67.70	1.81
41	215	Munda	2	Western	471	94.60	53.70
42	216	Mura Bui...	2	Western	270	66.80	73.80




Show All Features





- By holding **Shift** + clicking we can extend the selection up to the last item of our selection.

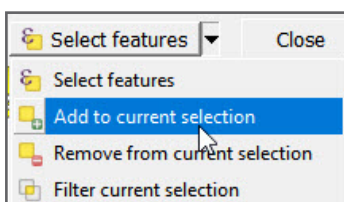
Sol_ward_Data :: Features Total: 183, Filtered: 183, Selected: ...

	WID	WName	pid	PName	tot_HH	safe_water	safe_toile
28	202	Inner Shortl...	2	Western	448	98.20	7.59
29	203	Simbo	2	Western	314	99.60	12.10
30	204	North Rano...	2	Western	92	96.70	9.78
31	205	Central Ran...	2	Western	488	69.00	20.90
32	206	South Rano...	2	Western	644	52.30	14.20
33	207	Vonunu	2	Western	645	86.00	37.90
34	208	Bikua	2	Western	754	91.10	10.00
35	209	Dovele	2	Western	378	73.80	15.60
36	210	Iringgla	2	Western	501	87.00	6.39
37	211	Gizo	2	Western	1335	88.30	60.60
38	212	South Kolo...	2	Western	722	61.90	35.80
39	213	Vonavona	2	Western	990	95.10	15.60
40	214	Kusaghe	2	Western	332	67.70	1.81
41	215	Munda	2	Western	471	94.60	53.70
42	216	Mura Bui...	2	Western	270	66.80	73.80


Show All Features

- Click on  to unselect all the selected features.
- Click on  to invert the selection.
- To select all the features, you can either click on the top-left corner of the table or on .


- i. To visualise the selected feature in the map, click on  and the map canvas will zoom to the selected item.
Click on  to open the **Select by Expression** panel. In **EXPRESSION**, type the following basic expression:
"PName" = 'Choiseul'
Then click on **SELECT FEATURES**, and then click on **CLOSE**.
- j. Click on  to zoom on the map the result of our selection. We have selected all the wards belonging to Choiseul Province.
- k. If we want to add to this selection the wards from Guadalcanal, we will go to the **Select by Expression** panel .
- l. Type the following expression: "PName" = 'Guadalcanal'
- m. Click on the arrow next to the **SELECT FEATURES** button and select the **ADD TO CURRENT SELECTION** option.

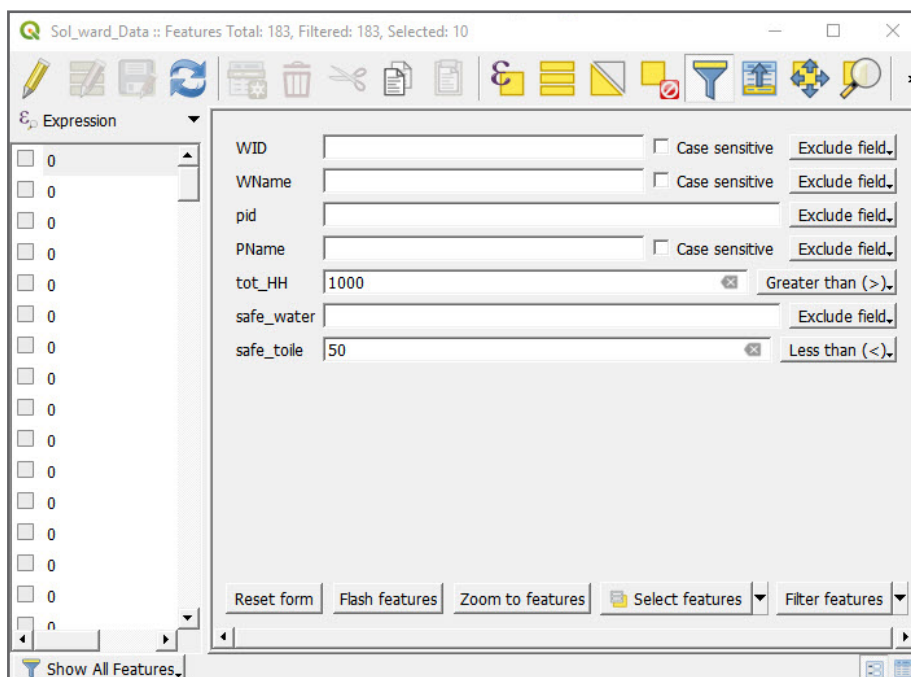


The selection will be added to the previous one.

Now we are going to select the wards where the percentage of HH accessing safe toilets is less than 50% and where the number of HH is greater than 1000. To do this, we can use two methods. First, you can use the **Select by Expression** panel  and type the following expression: "safe_toile" < 50 and "tot_HH" > 1000


Nevertheless, if you do not feel comfortable with expressions, you can use the **SELECT/FILTER FEATURES USING FORM** tool.

- a. Open the **ATTRIBUTE TABLE** and click on  to open the menu.
- b. In **tot_HH** field, type: 1000 and select the option **GREATER THAN (>)** using the control located on the right.
- c. In **safe_toile** field, type: 50 and select the option **LESS THAN (<)**.
- d. Click on **SELECT FEATURES** and check on the map and in the table which wards have been highlighted.



6.5 Dissolve

In this chapter, we will create the province layer from the wards layer.

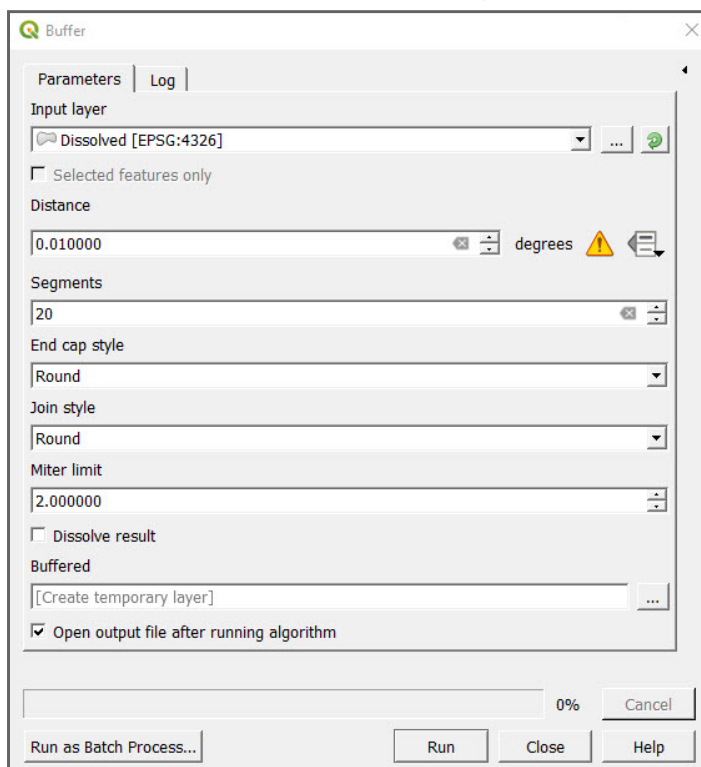
- Load *6_polygon_layers_advanced/layers/Sol_Ward_4326.shp*
- In the top menu, go to **VECTOR > GEOPROCESSING TOOLS > DISSOLVE** and a menu will appear.
- In **INPUT LAYER**, select *Sol_Ward_4326.shp*
- In **DISSOLVE FIELD**, click on  and select **PID** (the provinces code).
- In **DISSOLVED**, select the location and the name of the new layer (e.g. *Sol_prov.shp*).

The province layer will be displayed in the mapping interface. If you check the **ATTRIBUTE TABLE**, you will see that there are 10 features that represent the provinces. Because of the hierarchical relationship between the different levels in the **ATTRIBUTE TABLE** of the lowest administrative level layer, it is possible to generate the upper levels using the dissolve tool.

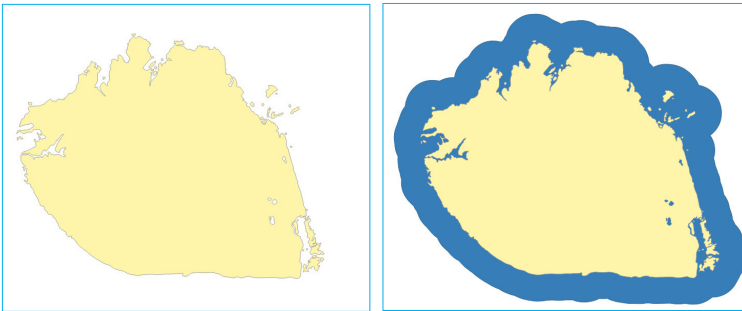
6.6 Creating buffers

In this chapter, we will learn how to generate a 1 km coastal strip that includes the areas of the country that are located at less than 1 km from the sea.

- Load the dissolve process result layer from the previous chapter *Sol_prov.shp*
- On the top menu, go to **VECTOR > GEOPROCESSING TOOLS > BUFFER** and the menu of the tool will be displayed.
- In **INPUT LAYER**, select *Sol_prov.shp*
- In **DISTANCE**, note that the units must be entered in degrees. In regions close to the equator, a degree is approximately 111 km. To roughly set a 1 km distance buffer, you should enter *0.01*
- The **SEGMENTS** parameter controls the number of line segments generated to create a quarter of a circle when rendering the buffer. The higher the value, the more accurately drawn the resulting buffer object is. In our case, we will enter *20* segments.
- In **BUFFERED**, leave the default value to generate a temporary layer and click on **RUN**.



- g. If you do not see the above buffer area, try to sort the layers in the **Layers** panel to ensure that the **Buffered** layer is below **Sol_prov**



What we have in fact created is a surface that extends the polygon's area 1 km towards the sea. What we were intending to do is to generate a 1 km strip inland. To achieve this follow the steps below. While there are faster ways to do this task, this workflow will allow you to engage more with the basic processing tools available in QGIS.

6.6.1 Convert polygons to lines

This algorithm takes a polygon layer and creates a line layer.

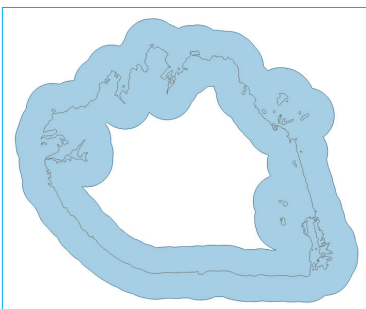
First, we need to convert the polygon layer into a line. This is because when applying the buffer tool to a line layer, the buffer is generated at both sides of the line.

- On the top menu, go to **VECTOR > GEOMETRY TOOLS > POLYGONS TO LINES...**
- In **INPUT LAYER**, select **Sol_prov.shp**
- In **LINES**, leave the default value to generate a temporary layer and click on **RUN**.



6.6.2 Generate the 1 km buffer around the line layer

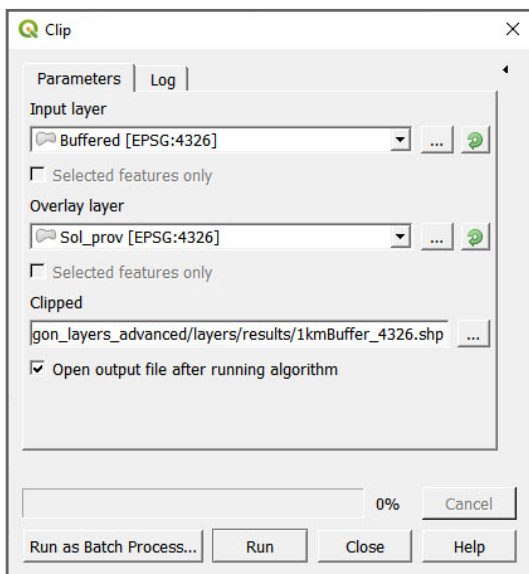
- In the top menu, go to **VECTOR > GEOPROCESSING TOOLS > BUFFER** and a menu will be displayed.
- In **INPUT LAYER**, select **Lines**
- In **DISTANCE**, enter **0.01**
- In **SEGMENTS**, enter **20** segments.
- In **BUFFERED**, leave the default value to generate a temporary layer and click on **RUN**. (Note that this process may take a few minutes.)



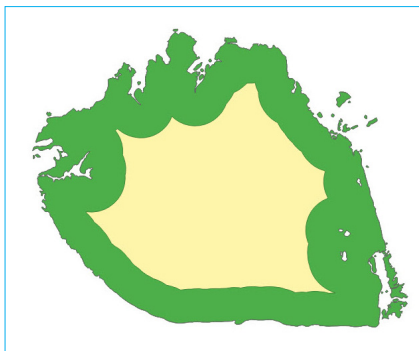
6.6.3 Extract the part of the buffer

In this step, we are going to remove the ocean-side section of the buffer. To undertake this operation, we are going to CLIP the current buffer zone with the *Sol_prov.shp* layer.

- On the top menu, go to **VECTOR > GEOPROCESSING TOOLS > CLIP...** and the menu of the tool will be displayed.
- In **INPUT LAYER**, select the buffer generated from the line shapefile in the previous step.
- In **OVERLAY LAYER**, select *Sol_prov.shp*
- In **CLIPPED**, select the name and the file of the 1 km coastal buffer (e.g. *1kmBuffer_4326.shp*).




Click on **RUN** and check the map canvas for a result similar to the layer represented in green in the image below.

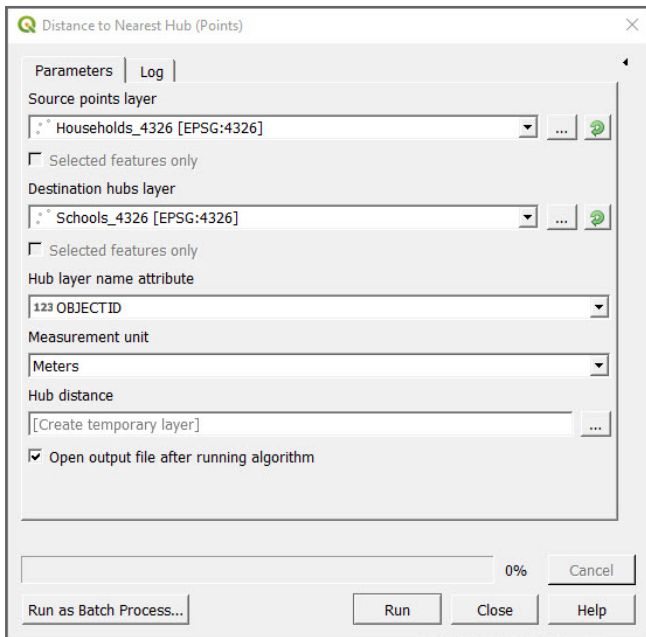


6.7 Find closest features to households – schools

In this section, you will learn how to conduct a point-to-point distance analysis. We are going to calculate the distance from each HH location (these locations have been randomly created) to the nearest school in Malaita Province. The resulting layer will help us to assess the accessibility to schools in this province.

- Click on  to open a new blank project.
- Load *6_polygon_layers_advanced/layers/Sol_Ward_4326.shp*, *6_polygon_layers_advanced/layers/Households_4326.shp* and *6_polygon_layers_advanced/layers/Schools_4326.shp*
- Sort the layers in the **Layers** panel to ensure that both HHs and schools are displayed over the provinces layer.
- In the top menu, go to **PROCESSING > TOOLBOX** to open the **Processing Toolbox** panel.
- In the search bar located at the top of the **Processing Toolbox** panel, type: **hub distance** and the matching tools will be filtered among the available options.

- f. Click on **DISTANCE TO NEAREST HUB (POINTS)**.
- g. In **SOURCE POINTS LAYER**, select *Households* layer.
- h. In **DESTINATION HUBS LAYER**, select *Schools* layer.
- i. In **HUB LAYER NAME ATTRIBUTE**, select *Id* field.
- j. In **MEASUREMENT UNIT**, select *Kilometers*.
- k. In **HUB DISTANCE**, enter the location and the name for the new layer (e.g. *HH_Dist2School*).
- l. Click **RUN** and **CLOSE** once the operation is completed. (Note that this process may take few minutes.)



The tool has generated a copy of the HH layer while adding a new field that contains the distance to the closest school. Now, playing with the symbology, we can highlight the different regions depending on the geographic access to school.

- a. Select the *HH_Dist2School* layer (it will be probably named as *Hub distance*) in the **Layers** panel, then open the **Layer Properties** panel and go to **SYMBOLOLOGY**.
- b. In the top drop-down menu, select the **GRADUATED** option.
- c. In **VALUE**, select the **HUBDIST** field.
- d. In **COLOR RAMP**, select the option you think is the most suitable. In our example, we have selected the **SPECTRAL** option.
- e. In **MODE**, select **EQUAL INTERVAL** and click on **CLASSIFY**.

You will notice that the furthest distances are represented in blue and the closest in red, but we want the opposite.

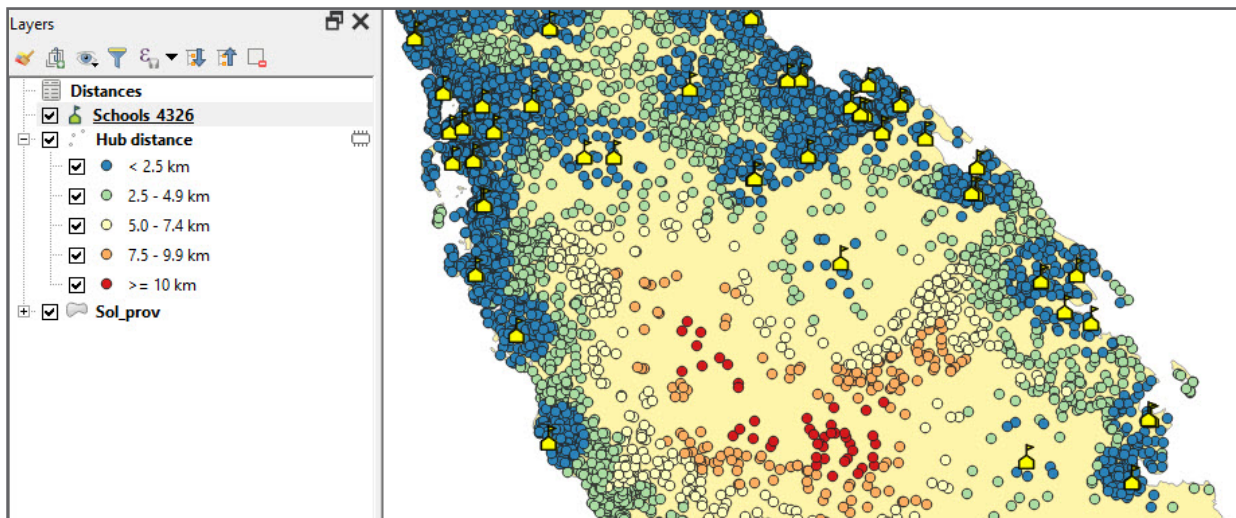
- f. Right-click over the **COLOR RAMP** button and select **INVERT COLOR RAMP**. Now the symbology is more logical.

To better represent the data, we need to "clean" the classification ranges and the legend to make them more accessible. It is always easier to read and remember a value like 5 km rather than a value like 4.82 km.

- g. Double-click on each of the **VALUES** and **LEGENDS** to modify the class bounds and the values that will be displayed in the legend. Then click **OK**.

Symbol	Values	Legend
<input checked="" type="checkbox"/> ●	0.006 - 2.500	< 2.5 km
<input checked="" type="checkbox"/> ●	2.500 - 5.000	2.5 - 4.9 km
<input checked="" type="checkbox"/> ●	5.000 - 7.500	5.0 - 7.4 km
<input checked="" type="checkbox"/> ●	7.500 - 10.000	7.5 - 9.9 km
<input checked="" type="checkbox"/> ●	10.000 - 12.248	>= 10 km

- h. Use a special symbol for the schools to better differentiate them from the HHs.
- i. Click **OK** and check the result on the map canvas.




7. Automated map production

The Atlas is the automatic map production tool for QGIS. This feature is essential when producing a large number of similar maps, as is the case when producing enumerator field maps.



In this chapter, you will start with a preconfigured project named *Atlas.qgz* where the basic format is already set in order to not repeat topics that have been covered in previous chapters.

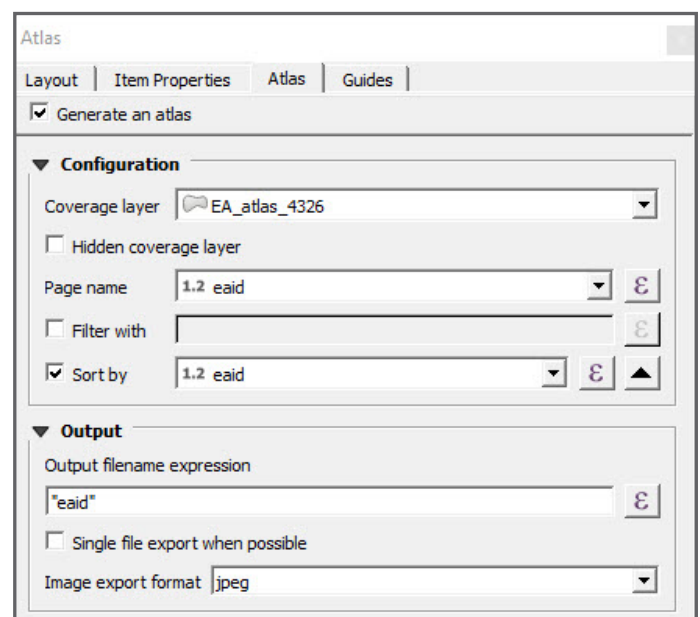
Given the complexity of the chapter, a project named *AtlasResult.qgz* has been placed in the training materials folder to guide you if you have any difficulties. The project contains all the layout results for the exercises presented in this chapter.

7.1 Layout and Atlas basic configuration

- Click on  to open the project *7_automated_map/Atlas.qgz*. Note that a HH locations and an EA framework layer have been loaded into the mapping canvas.
- Check that *EA_atlas_4326.shp*, *HH_atlas_4326.shp* and a satellite image background have been loaded into the canvas. If not, load the layers from the *7_automated_map/Layers* folder and a background from the **XYZ TILES** map service located in the **Browser** panel.

The atlas needs a coverage layer, which controls the map production. As we want to produce a map for each of the EAs, the coverage layer will be *EA_atlas_4326.shp*. This means that the atlas will "take a photo" of each EA and produce the maps automatically. Through the **ATTRIBUTE TABLE** of the coverage layer, you can automatically add titles, filter which maps are to be printed and assign filenames.

- In the top ribbon, go to **PROJECT > LAYOUTS** and open the *Atlas_landscape* layout. The **Layout** interface will be displayed with a basic layout configuration, including a map canvas and a title.
- The **Atlas** menu should appear on the right side of the interface where the different layout menus are located. If it does not appear automatically, you can either click on  or go to **ATLAS > ATLAS SETTINGS**.
- In the **Atlas** menu, check **GENERATE AN ATLAS**.
- In **COVERAGE LAYER**, select *EA_atlas_4326*, as this is the layer that contains the polygons that we want to map.
- Do not check** the option **HIDDEN COVERAGE LAYER**, as we need to display the EA boundaries on the maps.
- In **PAGE NAME**, select the *eaaid* field to assign page names using the EA codes.
- Leave the **FILTER WITH** option unchecked for the moment.
- Check the **SORT BY** option and select the *eaaid* field to sort the maps using the EA code.
- Uncheck **SINGLE FILE EXPORT WHEN POSSIBLE**, click on , delete the default expression and enter the following: *"eaaid"*

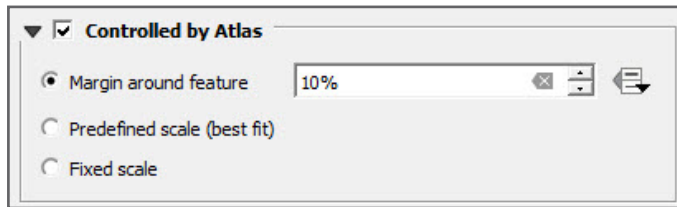





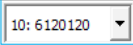
This setting will automatically assign the EA code as the filename when the atlas is exported into image format. The values used to name the maps must all be unique, otherwise maps with duplicated filenames will be overwritten during the export process.


- In **IMAGE EXPORT FORMAT**, select the desired format for the exported maps. Jpg, .jpeg and .png are the most common.

m. In the canvas, select the map and go to the **Item Properties** menu. Scroll down to find the **CONTROLLED BY ATLAS** option and check it.

n. Select **MARGIN AROUND FEATURE** and set **10%**






o. Go to the top menu and click on  to enable the **ATLAS TOOLBAR**. Use the   buttons to navigate through the different maps. By using the pages display , we can go directly to the different EAs, as we have already configured the **PAGE NAME** parameters in this way.

p. Make sure that you regularly save any changes to the project by clicking on .





By using this basic atlas configuration, we ensure that as the atlas navigates across the EA framework it will make a map of each of the enumeration areas. At this stage, we need to improve the layout in order to provide more information regarding the area that is being mapped, such as the EA code, the island name and the scale. The atlas feature can dynamically change the different titles by making use of the coverage layer's **ATTRIBUTE TABLE**.

7.1.1 Automatic titles

- Go to the **Layout Interface** and click on . Draw the rectangle where you want the title to be located.
- Make sure that the title frame is selected in the layout canvas** and go to the **Item Properties** menu.
- In **MAIN PROPERTIES**, click on **INSERT AN EXPRESSION** and enter the following expression: `'EA Code: '"eid"`
- Set the text font by changing the colour, making it bold and increasing the size to make the title more visible.
- Cycle through the maps by using   to check that the EA code matches with the EA represented on the map.
- Insert automatic titles for the island and village names by adding a new text box and using the following expression: `'Village name: '"v_name" || " / Island name: '"i_name"`

Remember that in the language for QGIS expressions, the `||` symbol is used to concatenate text or variables. Single quotes `'` are used to indicate text and double quotes `"` indicate fields from the **ATTRIBUTE TABLE**.




7.1.2 Automatic scale bar

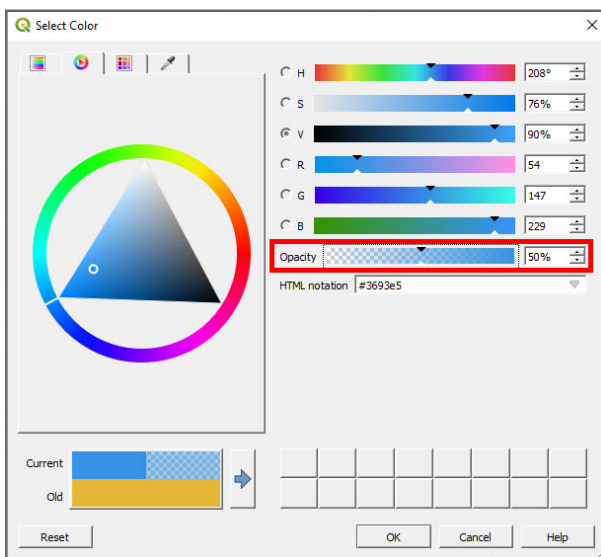
- Go to the **Layout Interface** and click on . Draw the rectangle where you want the title to be located.
- Go to the **Item Properties** menu and unfold the **UNITS** submenu.
- In **SCALEBAR UNITS**, select the **KILOMETERS** option, and in the **LABEL FOR UNITS**, type: **km**
- As our scale bar is dynamic, to ensure that the item does not exceed the frame, select the **FIT SEGMENT WIDTH** option and set the size between **50** and **100 mm**.
- Then go to **POSITION AND SIZE** and set **100 mm** for the **WIDTH** of the frame.
- Use   to check that the dynamic scale bar is working.
- Make sure that you save the changes to the project regularly by clicking on . We will keep working on the same project and layout in the next section.

7.2 Rule-based styles interacting with Atlas (Atlas variables)

In this section, we are going to set styles for both the EA and the HH layers, which will sync with the Atlas to improve the readability of the maps.





7.2.1 Style for the polygon layer


- Go back to the main QGIS interface and open *EA_atlas_4326*. From the **Layer Properties** panel, go to **SYMBOLOLOGY**.
- Select the **RULED-BASED** option in the top drop-down menu.
- Double-click on the rule that is currently displayed, or select it and click on  to open the **Edit Rule** panel.
- In **LABEL**, type: *Selected EA*
- In **FILTER**, click on  and enter the following expression: `@atlas_featureid = $id`
- Then click **OK**.
- Click on **TEST** to check that the formula is working properly.
- Next, set a transparent fill with an orange border style and click **OK**.
- Click on  to add a new rule.
- In **LABEL**, type: *Not selected EA*
- Check the option **ELSE**.
- Set the style with the same type of orange **STROKE**.
- For the **FILL**, select a shade of blue and set the **OPACITY** at 50%.



- Click **OK** in the following three menus to save the changes and check that the conditional formatting has synced with the *Atlas_landscape* layout. The selected EA should appear with a transparent fill format and the non-selected EAs with a semitransparent blue fill.





Next, we need to modify the EA labels so that only the non-selected EA labels are shown on the map. We do not need to show the selected EA label as it will be displayed in the title. Moreover, we avoid labelling the selected polygon so as to prevent the label blocking the features inside the polygon, such as HH locations or other labels.

- Return to the main interface and open *EA_atlas_4326*. From the **Layer Properties** panel, go to **LABELS**.
- Select the **RULE-BASED LABELLING** option and click on  to add a new rule. The **Edit Rule** panel will then be displayed.
- In **FILTER**, click on  and enter the following expression: `@atlas_featureid <> $id` and then click **OK**.
- Click on **TEST** to check that the formula is working properly.
- In **VALUE**, select the *eaid* field and set the same label format as we did in previous chapters, which will ensure the readability of the map.
- Create a new rule  and click on  to open the **Edit Rule** panel.


- g. In **FILTER**, click on  and enter the following expression: `@atlas_featureid = $id` but we do not enter any field in **VALUE** to make sure that no label is displayed. Then click **OK**.
- h. Click **OK** in the next menus that follow and check that the conditional formatting works as expected.



For the HH point layer style, we will configure similar settings to those of the EA polygons. In this case, we only want to show and label the points following these two conditions: points that have been selected for this hypothetical survey (points where the field **Selected** is equal to 1) and that are located within the EA selected by the atlas.

- a. Open **HH_atlas_4326**. From the **Layer Properties** panel, go to **SYMBOLOLOGY**.
- b. Select the **RULED-BASED** option from the top drop-down menu.
- c. Double-click on the rule that is currently displayed, or select it and click on  to open the **Edit Rule** panel.
- d. In **VALUE**, type: **Selected HH**
- e. In **FILTER**, click on  and enter the following formula in order to meet the conditions for the HH location layer: `"Selected" = 1 and intersects(@atlas_geometry, $geometry)`
- f. Click on **TEST** to check that the formula is working properly.
- g. Set the style in order to better make visible the points over the satellite image.
- h. Create a new rule , click on  to open the **Edit Rule** panel, then click **OK**.

This time, configuring the labels is simple; you just need to set basic labels displaying the HHid.

- a. Go to **LABELS** and select the **SINGLE LABELS** option.
- b. In **VALUE**, select the **id** field.
- c. Set the style by increasing font size and adding a white buffer to ensure the correct readability of the HH codes in the maps.
- d. Check in the **Layout Interface** that the conditional formatting works as expected and click on  to save the changes to the project.



- 



- TITLE, GROUP, SUBGROUP and ITEM.**

7.3 Landscape/Portrait layouts


Looking at the different EAs that we want to map in the project, we notice that some of the polygons fit better in a landscape page and others in a portrait map.




In this section, you will learn how to configure the atlas to automatically distinguish between both orientations and generate both landscape and portrait maps.

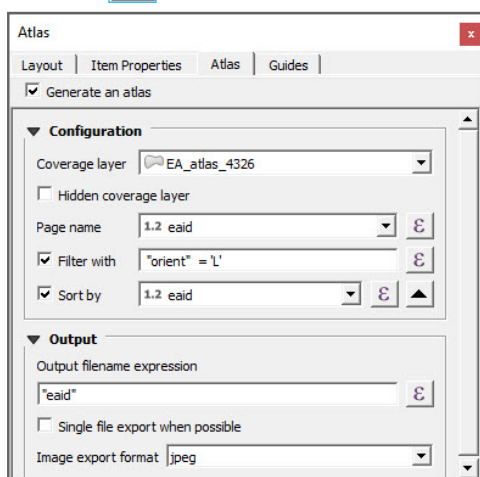
The first step will be to generate a field in the **ATTRIBUTE TABLE** that identifies whether the polygons fit better in landscape and portrait layouts.

- 

- f. In the **EXPRESSION** dialogue, enter the following formula:
`if(bounds_width($geometry)>bounds_height($geometry),'L','P')`
- g. Click **OK** and check in the **ATTRIBUTE TABLE** that the new field has been correctly generated. We should find a new field named **orient**, populated with **L** and **P** characters.
- h. Click on  to save the edits and close the editing session.

Now we will configure the *Atlas_landscape* layout to filter only the EAs that match a landscape-oriented page.

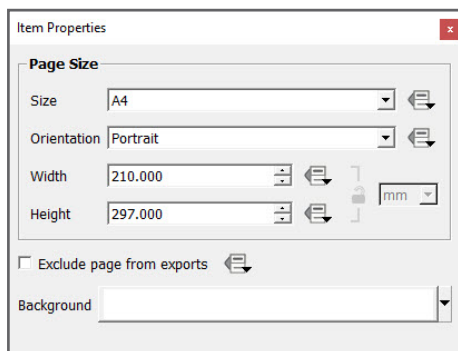
- a. Go to the **Atlas** menu and check the option **FILTER WITH**.
- b. Click on  and enter the following expression: `"orient" = 'L'`



- c. Check on the **ATLAS TOOLBAR** so that now the atlas is only selecting landscape-oriented EAs.

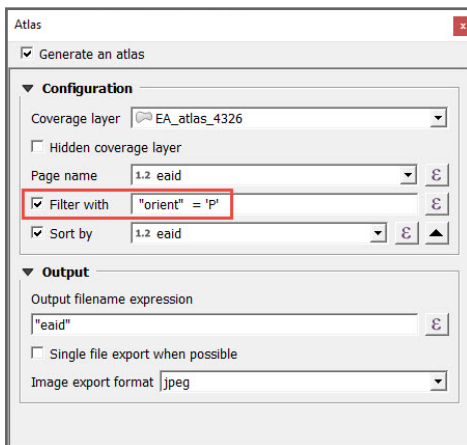
The next step involves duplicating this layout, changing the page orientation and repositioning all of the map elements.

- a. In the top menu of the **Layout Interface**, go to **LAYOUT > DUPLICATE LAYOUT**.
- b. Name the new layout as *Atlas_portrait*
- c. Right-click in the layout canvas and select **PAGES PROPERTIES...**
- d. The **Item Properties** menu will show the page properties (size, orientation and background colour).
- e. In **ORIENTATION**, select the **PORTRAIT** option.



- f. Open the **Atlas** menu.


- g. In **FILTER WITH**, replace the current expression by typing: `"orient" = 'P'`

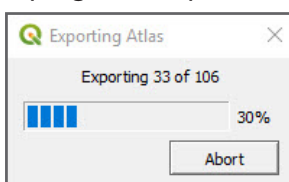


- h. To complete this new layout, we just need to drag and resize all of the map elements to make them fit into the new page configuration.



Once both portrait and landscape layouts are ready, we can proceed to exporting the maps into image files. The atlas feature allows us to produce all of these maps automatically.

- In the top menu of the **Layout Interface**, go to **ATLAS > EXPORT ATLAS AS IMAGES...**. Another option is to click on , which is located in the **ATLAS TOOLBAR**.
- Select the directory to where the maps will be exported.
- In the **Image Export Options** panel, we can configure the settings related to the resolution of the images. For this exercise, we will keep the default values. Click on **SAVE**.
- A progress bar panel will be displayed showing the number of maps already printed over the total.







We will export the maps from both landscape and portrait layout into the same folder. It is important to verify that the number of exported maps is equal to the number of EAs in the **ATTRIBUTE TABLE** and that the filenames correspond to the EA codes.



7.4 Atlas-controlled tables

In this section, we are going to create a map layout that includes a table of information related to the HHs displayed in the map. The atlas feature allows us to synchronise the information included in these tables with the area displayed on the map. To conduct the exercise, we need to duplicate the *Atlas_landscape* layout and create the *Atlas_landscape_table* following the steps explained in the previous chapter.

- Reduce the size of the map and move the scale bar to make space for the table.
- Click on  and draw a rectangle where the table will be located within the layout.
- Go to the **Item Properties** menu and select the **MAIN PROPERTIES** submenu.
- In **SOURCE**, select the **LAYER FEATURES** option.
- In **LAYER**, select *HH_atlas_4326*
- Click on **ATTRIBUTES** and remove the field **HHid** by selecting it in the **COLUMNS** display and clicking on .
- Then sort the fields this way **id**, **name**, **status**, **Selected** by selecting them and using  controls.
- In **SORTING**, select **id**, then select the **ASCENDING** option and click on .
- Click **OK** to save the changes in the table.

If we check on the content of the table and the points displayed in the map, we will notice that none of the points match with the ones displayed in the map. In addition, when moving from one map to the next one, the table remains the same. We need then to set the necessary parameters to synchronise both maps and tables.

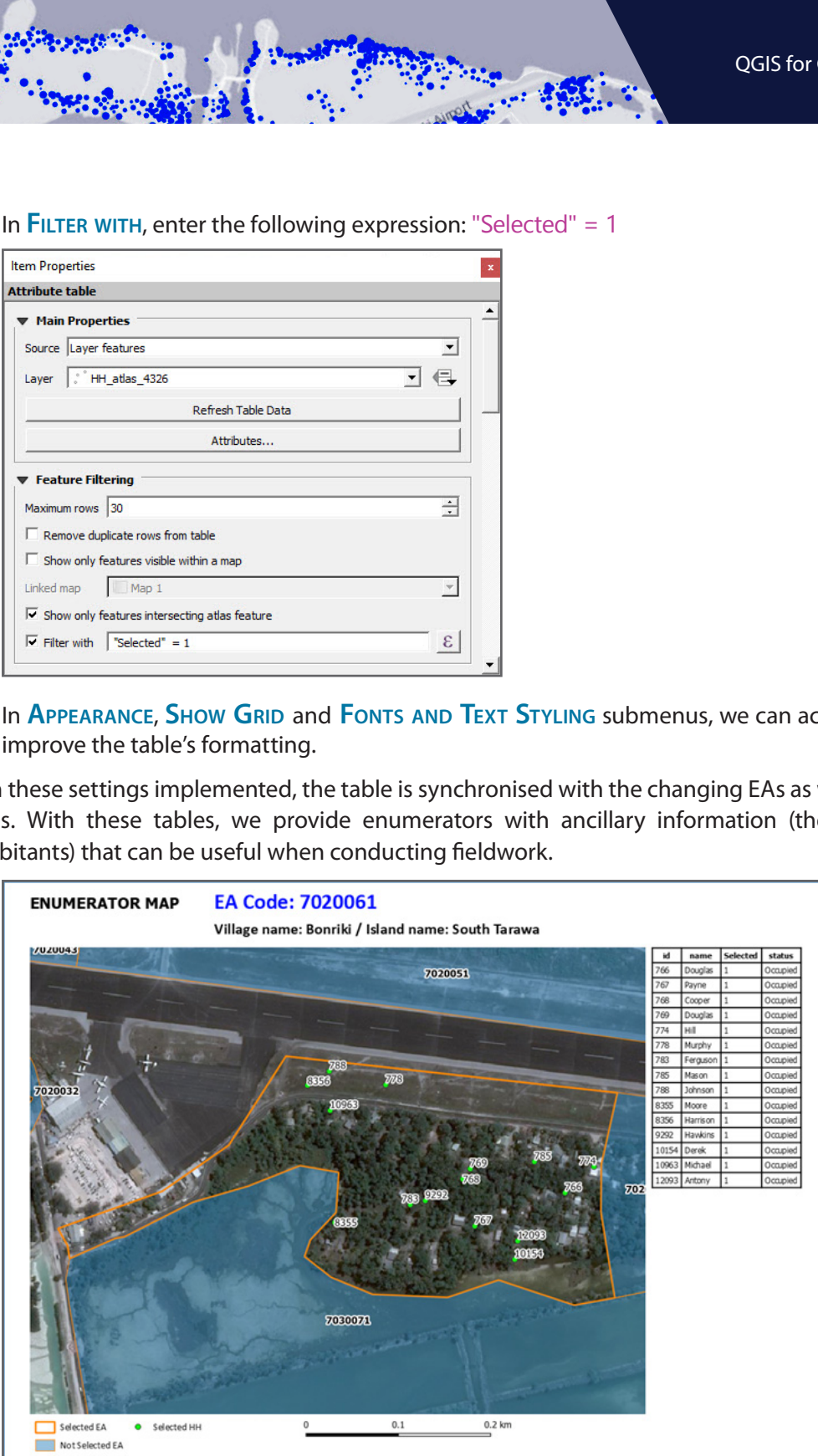
- Go to the **FEATURE FILTERING** submenu.
- In **MAXIMUM ROWS**, set **30** and make sure that the size of the table is enough to contain the 30 rows.
- Check the option **SHOW ONLY FEATURES INTERSECTING ATLAS FEATURE**.

-

- 
- QGIS for Census and Survey Mapping



QGIS for Census and Survey Mapping





8. Working with rasters (terrain data)

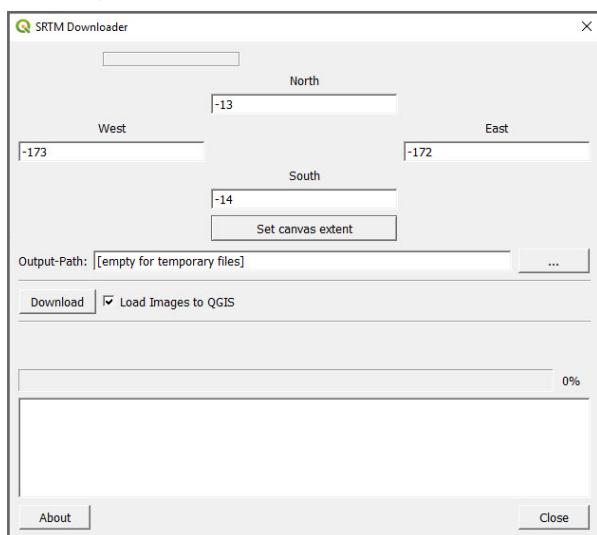
GIS systems mainly operate using two types of spatial data: vector data (points, lines and polygons) and rasters. In the previous chapters of the manual we have been working with vector data, which, in most of the cases, is more suitable for working on statistical data collection activities.

A raster dataset is made up of a matrix (or grid) of pixels. Each pixel or cell contains a value that represents the information of the area covered in that pixel; for example, the elevation, slope, land-use patterns or population density.

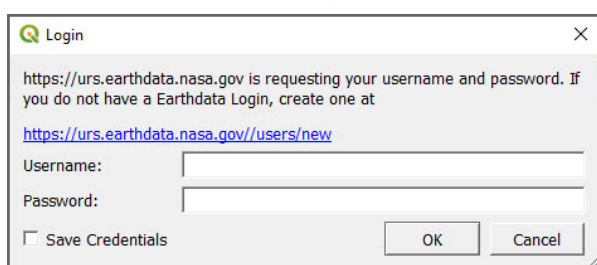
8.1 Retrieve digital elevation model data from NASA's Earthdata

A digital elevation model, or DEM, is a raster in which the pixels contain elevation data from a continuous surface. In this chapter, we are going to obtain a DEM from NASA's Earthdata service through the plugin **SRTM DOWNLOADER**.

- Open a new QGIS session or a new project by clicking on .
- Load **8_Raster/layers/land_4326.shp** to the main canvas.
- In the **Layers** panel, right-click on **land_4326.shp** and select **Zoom to Layer**, so that the map canvas focuses on the layer. This step is necessary in order to easily find which canvas or tile we need to download from the SRTM repository.
- In the top menu, go to **PLUGINS > SRTM DOWNLOADER**. If this plugin is not installed, please refer to chapter 2.2 where the plugin installation process is explained in detail.
- Go to **PLUGINS > SRTM DOWNLOADER** or click on  and the plugin menu will be displayed.
- Click on **Set Canvas Extent** to automatically enter the boundaries of the work area. With these automatic limits, the plugin will retrieve the relevant tiles of the DEM from the SRTM service.

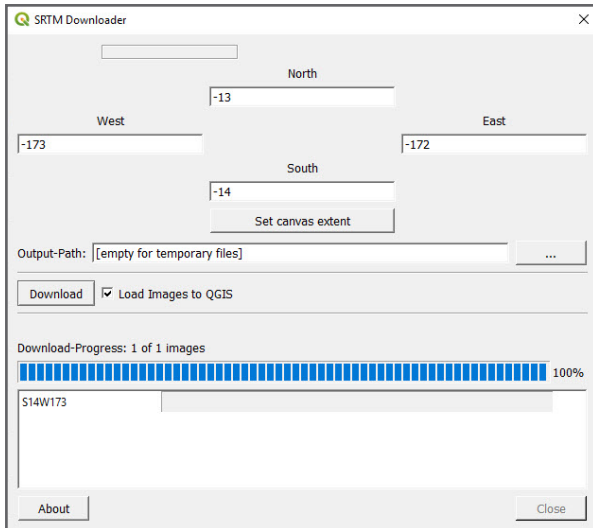


- In **OUTPUT-PATH**, select the folder where the raster file will be stored and check the option **LOAD IMAGES TO QGIS**.
- Click **DOWNLOAD** and the following panel will be displayed requesting login details to access NASA's Earthdata service. If you do not have an account for this service, you can quickly create one here: <https://urs.earthdata.nasa.gov/users/new>

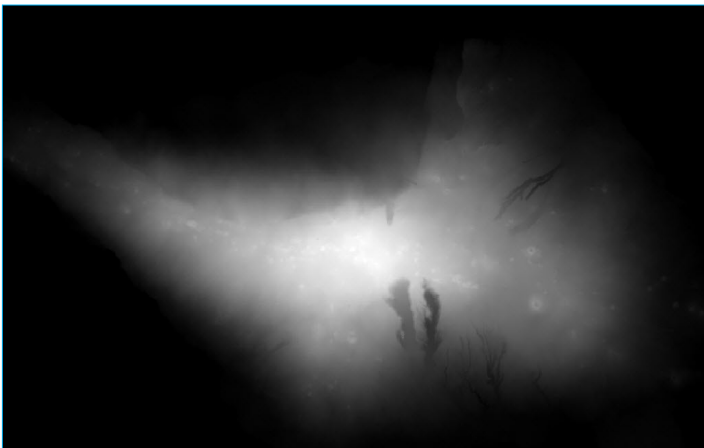


Once the sign-up process is finished, you will be sent your login details.

- i. Fill the **USERNAME** and **PASSWORD** fields with your user details and click **OK**. A progress bar will show the download process. Once it is finished, the raster file *S14W173.hgt* will be loaded automatically onto the map canvas.



- j. The raster shows the elevations of Savai'i Island in Western Samoa. Lighter tones show higher elevations and lower elevations are in darker tones.



If for any reason this process does not work on your computer, you can access the raster at *8_Raster/DEM/S14W173.hgt* in the training materials included with this manual.

8.2 Improve raster visualisation²

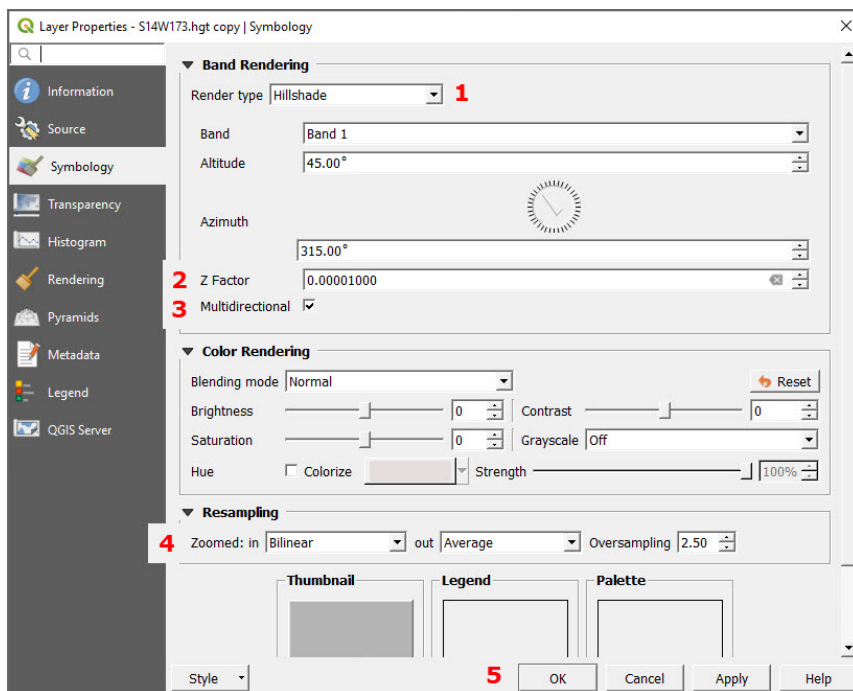
With the current display settings, you can quite easily distinguish between higher and lower elevations. Nevertheless, it is possible to enhance the way this spatial information is represented by creating a 3D model of the surface, which in turn makes it easier to interpret the gradient and the topography of the terrain. To achieve this, we will overlay a typical coloured elevation layer on a hillshade layer underneath. Note that both layers are generated from the same DEM raster.

8.2.1 Hillshade

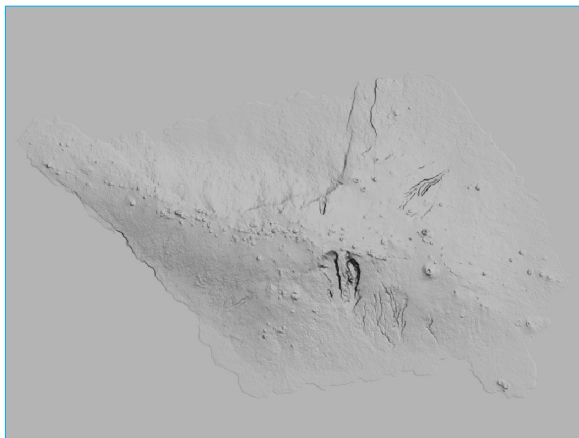
- a. In the **Layers** panel, right-click on *S14W173.hgt* and select **DUPLICATE LAYER**.
- b. Open the **Layer Properties** of *S14W173.hgt copy* (the layer that is underneath) and go to **SYMBOLLOGY**.
- c. Go to the **BAND RENDERING** submenu, and in the **RENDER TYPE** drop-down menu, select the **HILLSHADE** option.

² Both chapters 8.2 and 8.3 are based on this tutorial: <https://opengislab.com/blog/2018/3/20/3d-dem-visualization-in-qgis-30>

- d. In **Z FACTOR**, enter 0.00001
- e. Check the option **MULTIDIRECTIONAL**. Unlike the traditional hillshade models that use one source of light, the multidirectional method illuminates the surface from four different directions providing a more accurate model.
- f. In the **RESAMPLING** submenu, go to **ZOOMED**. For the **IN** option, set **BILINEAR**; for the **OUT** option, set **AVERAGE**; in **OVERSAMPLING**, leave the default value at 2.50



- g. Click **OK** to save the changes in the symbology and check the map canvas to make sure that your raster looks similar to the image below.

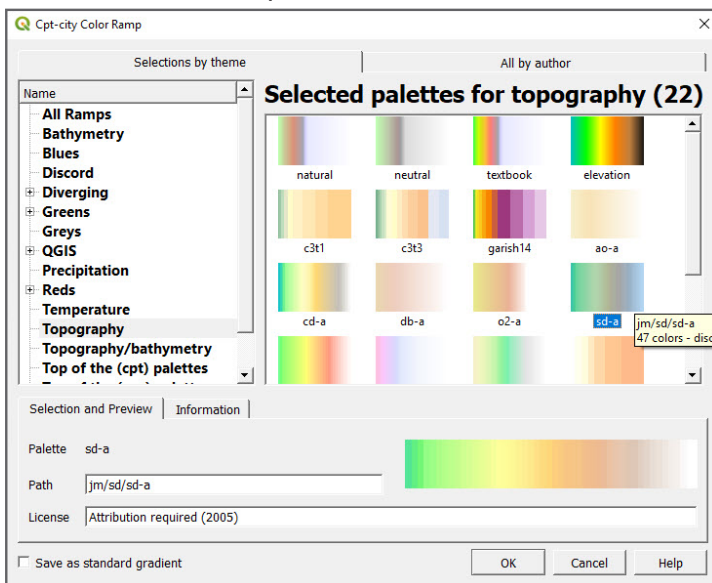


- h. Right-click on the layer and select **RENAME LAYER**. Change the name to indicate that this layer is a hillshade (e.g. *S14W173.hgt_hshade*).

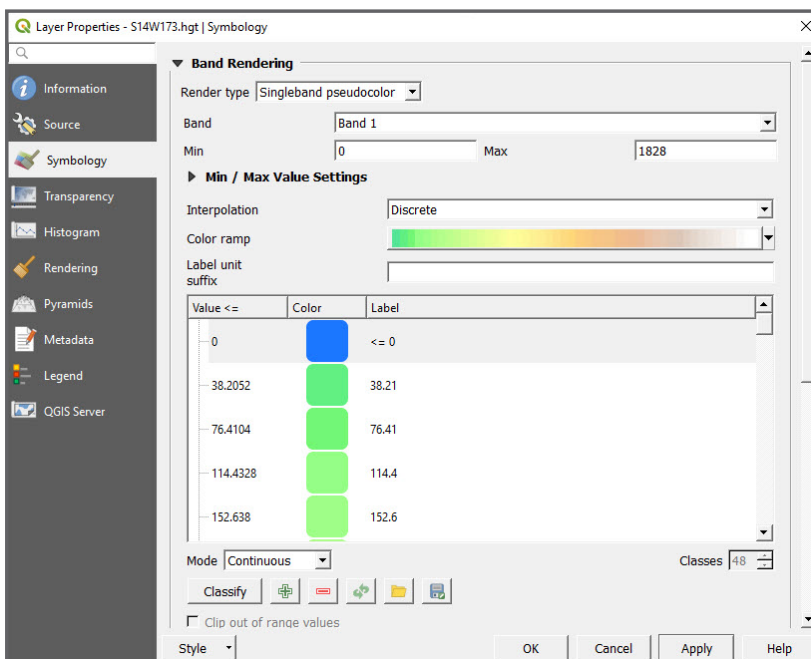
8.2.2 DEM displayed with an elevation colour ramp


- a. Open the **Layer Properties** of *S14W173.hgt* (the layer on top) and go to **SYMBOLOLOGY**.
- b. Go to the **BAND RENDERING** submenu, and in the **RENDER TYPE** drop-down menu, select the **SINGLEBAND PSEUDOCOLOR** option.
- c. Next to **COLOR RAMP**, click on the arrow located on the right to open the drop-down menu. Select the **CREATE NEW COLOR RAMP** option.
- d. In the **Color ramp type** panel, select **CATALOG: CPT-CITY** option and click **OK**.

- e. In the **Cpt-city Color Ramp** panel, select the **SELECTIONS BY THEME** tab, go to the **TOPOGRAPHY** section and select one of the colour ramps available. Then click **OK**.

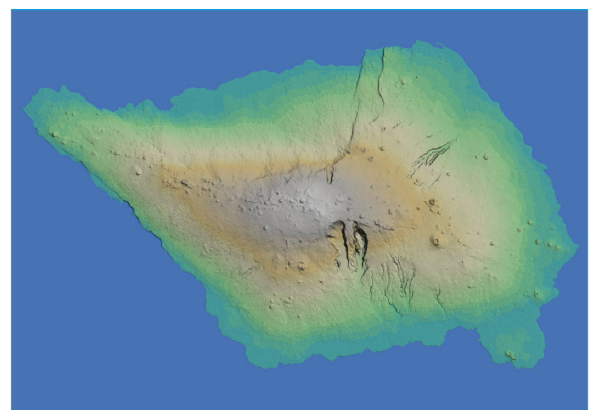


- f. Go back to the **SYMBOLOLOGY** menu, and in **INTERPOLATION**, select **DISCRETE**.
- g. Go to **MIN / MAX VALUE SETTINGS** and set **0 m** of elevation to be a blue colour to represent the ocean.



- h. In **COLOUR RENDERING**, go to **BLENDING MODE** menu and select the **MULTIPLY** option.
- i. Go to the menu on the left and select **TRANSPARENCY**, then set the **GLOBAL OPACITY** to **60%**. Click **OK** and check in the map canvas the results of these new symbology settings. Do not forget to save the changes to the project by clicking on .

The map now contains rich information regarding the terrain. Consequently, it is now possible to identify the elevation by virtue of the different shades and to read the shapes of the relief thanks to the hillshade.



8.3 Working with 3D map views

In QGIS 3, the 3D visualisation tool is native, whereas in previous versions, 3D visualisations were a function of an external plugin, [QGIS2THREEJS](#). 3D maps are a good way to display in the layouts additional information related to the landscape.


Prior to working in the 3D view, we are going to prepare our map canvas.

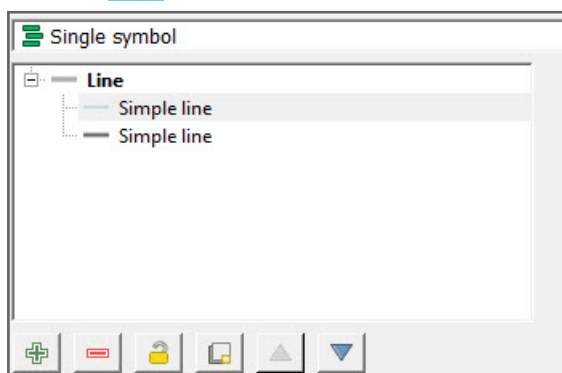
- a. Load [8_Raster/roads.shp](#) and [8_Raster/waterways.shp](#) and put both layers on top of the rasters in the [Layers](#) panel.

We will set a new symbology for these line layers so that they are easily identifiable on the map. For the waterways we will use basic blue lines, but for the roads we will use a more complex symbol.

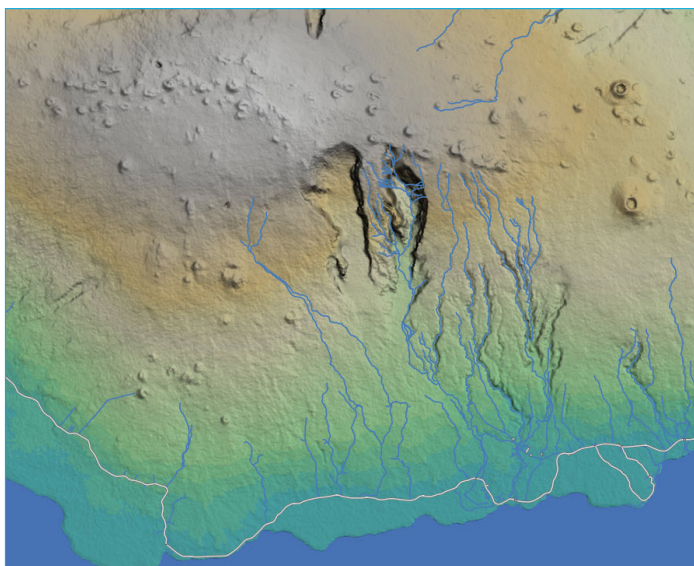
- b. Open the [Layer Properties](#) panel of [roads.shp](#) and go to [SYMBOLLOGY](#).
- c. Select the [SINGLE SYMBOL](#) option, as we will display all the roads using the same symbol.

To represent the roads, we will set a pale grey line with dark grey borders. We will construct this symbol by overlapping a pale grey line over a dark grey one. Then we will set different widths for both lines to create the border effect.

- d. Click on  to add a new symbol layer in the symbol panel.





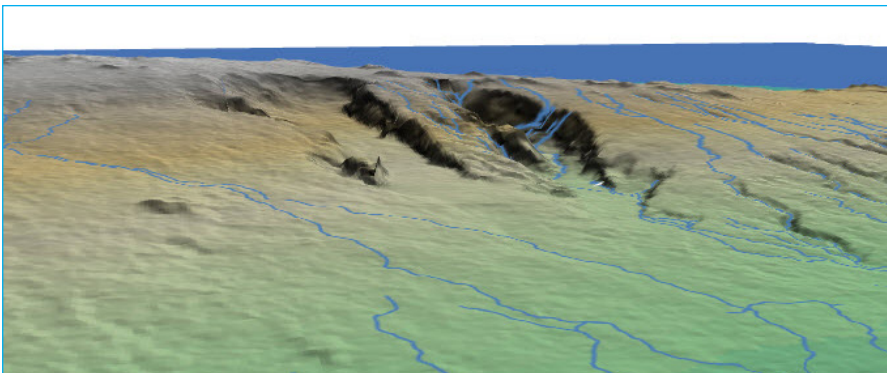
- e. Select the line on top, then set a pale grey [COLOR](#) and a [0.4 mm STROKE WIDTH](#).
- f. For the line underneath, set a dark grey [COLOR](#) and a [0.6 mm STROKE WIDTH](#).



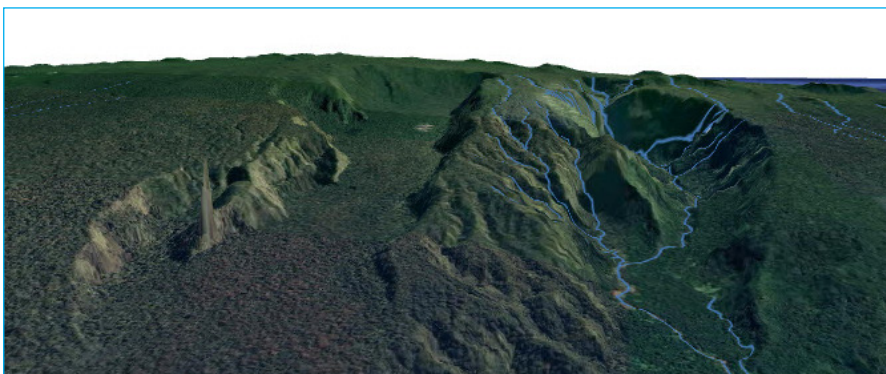
Now that we have all the layers of our map cleanly represented in our 2D map, we can start working with the 3D view.

- a. In the top menu, go to [VIEW > NEW 3D MAP VIEW](#). An error message will be displayed informing us that the 3D view is not supported on an unprojected CRS, like the default QGIS CRS.

- b. To change the CRS, go to **PROJECT > PROPERTIES** and select the **CRS** menu. It is also possible to access this menu by clicking on the  **EPSG:4326** icon located in the bottom-right corner of the screen.
- c. In the **CRS** menu, select a projected CRS. For this exercise, both EPSG: 3857 or 3832 will work. Select one of them and click **OK**.
- d. Try **VIEW > New 3D Map View** again. A new **3D Map** window will appear.
- e. Click on  to open the **3D Configuration** panel.
- f. In **ELEVATION**, select one of the two DEMs open in the project. The DEM will act as the data input to render the relief volume displayed in the 3D view.
- g. In **TILE RESOLUTION**, we will increase the value up to **50 px**, as the region we want to display is relatively small.
- h. In **MAP TILE RESOLUTION**, set the value to **200 px** (for better-quality rendering) and click **OK**. If you notice that your computer takes too long to render the 3D view, it is recommended that you restore the default values.
- i. The navigation controls within the 3D view are as follows:
 - Click to pan the map.
 - Hold **Shift** + click or click with the mouse wheel to rotate the view.
 - Roll the mouse wheel to zoom in/out.




If you want to create a realistic landscape, you can put a satellite image overlay above the DEM.



8.4 Assign elevation data from DEM to point layer

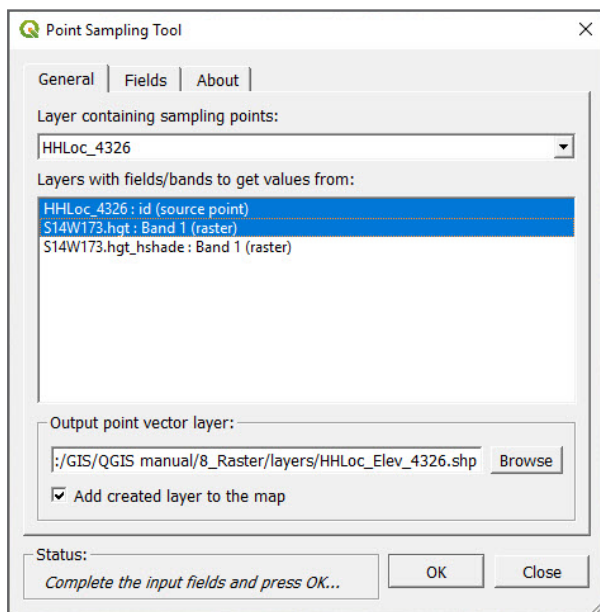
In this exercise, we are going to classify HH location waypoints according to their altitude. This will allow us to view the HH locations in terms of their vulnerability relative to potential natural disaster events linked to sea-level rise (tsunamis, storm surges, cyclones). We are going to obtain the elevation information from the DEM and add it to a point shapefile as a new field in the **ATTRIBUTE TABLE**.

- a. Load the layer **8_Raster/layers/HHLoc_4326.shp** in the map canvas.
- b. In the top menu, go to **PLUGINS > MANAGE AND INSTALL PLUGINS** and check if the **POINT SAMPLING TOOL** is installed. If not, proceed with the installation of the plugin.

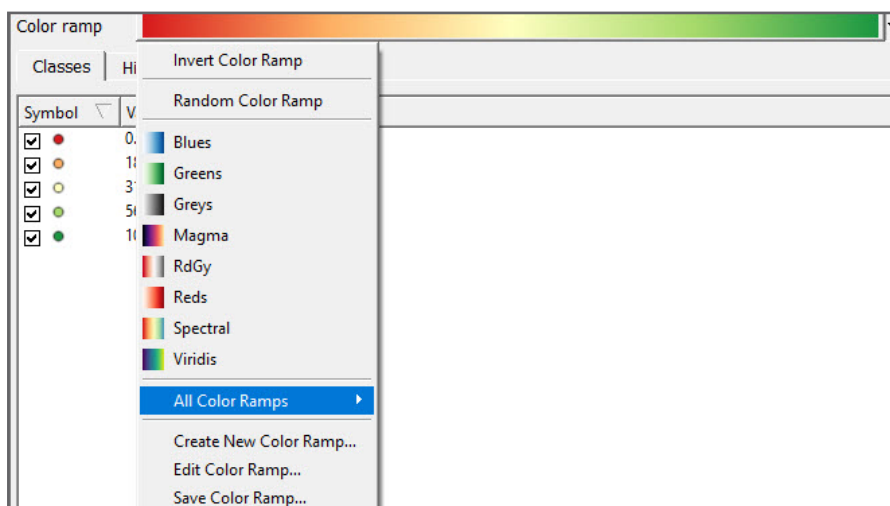
- c. Once it is installed, go to **PLUGINS > ANALYSES > MANAGE AND INSTALL PLUGINS** or click on  to open the plugin. The **Point Sampling Tool** panel will be displayed.
- d. In the **LAYER CONTAINING SAMPLING POINTS** drop-down menu, select the layer **HHLoc_4326**
- e. In **LAYERS WITH FIELD/BANDS TO GET VALUES FROM**, select **HHLoc_4326** to keep the fields from the point layer and **S14W173.hgt**, the layer containing the elevation data (use **Ctrl** + click to select multiple layers).

Note that the layers have to be checked as visible in the **Layers** panel to make them available in the plugin menu.

- f. In the **OUTPUT POINT VECTOR LAYER**, select the location and the name of the resulting point layer (e.g. **HHLoc_Elev_4326.shp**). Then click **OK** to start the process.

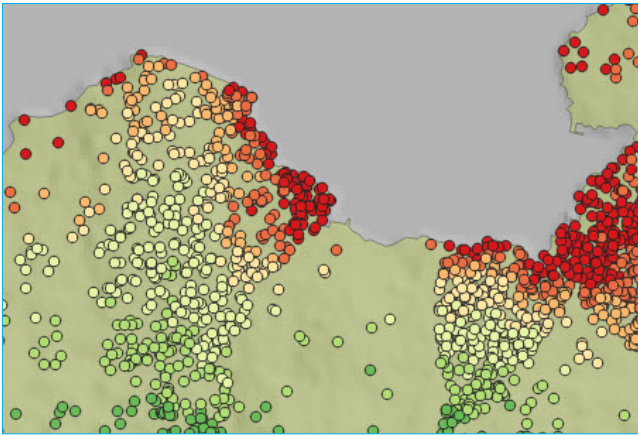


- g. The point layer containing the elevation data will be automatically loaded onto the map canvas. Open the **Layer Properties** panel and go to **SYMBOLOLOGY**.
- h. In the top drop-down menu, select the **GRADUATED** option.
- i. In **COLUMN**, select the field containing the elevation data.
- j. In **COLOR RAMP**, select a suitable ramp to display vulnerability. In the example, we have selected **RdYlGn**, located within the **ALL COLOR RAMPS** submenu.



- k. Click on **CLASSIFY**, select the classification **MODE** and the number of **CLASSES** and set the thresholds and labels for the different ranges.

The result will be a cloud of points represented on the map according to the degree of vulnerability determined by the altitude at which the points are located.



9. Data management and storage: Spatial databases – GeoPackage

In this chapter, you will learn how to store and manage different projects and datasets by using two different approaches. The first is based on the use of **projects and folders** and the second one relies on the use of **spatial databases**.

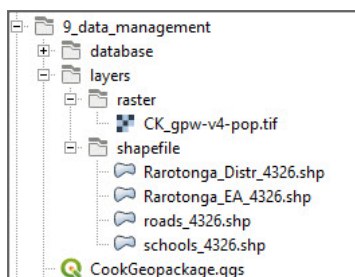
9.1 Data management and storage using projects and folders

This method is easier for beginner GIS users as it stores data in a folders and subfolders structure. In general, this technique works for small projects. However, this simple method may be insufficient when undertaking large and complex projects (e.g. large numbers of datasets from various sources, with different formats and levels of processing).

When using the **projects and folders** approach, it is necessary to choose the criteria by which we will classify the project data into folders. There are many different ways to do this and there is not necessarily one correct solution. For example, you can group by data types (e.g. vector, raster, table), by project (e.g. census, listings, year), or by topic (e.g. HH locations, boundaries, rivers, facilities).

You will find the hypothetical example of Rarotonga Island, in the Cook Islands, stored in the training materials folder, which accompany this manual.

- Open [9_data_management/CookProject.qgz](#)
- Either using the QGIS browser or the default file manager in your operating system, open the [9_data_management](#) folder and study how the data is organised across the different folders and subfolders. Note that the project file is located next to the [layers](#) folder. The [layers](#) folder contains subfolders that store data by type: [raster](#), [shapefile](#). The way the data will be arranged will depend on the user's preferences, the nature of the project, etc.



A dependence on folders can make sharing projects among users a very challenging process if we want to preserve workspace settings, like symbology and labels. If users are not familiar with GIS software, the sharing process can quickly become unmanageable and complicated.

The plugins **QCONSOLIDATE** and **QPACKAGE**, both available in QGIS, can package layers and projects to allow projects and folders to be shared, but remove any data storage structures in the process.

To install both plugins, we will follow these next steps:

- On the top menu, go to **PLUGINS > MANAGE AND INSTALL PLUGINS...** and select the **ALL** menu on the left side of the panel.
- Go to **SETTINGS** and check the **SHOW ALSO EXPERIMENTAL** plugins option.
- In the search bar, type: **Qpackage**. Select the plugin **QPACKAGE** and click on **INSTALL PLUGIN**.
- In the search bar, type: **Qconsolidate3**, select the **QCONSOLIDATE3** plugin and click on **INSTALL PLUGIN**.

As both plugins work in a similar way, it is only necessary to learn how to use one of the plugins. We will use **QCONSOLIDATE3**, as it is currently more stable in the QGIS 3 environment.

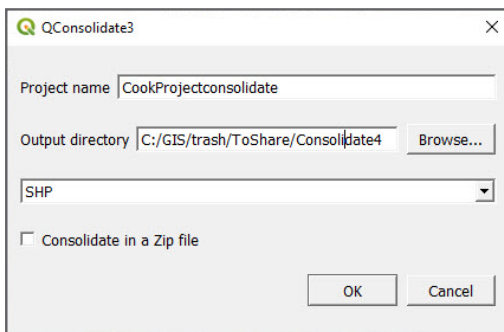
- Open [CookProject.qgz](#). You will notice that all of the layers have been configured with specific symbologies and labels and that a satellite image background has been added.

Because of a bug that has not yet been resolved, we need to save the project using the **.qgs** extension.

- b. In the top menu, go to **PROJECT > SAVE AS** or click on .
- c. In the **Save Project As** panel, in the **SAVE AS TYPE** drop-down menu, select the **QGIS FILES (*.QGS)** option.

Once the project is saved with a **.qgs** extension, we will start using the plugin to package and share the project and the layers.

- d. In the top menu, go to **PLUGINS > QCONSOLIDATE3**.
- e. In **PROJECT NAME**, we can change the name of the project to be shared if necessary.
- f. In **OUTPUT DIRECTORY**, set the new location for the package.
- g. In the drop-down menu below **OUTPUT DIRECTORY**, select the **SHP** option. You will notice that there is an option to convert all the layers into **GEOPACKAGE** format; we will explore this format in the next section.
- h. The option **CONSOLIDATE IN A ZIP FILE** allows the project and layers to be stored in a zip file. In this instance we will not select it.
- i. Click **OK**.



- j. The plugin will store the project in the specified location and will create a folder named **Layers** where all the project's layers will be stored. This means that any data structure that was put in place before will disappear.

QPACKAGE works the same way, but there are a few differences with **QCONSOLIDATE3**.

- In **QPACKAGE**, it is possible to select which layers will be packaged in the process.
- In **QPACKAGE**, it is possible to select the target CRS for the packaged project.
- **QPACKAGE** saves both layers and project file in the same file.
- There are issues with **QPACKAGE** when packaging rasters (this error had not been resolved while this manual was being written in 07/2019).
- When **QPACKAGE** packages the layers and the project, it saves the current project session to the new location. We have to be careful and open the original project again in case we want to keep working on it.

9.2 Data management and storage using spatial databases (GeoPackage)

Generally, we have opted to use the ESRI shapefile (**.shp**) for vector layers in this manual. We made this decision so that the manual could be used by beginner to intermediate GIS users. As the shapefile is the most common format in ESRI and QGIS environments, basic users are likely to already be familiar with it.

However, this does not make the **.shp** format the best support when working with vector layers. In this chapter, we will present other alternatives that have significant advantages over the shapefile format.

9.2.1 GeoPackage format

"GeoPackage is an open, standards-based, platform-independent, portable, self-describing, compact format for transferring geospatial information."³

3 GeoPackage official website: <https://www.geopackage.org/>

A more accessible definition of the GeoPackage format can be found in the QGIS documentation: "the GeoPackage open format is a container that allows you to store GIS data (layers) in a single file".⁴


The main advantages of using this format when managing our vector data, and in some cases raster data, are as follows:

- It is **OPEN** source.
- QGIS has been switched to work by default with GeoPackage even if it still perfectly supports shapefile and other formats.
- GeoPackage can store several layers with different geometries (points, lines, polygons) using different CRS in a **SINGLE FILE**. When working with shapefiles, it is necessary to create at least three files to store one single layer (see chapter 3.1).
- GeoPackage is compatible with other GIS software packages and programming languages (e.g. ESRI, Python, QGIS, R, GDAL).
- The workflow of GeoPackage (editing, selection, **ATTRIBUTE TABLE**, symbology ...) is the **SAME** as with shapefile.



In the following exercise, we will follow the workflow process of grouping several shapefiles (point, line and polygon), a raster and their styles, into a single GeoPackage file.

- a. Open *9_data_management/CookProject.qgz*

In this project, you will find four vectorial layers in shapefile format, plus one raster. Each layer already has a preconfigured symbology stored in the project file. We are going to put together these shapefiles in a group in the **Layers** panel. We do this in order to differentiate the pre-existing shapefile layers from the ones we will later create and store in a GeoPackage.

- b. At the top of the **Layers** panel, click on  to create a new layer group. Name it **Shapefile** and drag all the existing layers within the group.




Next, we will create the GeoPackage file. There are three ways to do this:

1. On the top menu, go to **LAYER > CREATE LAYER > NEW GEOPACKAGE LAYER...**
2. In the **Browser** panel, right-click on  **GeoPackage** and select **CREATE DATABASE**.
3. In the side menu bar located on the left side of the interface, click on .

For all of the three cases, the same **New GeoPackage Layer** menu will be displayed.

- c. In **DATABASE**, select the location for the new database and its name (e.g. *9_data_management/database/Rarotonga.gpkg*).
- d. In **TABLE NAME**, leave the current text.
- e. In **GEOMETRY TYPE**, select the option **NO GEOMETRY**.

We have to create this table as the GeoPackage file needs at least one item to store when it is first created. We will remove this item later from the database.

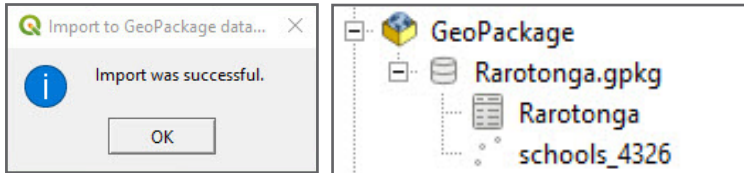
- f. Click **OK**. In the **Browser** panel, right-click on  **GeoPackage**, select **NEW CONNECTION** and open *Rarotonga.gpkg* from its location.
- g. In the **Browser** panel, *Rarotonga.gpkg* will be displayed under  **GeoPackage**. After undertaking any modification, it is recommended that you click on  to refresh the folders.

Now that we have created the GeoPackage file we will package all the vector layers and the raster inside. **There are two main ways to achieve this:**

⁴ Documentation QGIS 3.10: https://docs.qgis.org/3.10/en/docs/training_manual/basic_map/vector_data.html?highlight=geopackage

1. Browser panel

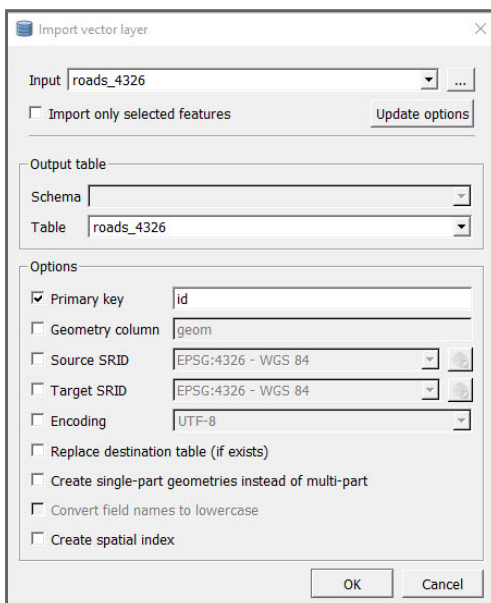
- Drag *schools_4326* from the **Layers** panel to the *Rarotonga.gpkg* folder located in the **Browser** panel.
- The following panel will be displayed and the layer *school_4326* will appear in the GeoPackage file tree.



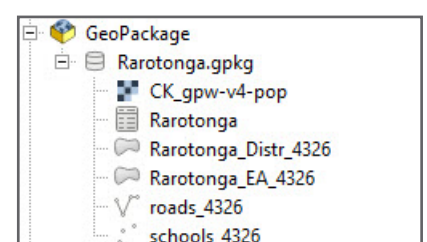
2. DB Manager

The **DB MANAGER** is one of QGIS's core plugins and is intended to be the main tool to integrate and manage spatial database formats supported by QGIS (PostGIS, Spatialite, GeoPackage, Oracle Spatial, Virtual layers) in one user interface.

- In the top menu, go to **DATABASE > DB MANAGER**.
- In the **DB Manager** menu, in the **PROVIDERS** window, click on **GeoPackage** to show the connections available. If *Rarotonga.gpkg* is not available, right-click on **GeoPackage**, then select **NEW CONNECTION** and open the GeoPackage file from its location.
- Double-click on *Rarotonga.gpkg* to display the items already included in the database.
- Click on **IMPORT LAYER/FILE**, and the **Import vector layer** panel will show.
- In **INPUT**, select *roads_4326*
- In **TABLE**, select the table from the same layer as in **INPUT**; in this case, *roads_4326*
- Check the **PRIMARY KEY** option and click **OK**.



Add the rest of the vector layers into the *Rarotonga.gpkg* and practise both methods to familiarise yourself with them. There is one thing we need to keep in mind and it is that rasters cannot be added using the DB Manager, as for the moment this plugin does not support raster layers. You will therefore need to use the dragging method. Once you have finished, your GeoPackage file tree should be structured like in the adjacent image.



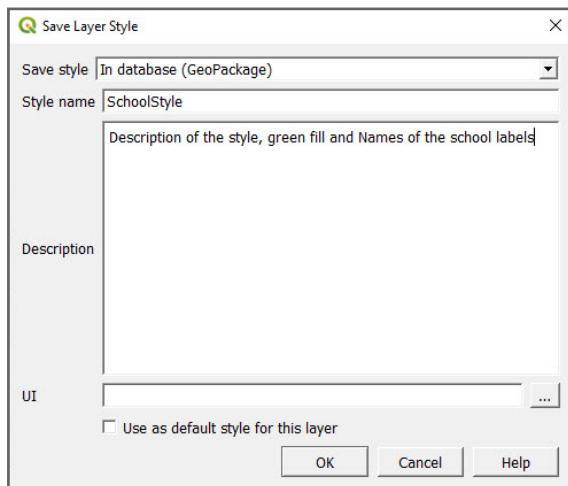
- Now we can delete the empty table *Rarotonga* that was created before. In the **Browser** panel, right-click on the *Rarotonga* table and select **DELETE LAYER**.

Now that we have packaged the layers into the GeoPackage, we will add them into the map canvas.

- b. From the **Browser** panel, in the GeoPackage branch, select *Rarotonga.gpkg* and either double-click on each layer or drag them into the map canvas. Make sure when adding the layers from the Geopackage that they remain outside the layers group created at the start of this section.

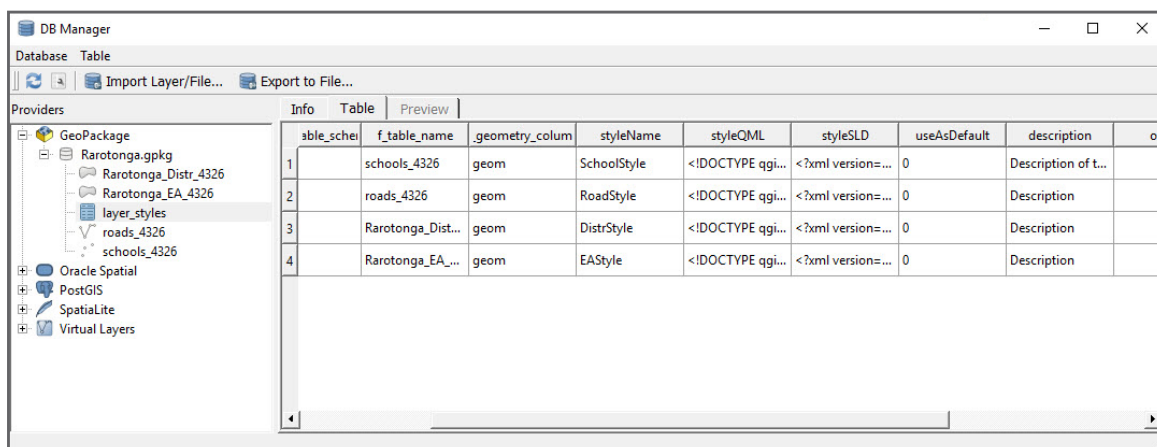
Next, we are going to copy the styles from the shapefiles and store them as a table in the GeoPackage file. This ensures that the layers will be displayed using the same symbology, even if they are opened in another QGIS project.

- c. Right-click on the layer *schools_4326* (the one inside the shapefile group) and select **STYLES > COPY STYLE > ALL STYLE CATEGORIES**.
- d. Right-click on the layer *schools_4326* from the GeoPackage file and select **STYLES > PASTE STYLE > ALL STYLE CATEGORIES**. Our layer will get the new symbology and labels settings.
- e. Go to the **Layer Properties** panel. In the **SYMBOLOLOGY** menu, click on the **STYLE** button (bottom-left corner), select the **SAVE STYLE** option and the **Save Layer Style** panel will be displayed.
- f. In the **SAVE STYLE** drop-down menu, choose the **IN DATABASE (GEOPACKAGE)** option.
- g. In **STYLE NAME**, set a name for the style (e.g. SchoolStyle), add a description, if you find it necessary, and click **OK**.



Follow the same steps to copy the styles from the shapefile vector layers onto the GeoPackage equivalents and save the styles in the database. You can do this for each of the layers except for the raster (we will explain why at the end of the chapter).

- h. Open the **DB MANAGER**, select the GeoPackage and deploy the *Rarotonga.gpkg* database. You will find a new table named *layer_styles* that now contains the styles for the vector layers contained in the database. You can check the content of the table by selecting it and clicking on the **TABLE** tab on the right side of the menu.



- i. Open a new session of QGIS and try to load the layers contained in the *Rarotonga.gpkg* database. Now the layers



will be displayed with the symbology settings stored in the GeoPackage database.

Although GeoPackage can store rasters, it cannot store their styles. This means that the way we will manage the styles is the same as before: either we store the style with the project or we save it with a *.sld* or *.qml* file that can be loaded once the raster layer has been opened.

As mentioned at the beginning of the chapter, when working with vector layers stored in a GeoPackage database, the workflow in the QGIS environment is the same as if we were working with shapefiles. No new skills or processes need to be learned to work with GeoPackage apart from the basics about how the format stores the information.

10. Metadata

10.1 Populate metadata (standards and compatibility)

Metadata is information about data. Metadata records and documents important information about a dataset, such as the author, description, abstracts, keywords, updates, dates of creation/update, etc.

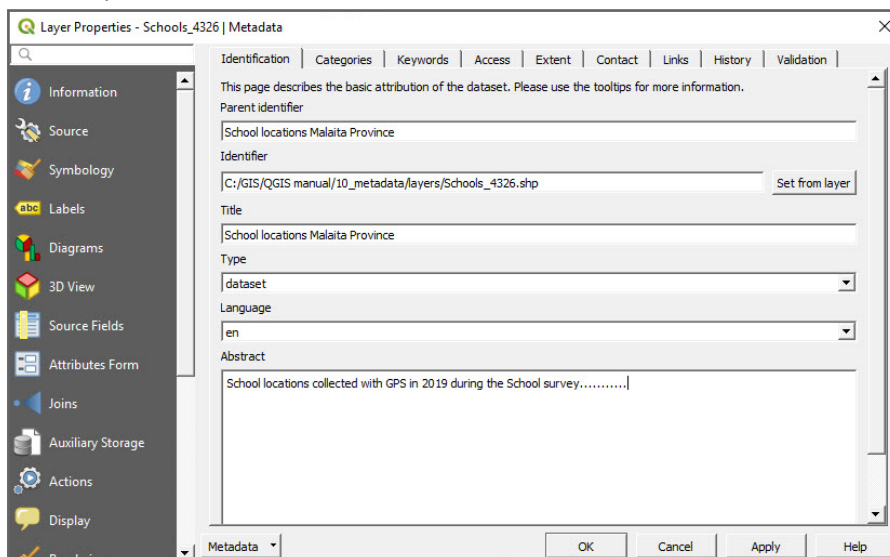
QGIS 3.x uses metadata differently compared to QGIS 2.x. At the time of writing (07/2019), the QGIS metadata editor does not support either ISO 19115 or ISO 19139 standards; however, its structure operates in a similar way to these standards.



In this example, you are going to populate the metadata file for a *School Locations* layer for Malaita Province in Solomon Islands. We will complete the metadata as if we were the authors and owners of this dataset.

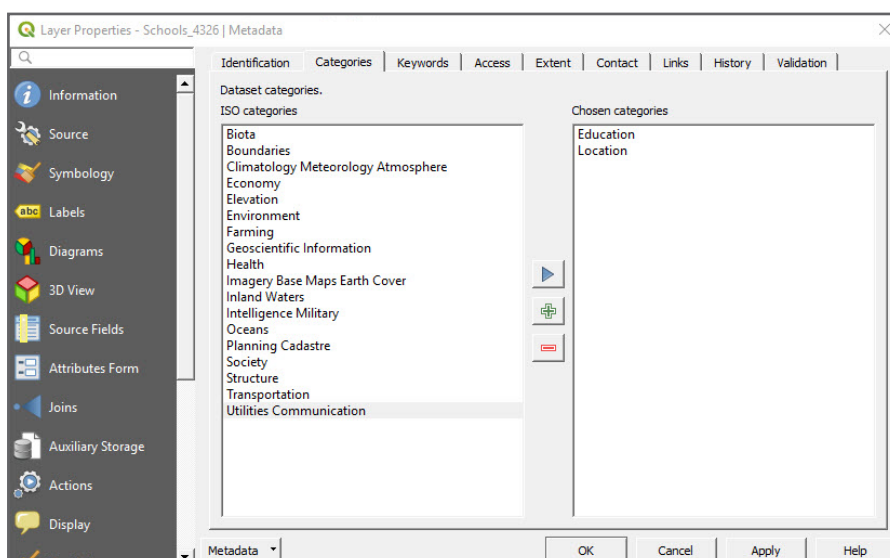
- Load *10_metadata/layers/Schools_4326.shp*, open the **Layers Properties** panel and go to **METADATA**.

The metadata menu helps streamline the data-entering process and will create a metadata summary for the layer.

- IDENTIFICATION** describes the basic attribution of the dataset (e.g. parent identifier, identifier, title, type, language, abstract).



- CATEGORIES**. The metadata editor includes ISO categories. Select the category from the **ISO CATEGORIES** panel and click on  to add it into the **CHOSEN CATEGORIES** panel. You can add custom categories by clicking on .



- d. **KEYWORDS** are used to help data retrieval processes follow standard concepts and vocabulary. In this case, we have verified the terminology via the GEMET website while adding one more concept and the related keywords.

Layer Properties - Schools_4326 | Metadata

Keywords are optional, and provide a way to provide additional descriptive information about the dataset. Edits made in the categories tab will update the category entry below. For the concept, we suggest to use a standard based vocabulary such as [GEMET](#).

	Concept	Keywords
1	gmd:topicCategory	Education, Location
2	school	education, cultural facility

- e. In the **ACCESS** section we will include all the information related to licences, rights, fees, and other constraints. In the link that follows, we can find information and guidelines to better understand how to complete this section: <https://theodi.org/article/publishers-guide-to-open-data-licensing/>
- f. The **EXTENT** tab comprises spatial (CRS, map extent, altitudes) and temporal information. Click **SET CRS FROM LAYER** and the information will set according to the preconfigured layer properties. For the extent, you can either fill it manually or use one of the three options available: **CURRENT LAYER EXTENT**, **CALCULATE FROM LAYER** or **MAP CANVAS EXTENT**.

Layer Properties - Schools_4326 | Metadata

Coordinate Reference System and spatial extent for this dataset.

Coordinate Reference System

CRS: EPSG:4326 - WGS 84 Set CRS from layer Set CRS from provider

Same as layer properties and provider.

Extent (current: Schools_4326)

West: 160.562857400 North: -8.297004930 East: 161.577601400 South: -9.690477210

Current Layer Extent Calculate from Layer Map Canvas Extent

Z maximum: 0 Z minimum: 0

Temporal extent for this dataset.

From: NULL To: NULL

OK Cancel Apply Help

- g. In **CONTACT** you should include owners and other related persons or institutions responsible for the dataset.

Layer Properties - Schools_4326 | Metadata

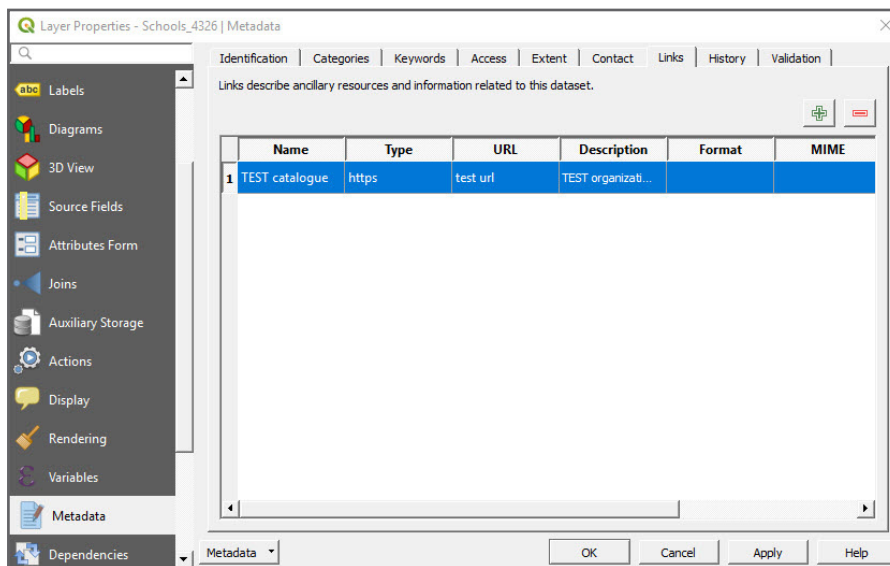
Contacts related to the dataset.

Name: TEST name Role: owner Organization: TEST organization Position: TEST position Email: TEST@TEST.com Voice: Fax: Address:

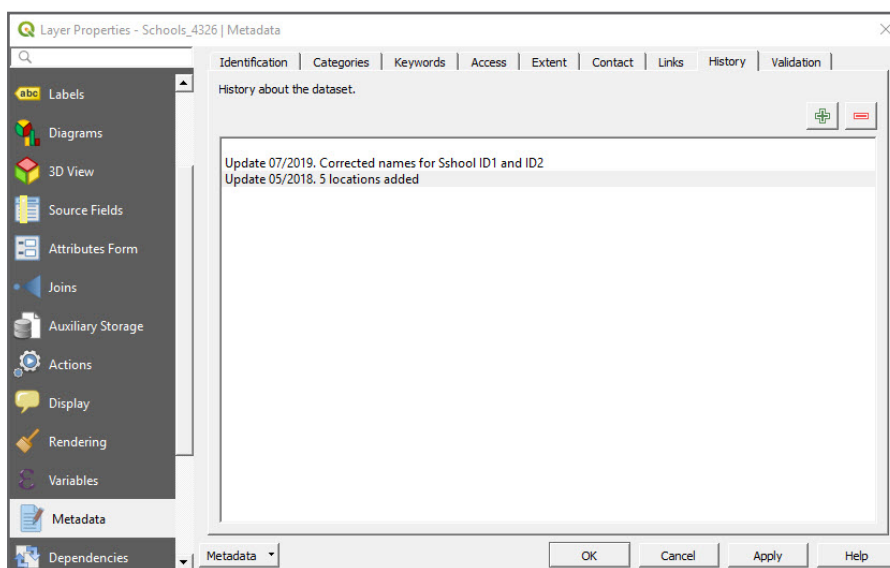
Type	Address	Postal Code	City	Administrative Area	Country
------	---------	-------------	------	---------------------	---------

OK Cancel Apply Help

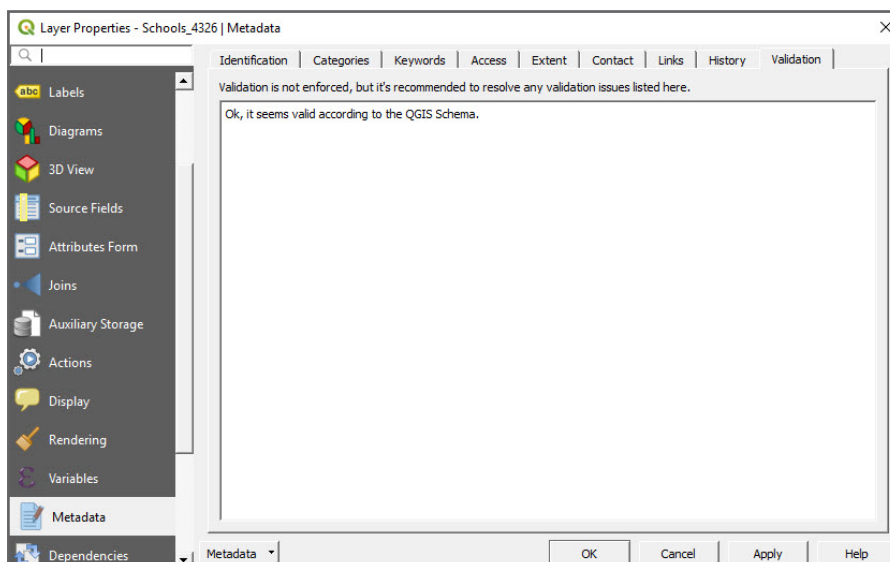
- h. Within the **LINKS** tab we can include ancillary resources and related information, such as online databases, catalogues or documentation.



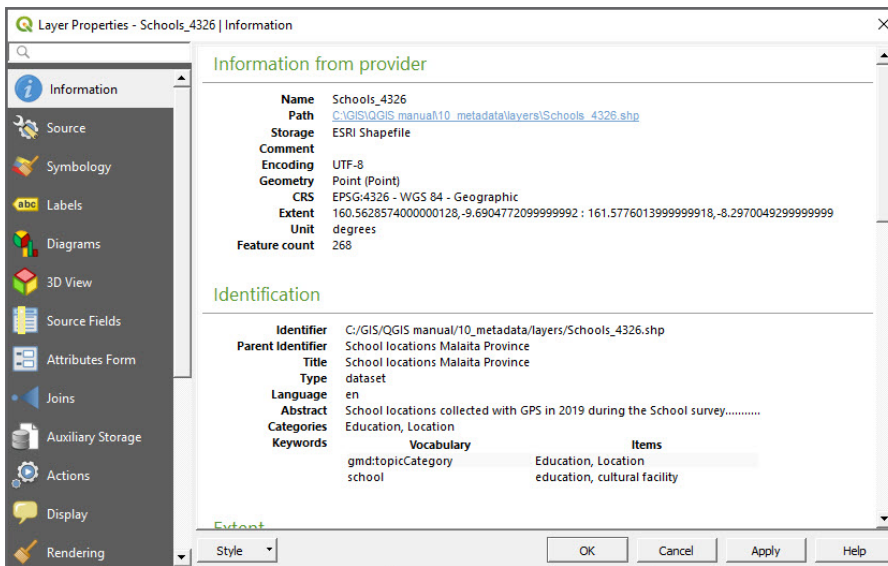
- i. The **HISTORY** section documents corrections, modifications and versions of the dataset.



- j. **VALIDATION** verifies that we have entered the minimum information required to meet metadata standards. The minimum requirements are **identifier, language, type, title, abstract, links, contacts, licence, CRS** and **extent**.



- k. Go to the **INFORMATION** tab and you will see that all the information added into the **METADATA** section has been included automatically.



By default, the metadata will be stored alongside the project file. However, this means it will not be accessible when opening this layer into a different project. To solve this, we will follow these steps:

- l. In **METADATA**, click on **METADATA** located at the bottom-left corner and select **SAVE METADATA**.
- m. Give the file the same title as the layer (*Schools_4326.qmd*). The extension *.qmd* will be automatically assigned. It is important to save this *.qmd* file alongside the other layer files (*.shp*, *.shx*, *.dbf*, etc.). This allows the program to retrieve automatically the metadata for the layer the same way it does for the other extensions containing the **ATTRIBUTE TABLE** or the projection information, for instance.

In the case where we are using either a different layer format (GeoPackage, KML) or the metadata is stored separately or with another name, we can still manually add the metadata to the layer.

- n. In **METADATA**, click on **METADATA** located at the bottom-left corner and select **LOAD METADATA**. Select the *.qmd* file that contains the metadata for our layer and click **OK**. The metadata will be displayed in the **INFORMATION** section.

ISBN 978-982-00-1308-7



Pacific Community (SPC)

B. P. D5 - 98 848 Noumea Cedex, New Caledonia

Telephone: + 687 26 20 00

Email: sdd@spc.int

Website: <http://www.spc.int> - <https://sdd.spc.int>

©Pacific Community 2020